United States Department of Agriculture

Rural Electrification Administration

1984 REA Telecommunications Engineering and Management Seminars

Toll Network Proposals

Satellite Network Studies

Switching Equipment—Specification Changes

Choosing the Right New Services

Industry Standards After Deregulation

Access Charges—Legislative Update

Lightwave Transmission

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CENTRAL OFFICE EQUIPMENT PURCHASE REPORT

Stanley M. Sorensen
Central Office Equipment Branch
Telecommunications Engineering and Standards Division

The Central Office Equipment Purchase Report is prepared on a calendar year basis with summaries issued in between. The report is based on information available on the REA Form 546, COE Bid Approval, and REA Form 840, COE Estimates Compared to Bid. These forms are prepared during the bid approval process. In addition, separate reports are submitted by "certified" projects that don't submit contracts for approval.

The purchase report presents information relating exclusively to digital switching systems as well as summaries going back to the beginning of the REA telephone loan program. The following is a brief description of the material presented in each of the enclosed tables.

1. Digital Central Office Equipment Summary (Number of HOST Digital Offices by Size Classification)

   The number of digital central offices purchased, sorted into groups of line sizes, e.g., 1000 to 1500 lines, total purchases in 1983, 1982, and total of all ever purchased.

2. Cumulative Central Office Equipment Summary (Number of Offices by Size Classification, Including RST's)

   The total number of offices of all kinds purchased since the beginning of the REA telephone loan program, sorted into groups of line sizes. This data represents initial purchases only; later additions to each of the offices are not included.

3. Digital Central Office Equipment Summary (Number of HOST Digital Offices by Size Classification)

   The number of lines equipped in the digital host not including the RST lines are sorted into groups of line size.

4. Cumulative Central Office Equipment Summary (Number of Offices by Size Classification, Excluding RST's)

   The total number of offices of all kinds purchased since the beginning of the REA telephone loan program, sorted into groups of line sizes. The number of lines associated with RST's have not been included.

5. <u>Digital Central Office Equipment Summary</u> (Number of Digital RST's by Size Classification)

   The number of digital RST's purchased, sorted into groups of line sizes. The figure in the parentheses is the number of RST's purchased on a separate contract after the host had been purchased. This quantity is included in the quantity shown before the parentheses.

6. <u>Central Office Equipment Summary</u> (Digital Equipment Only)

   The number of digital offices (hosts) and digital RST's and the total dollar amounts awarded in the current year and total dollars since the beginning of digital system purchases.

7. <u>Cumulative Central Office Equipment Summary</u> (Total Dollars)

   The total contract dollars amount awarded to each supplier of COE since the REA telephone loan program began. A number of companies shown here no longer supply COE to REA-financed systems.

CENTRAL OFFICE EQUIPMENT PURCHASE REPORT

THROUGH DECEMBER 1983

(Does Not Include Purchases by
"Certified" Borrowers)

Prepared By

REA Telecommunications Engineering & Standards Division

Central Office Equipment Branch

DIGITAL CENTRAL OFFICE EQUIPMENT SUMMARY

NUMBER OF HOST DIGITAL OFFICES BY SIZE CLASSIFICATION

THROUGH DECEMBER, 1983

(RST LINES INCLUDED)

NUMBER OF LINES	1983	1982	TOTALS	PERCENTAGE OF TOTAL
0 - 50	14	0	20	2.70
51 - 100	3	23	26	6.20
101 - 150	2	4	7	7.14
151 - 200	5	2	12	8.76
201 - 250	1	4	11	10.24
251 - 300	3	4	11	11.73
301 - 400	15	11	43	17.52
401 - 500	12	3	34	22.10
501 - 700	16	13	85	33.56
701 - 1,000	9	25	92	45.96
1,001 - 1,500	24	29	121	62.26
1,501 - 2,000	16	18	87	73.99
2,001 - 3,000	17	12	84	85.31
3,001 - 4,000	6	13	54	92.59
4,001 - 5,000	6	3	19	95.15
5,001 - 6,000	1	7	24	98.38
6,001 - 7,000	1	0	3	98.79
7,001 - 8,000	0	0	2	99.06
8,001 - 9,000	0	2	3	99.46
9,001 - 10,000	1	0	1	99.60
10,001 - 11,000	0	1	1	99.73
11,001 - 12,000	0	0	0	99.73
OVER 12,000	0	1	2	100.00
	152	175	742	

CUMULATIVE CENTRAL OFFICE EQUIPMENT SUMMARY

NUMBER OF OFFICES BY SIZE CLASSIFICATION

THROUGH DECEMBER, 1983

(RST LINES INCLUDED)

NUMBER OF LINES	1983	1982	TOTALS	PERCENTAGE OF TOTAL
0 - 50	14	0	927	15.23
51 - 100	3	23	1,160	34.29
101 - 150	2	4	735	46.36
151 - 200	5	2	581	55.91
201 - 250	1	4	353	61.71
251 - 300	3	4	366	67.72
301 - 400	15	11	441	74.96
401 - 500	12	3	327	80.34
501 - 700	16	13	332	85.79
701 - 1,000	9	25	259	90.04
1,001 - 1,500	24	29	183	93.05
1,501 - 2,000	16	18	131	95.20
2,001 - 3,000	17	12	127	97.29
3,001 - 4,000	6	13	81	98.62
4,001 - 5,000	6	3	29	99.10
5,001 - 6,000	1	7	37	99.70
6,001 - 7,000	1	0	5	99.79
7,001 - 8,000	0	0	3	99.84
8,001 - 9,000	0	2	5	99.92
9,001 - 10,000	1	0	1	99.93
10,001 - 11,000	0	1	1	99.95
11,001 - 12,000	0	0	0	99.95
OVER 12,000	0	1	3	100.00
	152	175	6,087	

HISTORICALLY, OFFICES WITHOUT LOCAL LINES HAVE NOT BEEN INCLUDED IN THE ABOVE TABULATION.

DIGITAL CENTRAL OFFICE EQUIPMENT SUMMARY

NUMBER OF HOST DIGITAL OFFICES BY SIZE CLASSIFICATION

THROUGH DECEMBER, 1983

NUMBER OF LINES	1983	1982	TOTALS	PERCENTAGE OF TOTAL
0 - 50	14	0	20	2.70
51 - 100	3	24	27	6.33
101 - 150	2	4	7	7.28
151 - 200	6	3	14	9.16
201 - 250	2	5	13	10.92
251 - 300	7	5	16	13.07
301 - 400	16	10	43	18.87
401 - 500	10	3	32	23.18
501 - 700	17	16	89	35.18
701 - 1,000	15	28	101	48.79
1,001 - 1,500	24	28	120	64.96
1,501 - 2,000	18	14	85	76.42
2,001 - 3,000	12	16	83	87.60
3,001 - 4,000	2	11	48	94.07
4,001 - 5,000	2	5	17	96.36
5,001 - 6,000	1	3	20	99.06
6,001 - 7,000	1	0	3	99.46
7,001 - 8,000	0	0	2	99.73
8,001 - 9,000	0	0	1	99.87
9,001 - 10,000	0	0	0	99.87
10,001 - 11,000	0	0	0	99.87
11,001 - 12,000	0	0	0	99.87
OVER 12,000	0	0	1	100.00
	152	175	742	

CUMULATIVE CENTRAL OFFICE EQUIPMENT SUMMARY

NUMBER OF OFFICES BY SIZE CLASSIFICATION

THROUGH DECEMBER, 1983

NUMBER OF LINES	1983	1982	TOTALS	PERCENTAGE OF TOTAL
0 - 50	14	0	927	15.23
51 - 100	3	24	1,161	34.30
101 - 150	2	4	735	46.38
151 - 200	6	3	583	55.96
201 - 250	2	5	355	61.79
251 - 300	7	5	371	67.88
301 - 400	16	10	441	75.13
401 - 500	10	3	325	80.47
501 - 700	17	16	336	85.99
701 - 1,000	15	28	268	90.39
1,001 - 1,500	24	28	182	93.38
1,501 - 2,000	18	14	129	95.50
2,001 - 3,000	12	16	126	97.57
3,001 - 4,000	2	11	75	98.80
4,001 - 5,000	2	5	27	99.24
5,001 - 6,000	1	3	33	99.79
6,001 - 7,000	1	0	5	99.87
7,001 - 8,000	0	0	3	99.92
8,001 - 9,000	0	0	3	99.97
9,001 - 10,000	0	0	0	99.97
10,001 - 11,000	0	0	0	99.97
11,001 - 12,000	0	0	0	99.97
OVER 12,000	0	0	2	100.00
	152	175	6,087	

HISTORICALLY, OFFICES WITHOUT LOCAL LINES HAVE NOT BEEN INCLUDED IN THE ABOVE TABULATION.

DIGITAL CENTRAL OFFICE EQUIPMENT SUMMARY

NUMBER OF DIGITAL RST'S BY SIZE CLASSIFICATION

THROUGH DECEMBER 1983

NUMBER OF LINES	1983	1982	TOTALS	PERCENTAGE OF TOTAL
0 - 50	8 (1)	1 (0)	9 (1)	1.93
51 - 100	21 (2)	12 (0)	51 (2)	12.85
101 - 150	22 (1)	13 (1)	66 (4)	26.98
151 - 200	18 (0)	10 (3)	60 (8)	39.83
201 - 250	15 (2)	8 (1)	53 (4)	51.18
251 - 300	8 (0)	7 (1)	36 (4)	58.89
301 - 400	26 (5)	4 (0)	57 (8)	71.09
401 - 500	10 (3)	5 (1)	28 (5)	77.09
501 - 600	4 (1)	9 (2)	25 (4)	82.44
601 - 700	5 (1)	6 (3)	22 (4)	87.15
701 - 800	7 (1)	4 (1)	16 (3)	90.58
801 - 900	3 (0)	0 (0)	6 (0)	91.86
901 - 1,000	1 (1)	0 (0)	2 (1)	92.29
1,001 - 2,000	5 (2)	6 (1)	23 (4)	97.22
2,001 - 3,000	0 (0)	7 (0)	9 (0)	99.14
3,001 - 4,000	0 (0)	2 (0)	2 (0)	99.57
4,001 - 5,000	1 (1)	1 (0)	2 (1)	100.00
5,001 - 10,000	0 (0)	0 (0)	0 (0)	100.00
	154 (21)	95 (14)	467 (53)	

NUMBER IN PARENTHESES INDICATES DIGITAL RST'S PURCHASED SEPARATELY (QUANTITY IS INCLUDED IN FIRST NUMBER).

CENTRAL OFFICE EQUIPMENT SUMMARY

- DECEMBER 1983 -

MANUFACTURER	NO. OF OFFICES 1983	NO. OF OFFICES TOTAL	NO. OF RST'S 1983	NO. OF RST'S TOTAL	DOLLAR AMOUNTS DIGITAL EQUIPMENT ONLY 1983	DOLLAR AMOUNTS DIGITAL EQUIPMENT ONLY TOTAL
GTE NETWORK SYSTEMS	4	13	12	25	$7,597,511	$23,003,190
HARRIS	0	7	0	0	$0	$622,137
ITT TELCOM PRODUCTS	4	28	34	38	$7,147,982	$24,176,864
NIPPON ELECTRIC CORP.	5	54	5	22	$5,833,749	$44,833,558
NORTHERN TELCOM	90	327	68	170	$41,010,546	$173,120,642
REDCOM LABS	16	34	0	0	$450,320	$1,072,660
STROMBERG CARLSON	33	220	35	149	$21,009,766	$133,952,092
TRW VIDAR	0	0	0	39	$0	$1,679,011
TSS-ALCATEL	0	0	0	0	$0	$0
WESTERN ELECTRIC CO.	0	0	0	0	$0	$0
	152	742	154	467	$83,049,874	$436,949,390

CUMULATIVE CENTRAL OFFICE EQUIPMENT SUMMARY

- DECEMBER 1983 -

MANUFACTURER	DOLLAR AMOUNTS 1983	TOTALS
GTE NETWORK SYSTEMS	$7,597,511	$44,202,616
HARRIS	$0	$622,137
ITT TELCOM PRODUCTS	$7,147,982	$95,493,093
ITEC	$0	$214,552
LEICH	$0	$9,397,534
NIPPON ELECTRIC CORP.	$5,833,749	$54,172,643
NORTHERN TELCOM	$41,010,546	$178,132,468
REDCOM LABS	$450,320	$1,072,660
SIEMENS	$0	$972,224
STROMBERG CARLSON	$21,009,766	$283,851,588
TRW VIDAR	$0	$36,168,247
TSS-ALCATEL	$0	$0
U.S. INSTRUMENTS	$0	$429,182
WESTERN ELECTRIC CO.	$0	$0
	$83,049,874	$704,728,944

DIGITAL TELEPHONE SWITCHING EQUIPMENT PARAMETERS

Information for this publication has been provided by the below-listed companies. This does not imply endorsement by REA of the products and companies involved.

GTE Network Systems
Hitachi America, Ltd.
ITT Telecommunications Corporation
NEC America, Inc.
Northern Telecom, Inc.
Stromberg-Carlson Corporation
CIT-Alcatel, Inc.
Western Electric Company

Prepared By:

REA Telecommunications Engineering & Standards Division
Central Office Equipment Branch

JUNE 1983

PARAMETERS	GTE GTD-5 EAX	HITACHI HDX 10 (Not Currently Available)	ITT 1210/32	ITT 1210/64	NEC NEAX-61K
REA Listing Status	No		Yes	Yes	Technical
Subscriber Lines					
Maximum	165,000	240,000	23,040	50,000	100,000
Minimum Initial Capacity	1,000	300	1,000	1,000	1,000
Minimum Addition	8	4	1	1	64
Loop Limit incl. Tel. Set (Ohms)	2,000	1,900	2,000	2,000	1,900
Trunks					
Maximum	25,000	60,000	6,000	15,360	63,360
Minimum Addition	4	2,4	10	10	30
Directory Numbers					
Maximum	300,000	320,000	32,000	320,000	160,000
Minimum	-	1,000	1,000	1,000	1,000
Minimum Addition	-	1	100	100	100
Office Codes (Quantity)	32	15	16	64	16
Traffic					
B.H. Calls	276,900	540,000	41,700	96,800	600,000
B.H. Attempts	360,000	720,000	52,100	121,000	700,000
Line Port CCS	6.75	5.76	26.4	26.4	10.6
Trunk Port CCS	27.0	28.8	30.6	30.6	30
Line Group CCS	5,184	28,800	1,268	1,268	680
Total CCS	660,000	720,000	88,200	235,000	792,000
Lines					
Per Card	8	6,4	1,2,4	1,2,4	4,8
Per Line Group	768		352	352	256
Trunks					
Per Card	4	2,4	1	1	3,6
Trunk Routes Maximum	2,000	255	I-256, O-256	I-512, O-512	512
Trunks per Route	1,024	60,000	128	512	1,024
Alternate Routes, Max.	7	255	255	511	12
Line Concentration					
Type	Electronic	Time Div.	None	None	Electronic
Ratios	4,6,8:1	5:1			2,4,6,8:1
Codec					
Per Line	Yes	Yes	Yes	Yes	No
Per Line Group	No	No	No	No	Yes
Per Analog Trunk	Yes	Yes	Yes	Yes	Yes
Class of Service					
Incoming	256		256	512	
Outgoing	128		4,096	4,096	
Combined		255			256

PARAMETERS	GTE GTD-5 EAX	HITACHI HDX 10 (Not Currently Available)	ITT 1210/32	ITT 1210/64	NEC NEAX-61K
A/D Conversion Point (Mb/s)	1.544	2.048	1.544	1.544	2.048
Digital Network (Mb/s)	74.112	2.048	18.432	18.432	32.768
Matrix					
No. of Stages	3	4	3	3	4
Type	T S T	T S S T	T S T	T S T	T S S T
Program Reload Method					
Cartridge Tape	No	No	Yes	No	Yes
Magnetic Tape	Yes	No	Yes	Yes	Yes
Disc	No	Yes	No	No	No
Redundant	Yes	Yes	Yes	Yes	No
Store Capacity Lines (POTS)					
Program					
Call					
Data					
Combined	165,000	240,000	23,040	50,000	
Store Capacity Words (Not Assigned)					
Program	1.5 MW				
Call	(22.5 MW				
Data	(				
Combined	24 MW	26 MW	585 KW	14,856 KW	
Store Redundant					
Full	Yes	Yes	Yes	Yes	Yes
Partial	No	No	No	No	No
Processor					
Distributed	Yes	Yes	No	No	No
Centralized	No	No	No	No	No
Both	No	No	Yes	Yes	Yes
Temperature Limits					
Normal °F	45/100	41/104	40/100	40/100	64/86
Short Term °F	35/120	32/113	40/120	40/100	32/104
Relative Humidity					
Normal (%)	20/80	40/80	20/60	20/60	30/80
Short Term (%)	20/80	20/85	20/80	20/80	5/95
Short Term Defined					
Duration (Hours)	72	72	72	72	72
Days per Year	15	15	15	15	6
Times per Year	-	4	-	-	2

PARAMETERS		GTE GTD-5 EAX	HITACHI HDX 10 (Not Currently Available)	ITT 1210/32	ITT 1210/64	NEC NEAX-61K
Ceiling Height						
Min. Clear (Ft.)		10	8	9	9	9
Bay or Cabinet Dimensions						
Height (Inches)		96	83	84	84	83
Width (Inches)		27,40.5	27	22,42	22,42	40.5
Depth (Inches)		22	18	18,25.5	18,25.5	21.25
Weight						
Bay or Cab. Max. lbs.		789	620	670	670	-
Floor Loading (lbs.) $Ft.^2$		100	70	50	50	70
DC Power Consumption						
(Amps)	Lines					
	500	103	50	69	69	87
3.2 CCS	1000	121	60	82	82	104
Per Line	1500	139	80	103	103	106
	2000	157	100	130	130	123
	3000	193	120	161	161	142
	5000	265	170	222	222	181
	Max.	4,302	-	770	1,900	2,600
Heat Dissipation						
(Watts)	Lines					
	500	5,152	2,700	4,030	4,030	15,500
3.2 CCS	1000	6,052	3,300	4,780	4,780	18,500
Per Line	1500	6,952	4,200	6,040	6,040	18,800
	2000	7,853	5,300	7,600	7,600	22,000
	3000	9,653	6,400	9,400	9,400	25,000
	5000	13,255	9,100	12,800	12,800	32,000
	Max.	215,175	-	46,000	110,200	461,700
Floor Space (Sq. Ft.)						
	Lines					
	500	640	230	450	450	103
10% Trunking	1000	680	260	450	450	123
	1500	680	285	450	450	123
	2000	746	300	450	450	144
	3000	775	330	450	450	149
	5000	798	400	565	565	161
	Max.	6,793	-	1,370	2,829	2,163

PARAMETERS	NT DMS-100	NT DMS-10	NT DMS-10M	S-C DCO	CIT-ALCATEL E10-FIVE
REA Listing Status	Yes	Yes	Yes	Yes	No
Subscriber Lines					
Maximum	100,000	10,000	1,600	32,400	15,360
Minimum Initial Capacity	2,500	110	110	30	500
Minimum Addition	1	2	2	6	4
Loop Limit incl. Tel. Set (Ohms)	1,900	1,900	1,900	1,900	1,900
Trunks					
Maximum	60,000	1,120	224	4,080	2,300
Minimum Addition	2	2	2	2	24
Directory Numbers					
Maximum	256,000	10,000	10,000	102,300	25,000
Minimum	2,000	300	200	100	100
Minimum Addition	1,000	1	1	100	100
Office Codes (Quantity)	64	8	8	15	16
Traffic					
B.H. Calls	350,000	21,600	14,300	98,000	46,000
B.H. Attempts	420,000	27,000	17,100	114,000	58,400
Line Port CCS	5.78	5.35	5.35	6.2	14.9
Trunk Port CCS	28	28	28	28.2	36
Line Group CCS	3,700	600	600	6,768	3,568
Total CCS	700,000	67,200	16,800	216,576	388,912
Lines					
Per Card	1	2,4	2,4	3,5,6	4,8
Per Line Group	640	112	112	1,080	240
Trunks					
Per Card	2	2	2	1,2	24/4
Trunk Routes Maximum	2,048	I-63, O-63	I-63, O-63	1,023	256
Trunks per Route	1,024	256	256	As Required	2,300
Alternate Routes, Max.	7	4	4	7	8
Line Concentration	No	No	No		
Type				PCM	PCM
Ratios				18,4.5:1	2:1
Codec					
Per Line	Yes	Yes	Yes	Yes	Yes
Per Line Group	No	No	No	No	No
Per Analog Trunk	Yes	Yes	Yes	Yes	Yes
Class of Service					
Incoming	128				
Outgoing	128				
Combined		56	56	1,024	256

PARAMETERS	NT DMS-100	NT DMS-10	NT DMS-10M	S-C DCO	CIT-ALCATEL E10-FIVE
A/D Conversion Point (Mb/s)	2.56	2.048	2.048	2.048	2.048
Digital Network (Mb/s)	2.56	2.048	2.048	8.192	8.192
Matrix					
No. of Stages	4	3	3	3	3
Type	Time	T S T	T S T	T S T	T T T
Program Reload Method					
Cartridge Tape	No	Yes	Yes	No	No
Magnetic Tape	Yes	No	No	No	No
Disc	No	No	No	Yes	Yes
Redundant	No	No	No	No	No
Store Capacity Lines (POTS)					
Program	100,000	-	-	-	-
Call	-	12,000	6,000	-	-
Data	100,000	12,000	6,000	-	-
Combined	100,000	-	-	32,400	15,360
Store Capacity Words (Not Assigned)					
Program	4 MW	-	12 KW	-	-
Call	-	-	-	-	-
Data	16 MW	-	64 KW	-	-
Combined	20 MW	512 KW	-	1.8 MW	100 KW
Store Redundant					
Full	Yes	Yes	No	Yes	Yes
Partial	No	No	Yes	No	No
Processor					
Distributed	No	No	No	No	Yes
Centralized	No	Yes	Yes	No	No
Both	Yes	No	No	Yes	No
Temperature Limits					
Normal °F	50/86	50/85	50/85	32/85	40/100
Short Term °F	41/120	40/120	40/120	32/120	35/120
Relative Humidity					
Normal (%)	20/55	20/55	20/55	20/65	20/55
Short Term (%)	20/80	20/80	20/80	20/90	20/80
Short Term Defined					
Duration (Hours)	72	72	72	8	72
Days per Year	15	15	15	-	15
Times per Year	-	-	-	4	-

PARAMETERS		NT DMS-100	NT DMS-10	NT DMS-10M	S-C DCO	CIT-ALCATEL E10-FIVE
Ceiling Height						
Min. Clear (Ft.)		10	9	8	10	9
Bay or Cabinet Dimensions						
Height (Inches)		84	90	72	87	82
Width (Inches)		27	32	102	32,51,54	36
Depth (Inches)		18	15	32	22	21
Weight						
Bay or Cab. Max. lbs.		750	250	2,200	800	380
Floor Loading (lbs.) $Ft.^2$		100	80	97	80	75
DC Power Consumption						
(Amps)	Lines					
	500	122	30	30	56	50
3.2 CCS	1000	131	40	40	73	69
Per Line	1500	144	50	50	96	89
	2000	162	60	-	114	108
	3000	171	90	-	155	150
	5000	230	130	-	236	223
	Max.	2,943	250	-	1,346	669
Heat Dissipation						
(Watts)	Lines					
	500	6,896	1,550	1,550	3,119	8,866
3.2 CCS	1000	6,896	2,100	2,100	4,044	12,235
Per Line	1500	7,996	2,600	2,600	5,364	15,781
	2000	8,561	3,100	-	6,355	19,151
	3000	10,446	4,650	-	8,656	26,598
	5000	12,330	6,700	-	13,162	39,542
	Max.	171,492	12,900	-	74,950	118,627
Floor Space (Sq. Ft.)						
	Lines					
	500	276	125	100	304	84
10% Trunking	1000	276	150	175	304	112
	1500	323	175	175	336	112
	2000	323	200	-	336	153
	3000	360	275	-	380	181
	5000	425	350	-	420	251
	Max.	3,400	750	-	1,296	709

PARAMETERS	WE 5 ESS				
REA Listing Status	No				
Subscriber Lines					
Maximum	52,000				
Minimum Initial Capacity	1,000				
Minimum Addition	256				
Loop Limit incl. Tel. Set (Ohms)	2,000				
Trunks					
Maximum	65,400				
Minimum Addition	64				
Directory Numbers					
Maximum	196,000				
Minimum	52,000				
Minimum Addition	1				
Office Codes (Quantity)	32				
Traffic					
B.H. Calls	130,000				
B.H. Attempts	162,500				
Line Port CCS	7				
Trunk Port CCS	32.4				
Line Group CCS	-				
Total CCS	152,000				
Lines					
Per Card	32				
Per Line Group	512				
Trunks					
Per Card	4				
Trunk Routes Maximum	999				
Trunks per Route	999				
Alternate Routes, Max.	5				
Line Concentration					
Type	PCM				
Ratios	4,6,8:1				
Codec					
Per Line	No				
Per Line Group	Yes				
Per Analog Trunk	Yes				
Class of Service					
Incoming	As Required				
Outgoing	As Required				
Combined					

PARAMETERS	WE 5 ESS				
A/D Conversion Point (Mb/s)	1.544				
Digital Network (Mb/s)	33				
Matrix					
No. of Stages	3				
Type	T S T				
Program Reload Method					
Cartridge Tape	No				
Magnetic Tape	Yes				
Disc	Yes				
Redundant	Yes				
Store Capacity Lines (POTS)					
Program	-				
Call	-				
Data	-				
Combined	52,000				
Store Capacity Words (Not Assigned)					
Program					
Call					
Data					
Combined					
Store Redundant					
Full	Yes				
Partial	No				
Processor					
Distributed	Yes				
Centralized	No				
Both	No				
Temperature Limits					
Normal °F	32/111				
Short Term °F	32/122				
Relative Humidity					
Normal (%)	10/75				
Short Term (%)	5/95				
Short Term Defined					
Duration (Hours)	72				
Days per Year	15				
Times per Year	1				

PARAMETERS		WE 5 ESS				
Ceiling Height						
Min. Clear (Ft.)		7				
Bay or Cabinet Dimensions						
Height (Inches)		72				
Width (Inches)		30				
Depth (Inches)		21				
Weight						
Bay or Cab. Max. lbs.		-				
Floor Loading (lbs.) $Ft.^2$		82				
DC Power Consumption						
(Amps)	Lines					
	500	107				
3.2 CCS	1000	127				
Per Line	1500	147				
	2000	167				
	3000	207				
	5000	349				
	Max.	2,400				
Heat Dissipation						
(Watts)	Lines					
	500	5,000				
3.2 CCS	1000	5,900				
Per Line	1500	6,800				
	2000	7,700				
	3000	9,600				
	5000	13,350				
	Max.	62,360				
Floor Space (Sq. Ft.)						
	Lines					
	500	368				
10% Trunking	1000	368				
	1500	368				
	2000	450				
	3000	450				
	5000	485				
	Max.	1,300				

RST PARAMETERS	GTE RSU	GTE RLU	HITACHI HDX 10S (Not Currently Available)	ITT RLS	ITT RSU
Subscriber Lines					
Maximum	6,144	1,536	1,000	2,100	6,000
Minimum	8	8	90	64	64
Minimum Addition	8	8	4	1	1
Trunks					
Separate EAS	Yes	No	Yes	No	Yes
Separate Toll	No	No	Yes	No	Yes
Separate RST	-	-	Yes	No	Yes
Stand-Alone Service					
POTS (Local Only)	Yes	No	Yes	No	Yes
Access to Another RST	No	No	Yes	No	Yes
Paths to Host (DS1)					
Maximum	32	8	5	12	36
Minimum	2	2	1	2	2
Traffic (CCS)					
All Span Lines in Service	9,600	2,400	5,760	7,608	22,824
Stand-Alone	9,600	-	5,760	No	22,824
Connect to Separate RST	No	No		No	
Maximum Number			4		4
Distributed RST	No	No	No	No	No
Locations per Span					
Housing, Supplier Furnished	No	No	Yes	No	No
Maximum Lines			570		
Minimum Lines			90		
Floor Space (Sq. Ft.) Lines					
50	147	147	77	80	240
100	147	147	77	80	240
250	147	147	77	80	240
500	147	147	77	80	240
Max.	380	213	77	119	350
Local Power Required					
AC - Max. (Watts)	11,035	4,448	2,700	3,550	18,600
Min. (Watts)	2,140	2,140	1,700	500	3,400
DC - Max. (Amps)	191	77	45	64	200
Min. (Amps)	37	37	28	10	40
Heat Dissipation					
Maximum Watts	9,550	3,850	2,500	3,550	18,600

RST PARAMETERS	NEC 61-KR	NEC 61-KRS	NT RLM (100)	NT REM (10,10M)	NT RCT (10,10M)
Subscriber Lines					
Maximum	3,072	240	1,216	432	252
Minimum	64	64	100	50	50
Minimum Addition	64	64	1	2	2
Trunks					
Separate EAS	No	No	No	Yes	No
Separate Toll	No	No	No	Yes	No
Separate RST	No	No	No	No	No
Stand-Alone Service					
POTS (Local Only)	Yes	No	Yes	Yes	No
Access to Another RST	No	No	No	Yes	No
Paths to Host (DS1)					
Maximum	20	3	8	4	2
Minimum	3	2	2	2	2
Traffic (CCS)					
All Span Lines in Service	10,580	2,600	3,390	1,880	940
Stand-Alone	10,580	-	2,000	2,400	-
Connect to Separate RST	No	No	No	No	No
Maximum Number					
Distributed RST	No	No	No		
Locations per Span				1	4
Housing, Supplier Furnished	No				
Maximum Lines		240	1,216	400	128
Minimum Lines		64	100	50	50
Floor Space (Sq. Ft.)					
Lines					
50	9.75	12	84	30	15
100	9.75	12	84	30	15
250	9.75	12	84	40	25
500	9.75	-	84	-	-
Max.	34.125	-	84	40	25
Local Power Required					
AC - Max. (Watts)	6,200	2,000	-	-	-
Min. (Watts)	1,500	676	-	-	-
DC - Max. (Amps)	120	41	52.5	20	15
Min. (Amps)	29	13	24.5	10	10
Heat Dissipation					
Maximum Watts	6,312	2,157	1,665	1,026	770

RST PARAMETERS	S-C DSU	S-C RLS	CIT-ALCATEL (Not Currently Available)	WE 5A RSM	
Subscriber Lines					
Maximum	240	1,080		4,096	
Minimum	24	30		256	
Minimum Addition	2	6		256	
Trunks					
Separate EAS	No	No		No	
Separate Toll	No	No		No	
Separate RST	No	No		No	
Stand-Alone Service					
POTS (Local Only)	No	Yes		Yes	
Access to Another RST	No	No		No	
Paths to Host (DS1)					
Maximum	3	8		20	
Minimum	2	2		4	
Traffic (CCS)					
All Span Lines in Service	1,873	11,524		20,876	
Stand-Alone	-	3,400		6,800	
Connect to Separate RST	No	No		No	
Maximum Number					
Distributed RST		No		No	
Locations per Span	10				
Housing, Supplier Furnished				No	
Maximum Lines	240	360			
Minimum Lines	30	30			
Floor Space (Sq. Ft.) Lines					
50	80	88		69	
100	80	88		69	
250	-	88		69	
500	-	88		69	
Max.	80	104		150	
Local Power Required					
AC - Max. (Watts)	1,058	2,035		-	
Min. (Watts)	589	891		-	
DC - Max. (Amps)	19	37		140	
Min. (Amps)	11	16		70	
Heat Dissipation					
Maximum Watts	1,058	2,035		2,665	

UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

GENERAL SPECIFICATION FOR DIGITAL,
STORED PROGRAM CONTROLLED CENTRAL OFFICE EQUIPMENT
FOR
SMALL EXCHANGES

REA Form 523

- 1st DRAFT -
AUGUST 1983

GENERAL SPECIFICATION

Contents

PART I

GENERAL SPECIFICATION FOR DIGITAL CENTRAL OFFICE SWITCHING EQUIPMENT

1. GENERAL

1.1 Definition and Discussion

1.1.1 This specification covers general requirements for a digital telephone central office switching system, which is fully electronic and controlled by stored program processors. A digital switching system switches information which is digitally encoded from any input port to a temporarily addressed exit port. The information may enter the system in either analog or digital form and may or may not be converted to analog at the exit port depending on the facility beyond. The switching system shall operate properly as an integral part of the telephone network when connected to physical and carrier derived circuits meeting REA specifications and other generally accepted telecommunications practices. This specification is to be used to describe the requirements to be met by small digital central offices. For the purpose of this specification, a small digital central office is one whose initial line requirements does not exceed 750 lines. The line capacity for the ultimate expansion of the small digital central office shall be determined by the seller of the equipment. For the purpose of this specification, the ultimate capacity may be chosen by the seller at levels below 750 lines. The bidder shall describe the ultimate capacity of the system proposed in Part IV, Information Supplied by the Bidder.

1.1.2 The output of a digital-to-digital port shall be Pulse Code Modulation (PCM) and shall be encoded in eight-bit words using the mu= 255 encoding law and D3 encoding format, and should be arranged to interface with a T1 span line.

1.1.3 There are two types of requirements listed in this specification as discussed in the following two paragraphs:

1.1.3.1 Fixed Requirements.

1.1.3.1.1 Unless otherwise indicated, the requirements listed herein are considered to be fixed requirements.

1.1.3.2 Optional Requirements.

1.1.3.2.1 In some cases, requirements are listed for features which may not be needed for every office. Such features are identifiable by the inclusion in the requirements of some such phrase as "when specified by the Owner" or "as specified by the Owner."

1.1.3.2.2 In some cases where an optional feature will not be required by an Owner, either now or in the future, a system which does not provide this feature shall be considered to be in compliance with the specification for the specific installation under consideration, but not in compliance with the entire specification.

1.1.3.2.3 The Owner may properly request bids from any supplier whose system provides all the features which will be required for a specific installation.

1.1.3.2.4 The Application Guide, REA TE&CM , provides information as to the economic and service factors involved in all optional features.

1.2 Reliability

1.2.1 Quality control and burn-in procedures shall be sufficient so that the failure rate of printed circuit boards does not exceed an average of 2.0 percent per month of all equipped cards in the central office during the first 3 months after cutover, and an average of 0.5 percent per month of all equipped cards in the central office during the second 3-month period. The failure rate for the equipment shall be less than 0.5 percent per month of all equipped cards after 6 months. A failure is considered to be the failure of a component on the PC board which requires it to be repaired or replaced.

1.2.2 The central office switching units shall be designed such that there will be no more than one hour of total outages in 20 years, excluding dispatch and travel time for unattended offices.

1.3 System Type Acceptance Tests

1.3.1 While general acceptance tests will be required on each system type, they will not be expected to cover every requirement herein. However, any installation of a system provided in accordance with this specification shall be capable of meeting any requirement herein on a spot-check basis.

1.3.2 A "completed call" test shall be made part of these acceptance tests. There shall be no more than 2 in 10,000 locally originating and incoming calls misdirected, unsuccessfully terminated, prematurely disconnected or otherwise failing as a result of equipment malfunction and/or equipment failures or as a result of transients, noise or design deficiencies. This test is to be made with a load box with no less than 10 lines access and 10 subscriber numbers for completion, or equivalent, with no other traffic in the system. If there is a failure in the equipment during this test the failure cause shall be repaired and the test restarted at zero calls.

1.3.3 System type acceptance testing applies basically to factory type testing, and not to Owner acceptance testing for individual installations. The overall installed and operating system is also expected to meet these requirements, except for unusual circumstances or where specifically excluded by this or other REA requirements.

1.4 Features Required

1.4.1 This paragraph lists the important general requirements for a digital switching system for use by REA borrowers. More detailed requirements, including quantitative requirements, are listed in subsequent paragraphs.

1.4.2 The equipment shall provide for terminating and automatically interconnecting subscriber lines and trunks in response to dial pulses (or pushbutton dialing signals, if specified) without the aid of an operator.

1.4.3 Complete flexibility shall be provided for connecting any subscriber directory number to any central office line equipment by the use of internal programmed memory. Thus, any subscriber line and/or directory number may be moved to another terminal, providing that the line equipment hardware is compatible with the service provided, to distribute traffic loads.

1.4.4 The system shall be arranged to interface with common carrier trunks and networks using single- or multi-digit access codes and initially equipped to handle 10-digit numbers. The design and software shall be such that equipment for handling 14-digit numbers and two-digit or three-digit access codes can be added. All subscriber directory numbers in the office will be seven-digit numbers.

1.4.5 The network and the control equipment shall be comprised of solid-state and integrated circuitry components. Peripheral equipment shall be comprised of solid-state and integrated circuitry components as far as practical and in keeping with the state-of-the-art and economics of the subject system.

1.4.6 The basic switching system shall include the provision of software programming and necessary hardware, including memory, for the following optional custom calling services: call waiting, call forwarding, and three-way calling. It shall be possible to provide these services to any individual line (single party) subscriber

The addition to these services shall not affect the anticipated ultimate capacity of the switch.

1.4.7 The number of parties per line is intended to be no more than two. The type of ringing to be used shall be as specified in Part III of this specification.

1.4.8 Provision shall be made for providing subscriber line identification for TSPS trunks, or equivalent, to the operator's office when required either initially or in the future. LAMA, local measured service and other call accounting information shall be delivered via a data port to an independent accounting and recording system.

1.4.9 When subscriber loops that exceed the resistance and voice frequency gain range of the switching equipment are required, external loop extenders and voice frequency repeaters or LE/VFR combination must be of a type accepted by REA.

1.4.10

1.4.11 The system shall be arranged to serve up to at least four ANC office codes per office, with discrimination on terminating calls by trunk group, numbering plan, or programmed memory and class mark, if specified in Part III of this specification.

1.4.12 Busy hour load handling capacity is an important feature when an office approaches capacity. Also, the delays which may occur in call completion during busy hour periods may prove to be excessive in some system designs. Accordingly, each Bidder will be expected to provide, in Part IV of this specification, data satisfactory to REA regarding the busy hour load handling capacity and traffic delays of his system.

1.4.13 Provision shall be made for hotel-motel arrangements, as required by the Owner, to permit the operation of message registers at the subscriber's premises to record local outdial calls by guests. See item 5.6, Part III.

1.4.14 Provision shall be made for identifying the calling line or incoming trunk on nuisance calls.

1.4.15 Full access from every subscriber line to every interoffice trunk shall be provided.

1.4.16 Facilities shall be provided to make possible the working of service orders, making traffic studies, and switching and transmission tests by means of remote control devices.

1.4.17

1.4.18 The system shall be capable of

the use of pair gain devices such as direct digitally connected concentration, regular concentrators or subscriber carriers, where specifically ordered by the Owner and its engineer.

1.4.19 The switch shall have means to synchronize its clock with switches above it in the network hierarchy.

1.4.20 Consistent with system arrangements and ease of maintenance, space shall be provided on the floor plan for an orderly layout of future equipment bays that will be required for anticipated traffic when the office reaches its ultimate size. Readily accessible terminals will be provided for connection to interbay and frame cables to future bays. All cables, interbay and intrabay (excluding power), if technically feasible, shall be terminated at both ends by use of connectors.

1.4.21 System designs shall give consideration to reducing power consumption during equipment design and any subsequent modifications.

1.4.22 While not required, it is desirable to supply equipment capable of operation over the widest range of temperature to permit economies in heating and air-conditioning.

1.4.23 Processors may be centralized, distributed or a combination at the manufacturer's discretion.

1.4.24 When specified, it shall be possible to operate several systems under a single office code. The supplier shall describe the communication facility required among the several switch locations to implement this feature.

2. LINE CIRCUIT REQUIREMENTS

2.1 General

2.1.1 Resistance of the Subscriber's Line: The range of dc resistances of subscriber loops, measured from the main frame in the central office and including the telephone set must meet at least the following:

Without Loop Extension - 0 - 1900 ohms
With Loop Extenders, or Equivalent - 1900 - 3000 ohms

These limits apply under maximum adverse environmental and manufacturing variation tolerance conditions. Central office voltage shall be stabilized at a value necessary to provide at least a nominal 21 milliamperes current with a non treated loop of at least 1900 ohms. Minimum loop insulation resistance without loop extenders shall be 25,000 ohms between conductors or from either conductor or both conductors in parallel to ground. Loop insulation resistance for loop extension devices may be 100,000 ohms minimum between conductors or from either conductor or both conductors in parallel to ground. Signaling limits for pay station lines are covered in REA TE&CM 703.

2.1.2 Ring Trip Range: With loop extension the trip and pretrip limits of the central office equipment and the ringing generator voltage must be such as to permit the satisfactory use of a maximum of six bridged, high impedance ringers.

The outside plant cable, both 24-gauge and 22-gauge, can be assumed to have an average mutual capacitance of 0.083 μF per mile. (Refer to TE&CM 212 for ringing criteria.)

2.1.3

2.2 Dialing

2.2.1 The line equipment and central office equipment in tandem shall operate satisfactorily when used with subscriber dials having a speed of operation between 8 and 12 impulses per second and a break period of 55 to 65 percent of the total impulse period, working on lines having the number and type of ringers and the loop and cable characteristics specified under "Ring Trip Range," paragraph 2.1.2, above.

2.2.2 Subscriber Dial Interdigital Time: The line equipment and central office equipment shall operate satisfactorily on subscriber rotary dial interdigital times of 200 milliseconds minimum, and 50 milliseconds minimum with pushbutton dialing.

2.2.3 Subscriber Line Pushbutton Dialing Frequencies: The frequency pairs assigned for pushbutton dialing shall be as listed below, with an allowable variation of $\pm$ 1.5 percent:

Low Group Frequencies (Hz)	High Group Frequencies (Hz) 1209	1336	1477	1633
697	1	2	3	Spare
770	4	5	6	Spare
852	7	8	9	Spare
941	*	0	#	Spare

The receiver shall check that two and only two of the tones are present, that one is from each group of four, that they are present for at least 40 milliseconds. The receiver shall provide a guard against false pulsing due to voice signals.

2.3 Impedance

2.3.1 For the purpose of this specification, the input impedance of all subscriber loops served by the equipment is arbitrarily considered to be 900 ohms at voice frequencies.

2.4 Lockout

2.4.1 All line circuits shall be arranged for line lockout. When a permanent condition occurs prior to placing a line into lockout, a timed low level warning followed by a timed high level receiver off-hook (ROH) tone (paragraph 5.2.11) or a howler circuit (paragraph 11.2.3.2) shall be applied to the line.

2.4.2 The line on lockout shall be reconnected automatically to the central office when the permanent is cleared.

2.5 Pay Stations

2.5.1 Pay stations may be prepay, or semi-postpay, as specified by the Owner.

2.6 Loop Extension

2.6.1

The number of lines which exceed 1900 ohms will be specified by the Owner. When requested by the Owner, the Bidder shall furnish equipment to guarantee satisfactory operation of all lines.

2.6.2 Working limits for subscriber lines with loop extenders are covered in REA Specification PE-61, "Central Office Loop Extenders and Loop Extender Voice Frequency Repeater Combinations."

2.6.3 Ringing from REA accepted loop extenders, or their equivalent, shall be cut off from the called line when the handset at the called station is removed, during the ringing or the silent interval.

2.7 PABX Lines

2.7.1 PABX trunk hunting shall be available. It will not be necessary to segregate PBX trunks to certain line groups.

2.8 Quantity

2.8.1 A sufficient number of terminations shall be provided, in addition to the quantity specified by the Owner for subscriber line service, to meet the requirements of the system for equipment testing, alarm checking, tone transfer, loop around test and other features.

2.9 Types

2.9.1 There shall be provisions for such types of lines as ground start, loop start, regular subscriber, pay stations, etc.

3. REQUIREMENTS FOR INTRAOFFICE SWITCHING

3.1 General

3.1.1 Provide dial tone in response to origination of a call by a subscriber except on special lines where the application of dial tone is not applicable, such as manual and hot lines.

3.1.2 Remove dial tone immediately after the first digit has been dialed.

3.1.3 Recognize the class of service of the calling subscriber.

3.1.4 Register the digits dialed by the calling subscriber where the rotary dial or pushbutton dialing characteristics and the minimum interdigital times are as specified.

3.1.5 Perform the necessary translation functions when the required number of digits has been registered and select a channel to a proper outgoing trunk to common carrier, if one is available.

3.1.6 Provide a transmission path from the calling subscriber line to the selected trunk, if an idle one is found.

3.1.7 When specified by the Owner, provide for one alternate route to the desired destination and to select an idle outgoing trunk in the alternate route trunk group, if all trunks in the first choice group are busy. If no trunks are available in the alternate route, a reorder signal shall be given to the subscriber.

3.1.X When specified by the Owner, provide for access to trunk appearances for multiple common carriers.

3.1.8

3.1.9 On outgoing calls, transmit the proper stored information over the selected trunk to permit completion to the desired destination by the distant office or offices. MF outpulsing shall be provided when specified.

3.1.10 On calls incoming from a distant office, register all the digital information from that office, when dial or MF pulsing characteristics and interdigital times are as specified.

3.1.11 On incoming or intraoffice calls, internally translate a registered directory number into line equipment location, ringing code and terminating class (such as "PBX hunting").

3.1.12 Test the called line for busy.

3.1.13 If the line is idle, cause the incoming trunk or locally originated call to be connected to it.

3.1.14 Permit any type of ringing voltage available in the central office to be associated with any SDN and cause the proper type of ringing voltage to be connected to the called line and remove ringing from the line upon answer whether in the ringing or silent period.

3.1.15 Self-testing shall be available to monitor the integrity of the system.

3.2 Classes of Service

3.2.1 Provide facilities for offering at least the following classes of services to subscribers, as specified by the Owner:

Flat rate individual line, bridged ringing.
Flat rate two-party, full selective ringing.

Flat rate PBX and trunk hunting numbers, bridged ringing.
Pay station.
Message rate subscriber line.
WATS service.

EAS service.
Data service.
Hotel-Motel capability.
Denied Originating.
Denied Terminating.
Custom Calling Features.
Special Common Carrier Accesses.

3.2.2 Provide for originating and terminating class-of-service indications, as required in this specification, on a per-line basis.

3.3 PABX

3.3.1 Make provision for at least one trunk hunting line group in each 100 subscriber directory numbers (SDN's) equipped. (More may be provided as specified by the Owner.)

3.3.2 PBX groups shall be of a reasonable size commensurate with the ultimate size of the switching system.

3.3.3 Provide that any available SDN may be used for PBX trunk hunting.

3.3.4 Provide that each PBX group shall have the capability of being assigned one or more nonhunting SDN's for night service.

3.3.5 If the called line is a PBX hunting line, test all assigned lines in the hunting group for busy.

3.3.6 If the called PBX group is busy, cause line busy tone, as specified in paragraph 5.2.3 to be returned to the originating end of the connection.

3.4 Pay Stations

3.4.1 Pay stations may be prepay or semi-postpay. The system shall be arranged so that an operator and emergency service (911) may be reached from prepay or semi-postpay coin lines without the use of a coin, when the proper pay station equipment is provided.

3.4.2 Test for presence of a coin in the pay station on prepay coin lines.

3.4.3 Pay station numbers shall be assigned to the 9000 series, e.g., 225-9XXX, unless otherwise specified by the Owner.

3.5 Dialing

3.5.1 Initiate the line lockout function after a delay, as specified in paragraph 14.3.1 if dial or pushbutton dialing pulses are not received after initiation of a call.

3.5.2 Connect 120 IPM paths busy tone, recorded message or other distinctive tone to the calling subscriber if an interval longer than that specified in paragraph 14.4 elapses between dialed digits.

3.5.3 If specified by the Owner, register the standard tone calling signals received from a subscriber station arranged for pushbutton dialing. Arrangements shall be provided to function properly with 12-buttor pushbutton dialing sets. If neither the 11th and 12th buttons are assigned functions, receipt of a signal from these buttons shall result in the return of a reorder signal to the subscriber.

3.5.4 Where direct dialing is received on calls from a distant office, provide for the incoming trunk to be connected to the digit register equipment within 120 milliseconds after seizure, and to cancel the bid for a register and return reorder tone to the calling end if dial pulses are received before a register is attached.

3.5.5 Provide for subscribers dialing up to 12 digits for international calling plus access codes to identify the common carrier chosen to carry the call.

3.6 Circuit Usage

3.6.1 To avoid inefficient utilization of the switching network, that portion of common equipment that establishes the connection on intra machine calls shall not require more than 400 milliseconds, exclusive of ringing and ring trip, to complete its function under no-delay conditions.

3.6.2 Provide for circuit elements or components, the failure of which would reduce the grade of service of 100 or more lines by more than 25 percent of the traffic carrying capacity to be available for service more than 99.99% of the time.

3.6.3 Provide necessary means to insure that failure of access to a high choice circuit shall not prevent subsequent calls being served by lower choice circuits, wherever possible.

3.6.4

3.6.5 Where only two circuits of a type are provided, every effort should be made to provide for alternate usage of such circuits on successive calls. Circuits must be designed so that failure of one circuit will not permanently block any portion of the system for the duration of the failure.

3.6.6 Where more than two circuits of a type are provided, successive usages should be on a random basis.

3.6.7

3.7 Busy Verification Facilities

3.7.1 Facilities for busy verification shall be provided with the method of access specified by the Owner.

3.7.2 Only an operator or a switchman shall be able to override a busy line condition.

3.7.3 If the called line is busy, off-hook supervision shall be given the operator or switchman.

3.7.4 The responsibility of restricting subscribers in distant offices from having access to busy verification shall be on the distant office personnel when the toll trunks are used for both toll connecting and verification traffic.

3.7.5 When a verification code is used, all digits of the code must be dialed before cut-through to the called line can be accomplished.

3.8 Revertive Call Facilities

3.8.1 Revertive call by directory number shall be provided to permit subscribers on the same party line to call each other.

3.8.2 A "don't answer" disconnect feature shall be provided which shall operate after an elapsed timing interval as specified in paragraph 14.6.

3.8.3 The equipment shall be designed to provide a recorded announcement to the calling party when he dials a party on the same line and provide an announcement or a distinctive tone as specified by the Owner, in Part III, to the called party when he answers.

3.9 Intercept Facilities

3.9.1 All unused numbering plan area codes, home numbering plan area office codes, service codes and subscriber directory numbers (SDN's) shall be routed to intercept. All intercept administration shall be by changes in memory administrable by telephone company personnel. Maximum machine time to place a subscriber on intercept shall be 5 seconds.

3.9.2 Unequipped SDN's intercept shall be effective if the processor memory does not have information concerning the SDN in question.

3.9.3 The intercept equipment shall be arranged so that specific SDN's can be routed to a separate intercept circuit for changed numbers.

3.9.4 When an intercept call is answered, either by an operator or by a recorded announcement, an off-hook or charge supervision signal shall not be returned, even momentarily, to the originating end.

3.9.5 When intercepting service is to be handled over the regular inter-office toll trunks, a distinctive identifying tone shall be transmitted when the operator answers. This tone shall be of the frequency and duration specified in paragraph 5.2.10.

3.10 Nuisance Call Trap Facilities

3.10.1 When nuisance call trap facilities are activated, a permanent record of the calling and called numbers complete with date and time of day must be made. Where the call originates over an interoffice trunk, the actual trunk number shall be recorded. There shall be optional provision for the called subscriber to hold the connection and for the positive trace of the call from origination to termination within the office.

3.11 Release

3.11.1 The office shall be so arranged that a connection to a terminating channel other than assistance operator shall be released under control of the calling party so that the channel can be reseized, unless call is to emergency 911 service.

3.11.2 If the called party disconnects first, the channel used in the originally established connection shall be held until the calling party disconnects or until the timing interval specified in paragraph 14.7 has elapsed. This feature shall not interfere with the normal operation of calls to intercept, fire alarm, or other special services.

3.12

3.12.1

3.12.2

3.12.3

3.12.4

4. INTEROFFICE TRUNK CIRCUIT REQUIREMENTS

4.1 General

4.1.1 The Bidder shall supply, as requested by the Owner, solid-state technology type trunk and signaling circuits of any of the types described in REA TE&CM 319, "Central Office Trunking and Signaling," or, with the approval of REA, any other more recent and desirable types not as yet covered in the manual. For dc signaling, the "DX" and loop types of signaling shall be the preferred type.

4.1.2 Trunks shall not be directly driven from the subscriber's dial on outward calls.

4.1.3 In order to reduce the spares inventory and minimize incidence of improper maintenance replacement of circuit assemblies, the types of trunk circuits shall be kept to a minimum. Variation in assemblies should be mainly limited to variation in signaling modes.

4.1.4 Trunk circuits which connect with carrier or 4-wire transmission facilities shall be arranged for 4-wire transmission to avoid an intermediate 2-wire interface between 4-wire switch and trunk facilities. On any interoffice trunk calls the delay without traffic congestion between end of dialing and receipt of indication that the call has not failed shall be no more than 4 seconds.

4.2 Quantity

Trunk quantities shall be as specified in Part III. Sufficient space shall be provided for an orderly layout of trunks. Trunks of a certain type going to the same destination shall be grouped together on the original installation.

4.3 Detailed Requirements for Interoffice Connections

4.3.1 When operator trunks are used in common for both coin and noncoin lines, they shall be arranged to provide an indication to the operator by means of a visual signal or tone when calls are from pay stations. When a tone is used, it shall be of the type specified in paragraph 5.2.5 and shall be connected to be heard only by the operator upon answer. It shall be possible to repeat the tone signal.

4.3.2 There are no requirements for trunks arranged for manual re-ring by a toll operator, either with the receiver on or off the hook, except to coin stations with the receiver on the hook.

4.3.3 On calls from subscribers to the assistance operator, the release of the connection shall be under control of the last party to disconnect except for operation with TSP/TSPS.

4.3.4 On calls originated by an operator, the release of the connection shall be under control of the operator.

4.3.5 Where trunks with E and M lead signaling are used, the trunk circuits for Type I signaling shall be arranged to place ground on the M lead during the on-hook condition and battery on the M lead in the off-hook condition. For E and M Type II, only a make contact between the MA and MB lead will be required. In either type, current limiting shall be provided in the E lead of the trunk circuit itself, as required for proper operation. It shall be assumed that connection equipment in the form of trunk carrier, multiplex or associated signaling apparatus furnishes only a contact closure to ground (Type I) or to a signal ground lead (Type II) for an off-hook condition on the E lead.

4.3.6 Where answer supervision is used to determine the initiation of the charging interval for a call, such answer supervision shall not be effective for charging until after the elapse of the timing interval listed in paragraph 14.5 .

4.3.7 When necessary, provision shall be made for reception of start and stop dial signals on toll trunk equipment.

4.3.8 When trunks arranged for AMA, toll ticketing, or message registration are specified by the Owner, they shall provide the pertinent features described in the REA specifications applicable to such functions. (REA Form 538a, for instance.)

4.4 Detailed Requirements for Direct Digital Connections

4.4.1 The following covers the detailed requirements for the provision of interface units which will permit direct digital connection to other digital switches, channel banks and remote line and/or trunk circuits over digital facilities. The digital transmission system shall be compatible with T1 type span lines using a DS1 interface and other digital interfaces that may be specifed by the Owner. The REA specification for the span line equipment is PE-60. Other span line techniques may also be used.

4.4.2 Each interface circuit will connect 24 voice channels to the switch from a 1.544 megabit per second DS1 bit stream. The DS1 bit stream entering or exiting the system will be in the D3 format and the voice signals will be encoded in 8 bit mu= 255 PCM. The format and processing of the bit stream must be compatible with characteristics of the D3 channel bank. Examples are alarm and maintenance characteristics. Loss of receive signal (DS1) or frame synchronization shall be detected and execute the equivalent of a carrier group alarm in 2.5 $\pm$ 0.5 seconds.

4.4.3 Signaling will be by means of MF or DP and the system which is inherent in the A and B bits of the D3 format. CCIS and any other common channel signaling system is permitted if it is REA approved. In the case where A and B bits are not used for signaling, these bits shall only be used for normal voice and data transmission.

5. TONES

5.1 General

5.1.1 Tones shall be provided to indicate the progress of a call through the office. Tone generators should be an integral part of the switching systems. The tones should be introduced digitally by the application of the appropriate bit stream to the line or trunk circuit via the digital switching network. The necessary precautions shall be made to assure the availability of tone sources at least 99.99% of the time.

5.2 Tone Specifications

5.2.1 Dial tone shall consist of 350 plus 440 Hz at a composite level of -10 dBmo which equates to -13 dBmo per frequency. This is the precise tone suitable for use with pushbutton dialing.

5.2.2 Low tone shall consist of 480 plus 620 Hz at a composite level of -21 dBmo which equates to -24 dBmo per frequency.

5.2.3 Line busy tone shall be low tone interrupted at 60 IPM, with tone on 0.5 seconds and off 0.5 seconds.

5.2.4 Reorder, all paths busy and no circuit tone shall be low tone interrupted at 120 IPM, with tone on 0.25 seconds and off 0.25 seconds.

5.2.5 Identifying tone on calls from coin lines shall be uninterrupted low tone.

5.2.6 High tone shall consist of 480 Hz at -17 dBmo.

5.2.7 Audible ringback tone shall consist of 440 plus 480 Hz at a composite level of -16 dBmo which equates to -19 dBmo per frequency.

5.2.8 Tick tone shall consist of high tone interrupted at 200 IPM with tone on 150 MS and off 150 MS.

5.2.9 The above listed tones are the tones adopted by the Bell System as their Precise Tone Plan. The 350, 440, 480, and 620 Hz tones shall be held at a ±0.5 percent frequency tolerance and + 3 dB amplitude variation. The amplitude levels specified are to be measured at the main distributing frame, excluding cable loss.

5.2.10 Identifying tone on intercepted calls shall consist of uninterrupted high tone impressed on the trunk circuit 300 to 600 milliseconds following the operator's answer of intercepted calls.

5.2.11 An ROH circuit shall have output tones which do not interfere with the pushbutton or multi-frequency signaling tones. The ROH tone is to be introduced digitally internal to the system not to exceed the overload level of +3 dBmo. No power adjustment will be required. The frequency of the output shall be chosen to be distinctive and urgent in order to attract the subscriber's attention to an off-hook situation.

5.2.12 During application of tones, office longitudinal balance must be maintained within 15 dB of that specified in paragraph 13.8

6. SYSTEM CLOCK

6.1 General

6.1.1 The Class 5 central office system clock shall have a frequency deviation of no less than 3.7 parts in 10^7 per day.

6.1.2 The clock shall have the ability to be synchronized with external clocks for network synchronization in a digital-to-digital environment.

6.1.3 Reference AT&T's Technical Advisory #58.

7. AUTOMATIC NUMBER IDENTIFICATION

7.1 General

7.1.1 The equipment shall be arranged for Automatic Number Identification (ANI) operation to a Centralized Automatic Message Accounting (CAMA) center.

7.2 Operation

7.2.1 Facilities shall be provided for transmitting to the CAMA center the identified calling station number, together with the necessary information regarding the nature of the call.

The format (or sequence of pulses) for Station-to-Station Sent Paid (SSSP) calls which is generally used for ANI-CAMA is shown in the latest edition of "Notes on the Network."

7.2.2 Cases may arise where additional information regarding the nature of the call may be required by the CAMA center, necessitating the transmission of more information. The problem here is one of compatibility between the ANI equipment and the CAMA equipment. Hence, any deviation from the "Notes on the Network" format for ANI pulsing shall be explained in a note in Item 11 of Part III of this specification and assurance shall be obtained that the differing format will be compatible with the connecting CAMA equipment.

7.2.3 In applications where the ANI equipment works into a CAMA center with TSPS, arrangements are needed for the ANI equipment to accept and identify 0+, 0-, and 1+ dialing. Special pulsing formats are required to identify the kind of call forwarded to the CAMA center. Special formats are also available for several other types of service such as coin lines, motel lines, mobile service, etc. These formats are also described in the latest issue of "Notes on the Network."

7.2.4 With the application of ANI(CAMA), provisions must be made to block coin lines from access to the ANI (CAMA) trunks. If this office connects to a TSPS office, it will be necessary for the identification function to work with coin lines.

8. FUSING AND PROTECTION REQUIREMENTS

8.1 General

8.1.1 The equipment shall be completely wired and equipped with fuses, trouble signals, and arranged for printout of fault conditions, with all associated equipment for the wired capacity of the frames or cabinets provided.

8.1.2 Design precautions shall be taken to prevent the possibility of equipment damage arising from the insertion of an electronic package into the wrong connector or the removal of a package from any connector or improper insertion of the correct card in its connector.

8.2 Fuses

8.2.1 Fuses and circuit breakers shall be of an alarm and indicator type, except where the fuses or breaker location is indicated on the alarm printout. Their rating shall be designated by numerals or color code on the fuse or the panel, where feasible.

8.3 Components

8.3.1 Insofar as possible, all components shall be capable of being continuously energized at rated voltage without injurious results. Insofar as possible, design precautions must be taken to prevent damage to other equipment and components when a particular component fails.

8.3.2 Printed circuit boards or similar equipment employing electronic components shall be self-protecting against external grounds applied to the connector terminals, where feasible. Board components and coatings applied to finished products shall be of such material or so treated that they will not support combustion.

8.3.3 Every precaution shall be taken to protect electro-statically sensitive components from damage during handling. This shall include written instructions and recommendations.

9. SWITCHING NETWORK REQUIREMENTS

9.1 The Network

9.1.1 The network shall be comprised of solid-state components.

9.1.2 The switching network shall employ time division digital switching and be compatible for connection to D3 type PCM channel banks without conversion to analog.

9.1.3 Equipment shall be available as required to connect analog lines and trunks, analog or digital service circuits, D3 channel banks or other digital line concentrator units.

9.2 Network Quantity

9.2.1 Where the number of stages in the switching network and their control varies with the capacity of the system, sufficient equipment and wiring shall be supplied initially in order that there will be no service interruptions when additions are made up to the ultimate capacity as specified in Part III. This does not imply the necessity of supplying empty cabinets unless this is the only way the necessary wiring can be accomplished.

10. STORED PROGRAM CONTROL (SPC) EQUIPMENT REQUIREMENTS

10.1 Major Features

10.1.1 Call processors shall provide service more than 99.99% of the time. No answered calls in progress shall be lost when there is a transfer from one processor to the other. Quality assurance of all software programs shall be in accordance with ANSI/IEEE Standard 730, or equivalent.

10.1.2 Programs shall be modular, flexible and structured. In the interests of more dependable and easier read programs it is desirable to use a language which is more person-oriented leaving the detailed machine-oriented problems to a compiler program. This compiler program is used in the design of the software and not expected to be supplied with the machine.

10.1.3 The office administration program shall have checks within it to prevent failure due to erroneous or inconsistent input data. It shall safeguard against the possibility of upsetting machine performance with improper instructions of information into data store. Introduction of valid instructions shall not require transfer to secondary equipment when non redundant processors and memories are supplied. In addition, modular structure shall allow the use of a variety of human engineered service order formats. Service changes may be performed remotely if so desired. Average machine time for service change shall be 5 seconds or less. Service changes shall not be registered in permanent memory until verified. The access to service change shall not have access to generic program.

10.1.4 The machine shall be able to offer at least the following printouts of its routine stored data for administrative purposes. The printouts may be delayed to times of light traffic.

a. By request, a list of all assigned directory numbers, in order, with their assigned class of service and line terminal numbers.

b. By request, a list of all directory numbers, in order, associated with a class of service.

c. By request, a list of all unassigned line terminals.

d. By request, traffic data in proper form for separation studies in accordance with the USITA procedures.

e. By request, all lines on lockout.

f. By request, all lines assigned to intercept.

g. By request, all available unassigned directory numbers.

h. By request, a list of equipment busied out for maintenance.

10.1.5 Maintenance diagnostics shall be performed by a fault recognition system utilizing both software and hardware, each being used where they are most effective for maintenance and reliability. In the economic interests of providing early and efficient fault detection and accurate pinpointing of faulty areas it is desirable to have a comprehensive man-machine interface supported by extensive automatic fault detection and analysis, involving diagnostic software for fault resolution and automatic recovery mechanisms to maintain continuous service. Maintenance messages may be channeled to a remote maintenance center if so desired.

10.1.6 Information stored having no requirement for changes to be introduced in the maintenance or operation of the system may use memory devices such as PROM's or other devices that cannot be reprogrammed in the field.

11. MAINTENANCE FACILITIES

11.1 Alarm Features, Including Alarm Sending

11.1.1 The equipment shall be arranged to provide audible and visual alarms indicating fuse operation or other circuit malfunctions resulting from component failure, crosses or open wiring, or any other conditions affecting service which can be detected economically.

11.1.2 The alarms shall be classified in accordance with their effect on the system. The classification shall be as follows:

Catastrophic - Demands immediate attention. Such as loss of service, loss of one or more remote line switches, loss of network control, loss of computer program in both processors. Requires notification of highest level of supervisory personnel.

Alarm - Demands rapid action. Such as loss of one or more groups of subscribers or trunk ports. Fuses for common groups of channels and control to groups of channels. When one of a redundant fails but the other is working without problems. Total loss of battery charging current for more than fifteen minutes. Non-emergency conditions which cause degraded service or a fault condition which makes the system operate within less than designed for performance. A condition discovered in automatic routining which has not shown in the operation of the equipment, but requires attention. Cumulative line lockout (level adjustable).

11.1.3 When the office is arranged for unattended operation, facilities shall be provided for extending the alarm indications to an attended point.

11.1.4 When the use of a separate outside plant facility for alarm sending is specified, the nature of the alarm may be indicated to the distant point by machine printout or other display device.

11.1.5 When alarm sending is accomplished over a regular operator office trunk, the operator will be apprised that the call is an alarm indication by a distinctive tone, as specified by the Owner in Part III.

11.1.5.1 It shall be possible for the operator to determine at any time the presence of a trouble condition by dialing a number set aside for that purpose. This number shall also be accessible from lines with proper class marks.

11.1.6 When the alarm sending circuit seizes an interoffice operator trunk, the operator must dial the alarm checking code over another trunk before the first trunk can be released except where the alarm condition has disappeared first.

11.1.7 The alarm sending circuit shall have access to a circuit which cannot be made busy by a circuit used for equalizing usage. The alarm sending circuit shall have access to two or more trunks if the trunks are used for subscriber traffic.

11.1.8 An alarm indication of higher priority shall supersede an original alarm indication and reseize an interoffice operator trunk.

11.1.9 In any group of offices purchased under one contract the same codes shall be used in each office for alarm checking and test.

11.1.10 When the alarm checking number is dialed, the alarm indications received shall be as follows:

Catastrophic Alarm	-	No Tone.
Alarm	-	Continuous busy tone 60 IPM, unless alarm is overridden.
No Trouble	-	Continuous 2-ring code ringback tone, unless alarm is overridden.

11.1.11 Audible and visual local alarms and transmitted alarms shall be provided as follows:

Classification	Delay Interval		
	Local Alarms	Alarms Transmitted	
Catastrophic	0	0	
Alarm	0	0	Except no charge alarm delayed 15 Min.

11.1.12 The central office alarm circuits shall be arranged to provide optional wiring to transmit either a minor alarm or a major alarm and printout to accommodate various types of trunk and subscriber carrier systems, microwave, mobile radio, other transmission systems, and environment protection systems with different priorities when a set of contacts is closed in the equipment of such systems and the alarm checking code is dialed. The alarm relay shall be furnished by the supplier of the carrier multiplex and/or mobile radio equipment. The option or options shall be specified by the Owner.

11.2 <u>Trouble Location and Test</u>

11.2.1 Equipment

11.2.1.1 A maintenance center shall be provided with a fault recorder (printer and/or display) for troubles. Here, system and sub-system visual trouble indications are shown for maintenance aid. When specified, a remote maintenance center shall be supplied.

11.2.1.2 The fault recorder shall provide a permanent or semipermanent record of the circuit elements involved whenever a trouble is encountered. It shall be arranged to recognize an existing fault condition and not cause multiple printouts of the same fault, except during test routine.

11.2.1.3 A receive only printer may be used when system commands and other information can be entered using an input device other than a printer keyboard.

11.2.2 Maintenance System

11.2.2.1 The maintenance system shall monitor and maintain the system operation without interruption of call processing except for major failures.

11.2.2.2 The maintenance system shall provide both specialized maintenance hardware circuits and access to an extensive software package to enable maintenance to determine trouble to an individual card or functional group of cards.

11.2.2.3 Maintenance programs may be both on-line and off-line. On-line maintenance programs are activated by system errors and shall be scheduled to routine call tests executed during low traffic periods and periodic hardware tests (executed at specific time intervals). Programs shall provide diagnostic tools for the maintenance personnel and be initiated by them, either on line or off line depending upon the use of non redundant facilities.

11.2.2.4 Scheduled periodic hardware tests shall automatically detect faults and alert maintenance personnel via alarm or appropriate input/output device(s) at local and/or remote locations.

11.2.2.5 Facilities shall be provided so that test calls can be set up using pre-selected items of switching equipment.

11.2.2.6 Every trunk and every item of switching equipment shall be provided with means for the maintenance personnel to make tests to determine if the equipment is functioning properly. Also, means shall be provided for making each trunk and each SPC equipment, or part thereof, busy to service calls. Where possible, equipment which is made busy to service calls shall still be accessible for test calls.

11.2.3 Outside Plant and Subscriber Stations

11.2.3.1 A subscriber loop test set or equivalent shall be provided either as a separate set or as a part of the maintenance center, as specified in Part III. This circuit shall include a high resistance volt-ohm meter, wiring to tip and ring terminals to permit a portable wheatstone bridge to be used, an operator's telephone circuit, a dial circuit (and pushbutton dialing keys, if specified), outgoing trunks to dial equipment for access to lines under test without use of MDF test shoe and the necessary test keys. No dry cell batteries will be accepted for test potentials. Circuits must be designed so that ac induction on the line will have no effect on dc measurements. All functions must be under control of lever or pushbutton keys. The following test features shall be a minimum that is available:

Test for bridged foreign E.M.F.
Test for regular line battery.
Test for booster battery voltage and polarity through test shoe.
Tests for open circuits, short, tip ground and ring ground.
Test for tip or ring negative potential.
Test for capacitance of subscriber's line.
Supply talking battery to the line with and without booster battery.
Ring the subscriber through the test access circuit or through a test shoe.
Test in and out of central office.
A reverse polarity key for voltage readings must be supplied.

An acceptable arrangement for making these tests is to have them under software control with results displayed at one of the system's I/O ports.

11.2.3.2 A howler circuit for maintenance purposes, if ordered by the Owner, shall have output tones which do not interfere with the pushbutton or multi-frequency signaling tones. The harmonics of the output tones shall be attenuated at least 26 dB below the fundamental frequency for all load conditions. The frequency stability must be 2 percent or less for all output tones when the unit is operated in the specified load and environmental range. The circuit shall include a means to vary the output voltage (power). It shall be so designed that it will remove tone and restore the line to service when the telephone instrument receiver is placed on hook. The frequency of the output shall be chosen to be distinctive and urgent in order to attract the subscriber's attention to an off-hook situation.

11.2.3.3 When a dial speed test facility is specified by the Owner, it shall operate as follows: It shall be accessed by dialing a special code and shall return to the calling station readily identifiable signals to indicate that the dial speed is slow, normal, or fast.

11.2.3.4 When the office is arranged for pushbutton dialing, optional facilities shall be provided for testing the pushbutton dialing equipment at the subscriber station.

11.2.3.5 When a system for testing subscriber lines in remote offices from a test position in a centrally located office is specified by the Owner, it shall be capable of working with all the central offices in the area . This testing equipment shall preferably be solid-state with a minimum of electromechanical devices and shall operate from central office battery. It shall be capable of working over any voice grade telephone circuit and shall not require a dedicated trunk. There shall be no interference to or from "in-band" voice channel tones. When used over a network, the verification or access shall be guarded to prevent unauthorized access by subscribers. Access to this system shall only be available to the test operator in all cases.

11.3 Transmission Testing

11.3.1 When transmission test circuits are specified in item 6.3.1 of Part III, they shall permit testing of trunks by a distant office without any assistance in the local dial office. Analog test ports shall meet appropriate trunk requirements. If Centralized Automatic Reporting on Trunks (CAROT) is to be used, the equipment at the end office shall comply with AT&T's Advisory TA17.

11.3.2 Transmission test circuits are available with a variety of options. These include single- and multi-frequency tone generators with one or more generator output terminals, quiet terminations, and loop around test arrangements for both one- and two-way trunks.

11.3.3 Where multifrequency generators are used, they are usually arranged to provide a minimum of three frequencies. With some equipments up to seven additional frequencies may be provided if needed. No industry standardization of test frequencies is as yet provided. Therefore, it is important that the selection of frequencies, the order in which they are applied and the time interval for application of each frequency be agreed upon by the connecting company and the REA borrower and listed in Part III in those situations where connecting companies request the installation of multifrequency generators in borrowers' central offices.

11.3.4 The milliwatt generator shall be solid-state and generate the analog or digital equivalent of 1004 Hz. The milliwatt generator shall be assigned to a 4-wire analog test port or be digitally generated. All 2-wire and 4-wire voice frequency ports are at a nominal 0 dBm0 level. The level of the 1004 Hz tone generator shall appear at outgoing 2-wire and 4-wire ports at 0 dBm ± 0.5 dB. For direct digital connections, the encoded output shall be the digital equivalent of a 0 dBm0 ± 0.5 dB signal.

11.3.5 Reference tone generators can be used individually or they can be part of a loop around test arrangement. If both single and multi-frequency reference tone generators are to be provided, only one can be arranged as part of a loop around test. Where a loop around arrangement is provided, the generator output can be obtained by dialing singly, one of the two line terminals. By dialing the other line terminal singly, usually a 900 ohm resistor in series with a 2.16 μF capacitor is connected to the circuit under test to act as a "quiet termination" for noise measurements and other tests. Whenever both line terminals are held simultaneously, both the milliwatt supply and the quiet termination shall be lifted off and a "loop around" condition established. This permits the overall loss to be determined from the distant office by going out over one trunk, looping around in the end office and returning over the other trunk. The insertion loss of this test arrangement when used in a loop around configuration should not exceed 0.1 dB at the frequencies specified for the milliwatt supply. Unless otherwise specified, continuous off-hook supervision is to be provided on both line terminals to prevent collusive calling without charge.

11.3.5.1 It will be permissible to accomplish the quiet termination by opening the 4-wire path internally and to accomplish the loop around by digital switching.

11.3.6 Provision should be made so that the milliwatt supply can be manually patched to circuits.

11.3.7 Test jack access shall be provided for all interoffice trunks of the voice frequency type. The jack access shall be properly designated for line, drop, monitor, and signaling leads plus any other jacks as requested by the Owner. This may be accomplished by a set of jacks located in the maintenance center which have access to each trunk on a switching basis.

11.3.8 When required, provide a loop back facility controllable from the far end to permit testing of the DS-1 data stream without requiring on site assistance.

12. TRAFFIC

12.1 General

12.1.1 Traffic and Plant Registers. Traffic measurements consist of three types: peg count, usage and congestion. A peg count register scores one count per call attempt per circuit group such as trunks, digit receivers, senders, etc. Usage counters measure the traffic density in networks, trunks and other circuit groups. Congestion registers score the number of calls which fail to find an idle circuit in a trunk group or to find an idle path through the switching network when attempting to connect two given end points. These conditions constitute "network blocking."

12.1.1.1 Traffic data will be stored in electronic storage registers or block of memory consisting of one or more traffic counters for each item to be measured. The call peg count, overflow, all trunks busy, etc., registers shall be associated with the interoffice trunks, switching network and central control equipment in such a manner that the register readings can be used to determine the traffic load and flow to, from and within the system. Two-way trunks shall be metered to indicate inward and outward seizures. The Bidder shall indicate what registers are to be supplied and their purpose.

12.1.1.2 The measured data shall be shown on a printout. It should be possible to have local or remote printout, or both. Arrangement shall be made for automatic data printout on command for 15-, 30-, or 60-minute intervals as required, and be arranged for automatic start-stop and in accordance with revenue separation procedures current at the time of contract.

12.1.1.3 All traffic records shall have dates and times and office identification.

12.1.2 Full Availability Traffic Table. The Traffic Table, based on the Erlang Lost-Calls-Cleared Formula, shall be used for determining the quantity of intraoffice paths, registers and senders where full availability conditions apply. The table in paragraph 12.4 shows the traffic capacity in CCS for 1 to 200 trunks at nine grades of service.

12.1.3 It will be noticed that the character "B" is used to express the grades of service listed in paragraph 12.2.2 based on the Traffic Table, whereas the character "P" was used with reference to the Poisson Table.

12.1.4 Limited availability is not permitted.

12.1.5 Traffic Table for Small Groups of Service Trunks. The traffic capacity in this table should be used for small trunk groups such as pay station, special service trunks, revertive circuits, intercept and PBX trunks, unless otherwise specified in Part III.

Number of Circuits	Permissible CCS
1	10
2	20
3	30
4	40

12.1.6 The traffic capacity for all interoffice trunks shall be based on full availability though the distant office may not provide full availability.

12.1.7 The Traffic Table may also be used to determine the approximate traffic capacity of high-usage intertoll trunks. The traffic offered to high-usage groups may be read at B.10, signifying that 10 percent of the traffic overflows to the alternate route. This approximates the HU12 table used by AT&T.

12.1.8 In reading the trunk quantity from the table, the higher quantity shall be used when the CCS load is 3 or more CCS over the lower quantity. For example, the number of trunks justified for 294 CCS at B.005 is 16, but for 295 CCS 17 trunks are justified.

12.2 Grade of Service

12.2.1 Switching Network

12.2.1.1 The switching network objectives shall provide sufficient channels between lines and trunks to meet the following service standards, called "Matching Loss Standards." These standards express the probability of internal blocking (called "congestion"), that is the probability of failure to find a path from an originating line or trunk to an idle register, line or trunk:

A.	Dial Tone Delay	1.5% of Calls Delayed Over 3 Seconds
B.	Post Dialing Delay	1 Second
C.	Intraoffice Matching Loss	2:100
D.	Outgoing Matching Loss	1:100
E.	Incoming Matching Loss	2:100

These service standards apply, for the average busy season, busy hour load and are met by retrials in case of selecting an idle trunk or register.

A. Dial Tone Delay - The dial tone delay is a measure of the time from off-hook to the return of dial tone. The dial tone standard specifies that the number of calls encountering delay in excess of 3 seconds, measured over the busy hour of all business days during the busy season, is not more than 1.5 percent. The circuits in the path of dial tone shall be provided at the grades of service mentioned in paragraph 12.2.2.

B. Post Dialing Delay - The post dialing delay is defined as the time from the registration of the last digit to switch through. The average post dialing delay objective for an intraoffice call shall be one second. This includes the circuit operate and translation time.

C. Intraoffice Matching Loss - This grade applies to systems in which connection of line-to-line is made in one step in contrast to systems in which connection is first made to an originating junctor and then to the line. This standard represents the weighted average loss of all classes of connections.

D. Outgoing Matching Loss - This grade represents the internal blocking from a particular inlet in the trunk network to any idle trunk in the desired route.

E. Incoming Matching Loss - This grade represents the total blocking from a particular inlet in the trunk network to a particular line. It includes the blocking on the terminating junctors, or equivalent, as well as the internal blocking in the line network.

12.2.2 Paths and Control Circuits Provision:

Intraoffice Paths	B.005
Incoming Registers:	
Without Start Signal	B.001
With Start Signal	B.01
Senders, MF or DP	B.001
Direct Digital Interface	B.005

12.2.3 Pushbutton Dial Traffic

12.2.3.1 The percentage of lines equipped for pushbutton dialing is to be used to determine the number of tone receivers. All local registers must be supplied on the basis of all dial pulse. This may be excepted where an office specifies 100 percent pushbutton dialing will be used at cutover.

12.3 Holding Times

12.3.1 For the purpose of estimating the quantity of common control circuits, the following average holding times may be used. These holding times are conservative and represent the average effective and ineffective call. If these holding times are to be used it must be so stated in Part III.

12.3.2 Average Call Holding Times:

Type of Call	H.T. - Seconds
Intraoffice	120
Revertive	150
EAS	150
Special Service, Intercept, Verification	60
Toll, CLR	300
Toll, S-S	240
Toll, PPCS	270

12.3.3 Average Subscriber Dialing Holding Times (Times used to dial digits do not include machine time):

	Digits Dialed	DP Sec.	Pushbutton Sec.
Operator, Non-Pay Station	1	4.7	3.4
Special Service	3	7.7	5.0
Local	7	13.7	8.2
EAS	7	13.7	8.2
DDD 1/0+7	8	15.2	9.0
DDD 1/0+10	11	19.7	11.4
Dialing Time Per Digit	-	1.5	0.8
Dial Tone Response	-	3.2	2.6

12.3.4 Average Incoming Registers Holding Times (Times for digit registrations do not include machine time):

	Basic		
	Holding Time (Sec.)	Digits	Additional Per Digit
MF Receiver From:			
No. 5 Crossbar-Non LAMA	1.4	4	0.14
No. 5 Crossbar-LAMA	2.3	4	0.14
Crossbar Tandem and 4A Toll	3.1	4	0.14
No. 1 ESS	1.4	4	0.14
Key Pulsing Switchboard	5.2	4	0.60
DP Receivers - 10 PPS From:			
SxS	6.0	4	1.5
Dialing Switchboard	6.6	4	1.3
4A Toll	5.6	5*	-
Crossbar Tandem	4.9	4	1.2

*No reduction for fewer digits.

12.3.5 Average Sender Holding Times (Does not include machine set up and release time):

	Basic		
	Holding Time (Sec.)	Digits	Additional Per Digit
MF Senders			
No. 5 Crossbar	1.5	4	0.14
Crossbar Tandem and 4A Toll(1)	2.0	4	0.14
TSP/TSPS	2.4	7	0.14
SxS-CAMA, Called Number	3.7	7	0.14
SxS-CAMA, Calling Number	1.3	7	-

	Basic Holding Time (Sec.)	Digits	Additional Per Digit
DP Senders - 10 PPS:			
With Overlap Pulsing[2]	9.1	Up to 6	1.8
Without Overlap Pulsing	4.6	4	1.2

(1) Add 1.3 seconds for ANI outpulsing on special toll (0+) calls and on DDD calls if AMA is not provided.

(2) Assumes overlap outpulsing starting on receiving of third digit; applies only to calls handled on direct trunk groups.

TRAFFIC TABLE

Full Availability for Random Traffic

LOST-CALLS-CLEARED

Offered Traffic Expressed in CCS

Number of Trunks	B-.001	.002	.005	.01	.02	.05	.1	.2	.5	Number of Trunks
1	0	0	0	0	1	2	4	9	36	1
2	2	3	4	5	8	14	22	36	98	2
3	7	9	13	17	22	32	46	69	165	3
4	16	19	25	31	39	55	74	106	234	4
5	27	32	41	49	60	80	104	144	304	5
6	41	48	58	69	82	107	135	184	374	6
7	57	65	78	90	106	135	168	224	445	7
8	74	83	98	113	131	163	202	265	516	8
9	92	103	120	136	156	193	236	307	586	9
10	111	123	143	161	183	224	270	348	656	10
11	131	145	166	186	210	255	306	391	729	11
12	152	167	190	212	238	286	341	433	801	12
13	174	190	215	238	266	318	377	476	872	13
14	196	213	240	265	295	350	413	519	944	14
15	219	237	266	292	324	383	449	562	1015	15
16	242	261	292	320	354	415	486	605	1087	16
17	266	286	318	347	384	449	523	648	1158	17
18	290	311	345	376	414	482	560	692	1230	18
19	314	337	372	404	444	515	597	735	1302	19
20	339	363	399	433	474	549	634	779	1374	20
21	364	388	427	462	505	583	671	823	1445	21
22	389	415	455	491	536	617	709	866	1517	22
23	415	441	483	521	567	651	747	910	1589	23
24	441	468	511	551	599	685	784	954	1661	24
25	467	495	540	580	630	720	822	998	1733	25
26	493	523	568	611	662	754	860	1042	1805	26
27	520	550	598	641	693	788	898	1086	1876	27
28	546	578	627	671	725	823	936	1130	1948	28
29	573	606	656	702	757	858	974	1174	2020	29
30	600	634	685	732	789	893	1012	1218	2092	30
31	628	662	715	763	822	928	1050	1263	2164	31
32	655	690	744	794	854	963	1089	1307	2236	32
33	683	719	774	825	887	998	1127	1351	2308	33
34	711	747	804	856	919	1033	1165	1395	2380	34
35	739	776	834	887	951	1068	1203	1439	2452	35
36	767	805	864	918	984	1104	1242	1484	2524	36
37	795	834	895	950	1017	1139	1281	1528	2595	37
38	823	863	925	981	1050	1174	1319	1572	2667	38
39	851	892	955	1013	1083	1210	1358	1617	2739	39
40	880	922	986	1044	1116	1246	1396	1661	2811	40
41	909	951	1016	1076	1149	1281	1435	1706	2883	41
42	937	980	1047	1108	1182	1317	1474	1750	2955	42
43	966	1010	1078	1140	1215	1352	1512	1795	3027	43
44	995	1040	1109	1171	1248	1388	1551	1839	3099	44
45	1024	1070	1140	1203	1282	1424	1590	1884	3171	45
46	1053	1099	1171	1236	1315	1459	1629	1928	3243	46
47	1083	1129	1202	1268	1349	1495	1668	1973	3315	47
48	1112	1159	1233	1300	1382	1531	1706	2017	3387	48
49	1141	1189	1264	1332	1416	1567	1745	2062	3459	49
50	1170	1220	1295	1364	1449	1603	1784	2106	3531	50

TRAFFIC TABLE

Full Availability for Random Traffic

LOST-CALLS-CLEARED

Offered Traffic Expressed in CCS

Number of Trunks	B-.001	.002	.005	.01	.02	.05	.1	.2	.5	Number of Trunks
51	1200	1250	1327	1397	1483	1639	1823	2151	3603	51
52	1229	1280	1358	1429	1516	1675	1862	2195	3675	52
53	1259	1310	1390	1462	1550	1711	1901	2240	3747	53
54	1289	1341	1421	1494	1584	1747	1940	2285	3819	54
55	1319	1371	1453	1527	1618	1783	1979	2329	3891	55
56	1349	1402	1484	1559	1652	1819	2018	2374	3962	56
57	1378	1432	1516	1592	1686	1856	2057	2418	4034	57
58	1408	1463	1548	1625	1719	1892	2096	2463	4106	58
59	1439	1494	1579	1657	1753	1928	2136	2508	4178	59
60	1468	1525	1611	1690	1787	1965	2174	2552	4250	60
61	1499	1556	1643	1723	1821	2001	2214	2597	4322	61
62	1529	1587	1675	1756	1855	2037	2253	2642	4394	62
63	1559	1617	1707	1789	1889	2073	2292	2687	4466	63
64	1590	1648	1739	1822	1923	2110	2331	2731	4538	64
65	1620	1679	1771	1855	1958	2146	2370	2776	4610	65
66	1650	1710	1803	1888	1992	2182	2409	2821	4682	66
67	1681	1742	1835	1921	2026	2219	2449	2865	4754	67
68	1711	1773	1867	1954	2060	2255	2488	2910	4826	68
69	1742	1804	1900	1987	2094	2291	2527	2955	4898	69
70	1773	1835	1932	2020	2129	2328	2566	3000	4970	70
71	1803	1867	1964	2053	2163	2364	2606	3044	5042	71
72	1834	1898	1997	2087	2197	2401	2645	3089	5114	72
73	1865	1929	2029	2120	2232	2438	2684	3134	5186	73
74	1895	1961	2061	2153	2266	2474	2723	3178	5258	74
75	1926	1992	2093	2186	2300	2511	2763	3223	5330	75
76	1957	2024	2126	2219	2335	2547	2802	3268	5402	76
77	1988	2055	2159	2253	2369	2584	2841	3313	5474	77
78	2019	2087	2191	2286	2404	2620	2881	3357	5546	78
79	2050	2118	2223	2319	2438	2657	2920	3402	5618	79
80	2081	2150	2256	2353	2473	2694	2959	3447	5690	80
81	2112	2182	2289	2386	2507	2730	2999	3492	5762	81
82	2143	2213	2321	2420	2542	2767	3038	3537	5834	82
83	2174	2245	2354	2453	2577	2803	3077	3581	5906	83
84	2206	2277	2386	2487	2611	2840	3117	3626	5977	84
85	2237	2309	2419	2521	2646	2877	3156	3671	6049	85
86	2268	2340	2452	2554	2680	2913	3196	3716	6121	86
87	2299	2372	2485	2588	2715	2950	3235	3761	6193	87
88	2331	2404	2517	2621	2750	2987	3275	3805	6265	88
89	2362	2436	2550	2655	2784	3024	3314	3850	6337	89
90	2393	2468	2583	2688	2819	3060	3353	3895	6409	90
91	2425	2500	2616	2722	2854	3097	3393	3940	6481	91
92	2456	2532	2649	2756	2889	3134	3432	3984	6553	92
93	2488	2564	2682	2790	2923	3171	3471	4029	6625	93
94	2519	2596	2715	2823	2958	3208	3511	4074	6697	94
95	2551	2628	2748	2857	2993	3244	3551	4119	6769	95
96	2582	2660	2781	2891	3028	3281	3590	4164	6841	96
97	2614	2692	2814	2925	3063	3318	3630	4209	6913	97
98	2645	2724	2847	2958	3097	3355	3669	4253	6985	98
99	2677	2757	2880	2992	3132	3392	3708	4298	7057	99
100	2709	2789	2913	3026	3167	3429	3748	4343	7129	100

TRAFFIC TABLE

Full Availability for Random Traffic

LOST-CALLS-CLEARED

Number of Trunks	Offered Traffic Expressed in CCS B-.001	.002	.005	.01	.02	.05	.1	.2	.5	Number of Trunks
105	2867	2950	3078	3196	3342	3613	3946	4567	7489	105
110	3027	3112	3244	3366	3516	3798	4143	4792	7849	110
115	3186	3275	3411	3536	3691	3983	4341	5016	8209	115
120	3347	3437	3578	3707	3867	4168	4539	5241	8569	120
125	3507	3601	3745	3878	4043	4353	4737	5465	8929	125
130	3669	3765	3912	4049	4219	4539	4935	5689	9289	130
135	3830	3929	4081	4221	4395	4724	5133	5914	9649	135
140	3992	4093	4249	4392	4571	4910	5332	6138	10009	140
145	4155	4258	4418	4564	4748	5095	5530	6363	10369	145
150	4318	4423	4586	4737	4925	5282	5728	6587	10729	150
155	4481	4589	4755	4909	5102	5467	5927	6812	11089	155
160	4644	4755	4925	5082	5279	5654	6125	7037	11449	160
165	4808	4920	5094	5255	5457	5840	6324	7261	11809	165
170	4972	5087	5264	5428	5634	6026	6523	7486	12169	170
175	5137	5253	5434	5602	5811	6213	6722	7710	12529	175
180	5301	5420	5604	5775	5989	6399	6920	7935	12889	180
185	5466	5587	5775	5949	6167	6586	7119	8160	13249	185
190	5631	5754	5945	6123	6345	6773	7318	8384	13609	190
195	5797	5922	6116	6296	6524	6960	7517	8609	13969	195
200	5962	6089	6287	6471	6702	7146	7716	8834	14329	200

13. TRANSMISSION

13.1 General

13.1.1 The transmission characteristics will be governed by the fact that the switching matrix will be based on digital operation. Unless otherwise stated, the requirements are in terms of analog measurements made from Main Distributing Frames (MDF) to MDF terminals excluding cabling loss.

13.2 Impedance

13.2.1 For the purpose of this specification, the nominal input impedance of analog ports in a class 5 office shall be 900 ohms for 2-wire ports and 600 ohms for 4-wire ports. Where the connecting facility or equipment is other than this impedance, suitable impedance matching shall be provided by the Bidder when specified by the Owner.

13.3 Insertion Loss

13.3.1 The insertion loss in both directions of transmission at 1004 Hz shall meet the following requirements when measured with a 0 dBm input signal at 900 ohms (or 600, when required) at a temperature of 25°C ± 5°C.

13.3.1.1 Trunk-to-Line: The loss through the office shall be set between 0 and 0.5 dB for 2-wire to 2-wire, or 2-wire to 4-wire connections. The proper circuit loss will be set in the connecting facility.

13.3.1.2 Line-to-Line: The loss through the office shall be set between 0 and 2 dB.

13.3.1.3 Direct Digital Interface: On a direct digital interface, the loss through the office shall be adjusted to the proper level in the receive side.

13.3.1.4 Stability: The long-term allowable variation in loss through the office shall be ± 1.0 dB from the loss specified by the Bidder.

13.4 Frequency Response (Loss Relative to 1004 Hz)

Here, (-) means less loss and (+) means more loss.

13.4.1 Trunk-to-Trunk

Frequency (Hz)	Loss at 0 dBm0 Input 2-Wire to 2-Wire
60	20 dB Min.*
200	0 to 5 dB
300 - 3000	-0.5 dB to 1 dB
3300	1.5 dB Max.
3400	0 to 3 dB

*Transmit End

13.4.2 Line-to-Line

Frequency (Hz)	Loss at 0 dBm0 Input
60	20 dB Min.*
300	-1 to +3 dB
600 - 2400	±1 dB
3200	-1 to +3 dB

*Transmit End

13.4.3

13.5 Overload Level

13.5.1 The overload level at 900 ohm impedance shall be +3 dBm0.

13.6 Gain Tracking (Linearity) 1004 Hz Reference at 0 dBm0

Input Signal Level	Maximum Gain Deviation
+3 to -37 dBm0	±0.5 dB
-37 to -50 dBm0	±1 dB

13.7 Return Loss

13.7.1 The specified return loss values are determined by the service and type of port at the measuring end. Two-wire ports are measured at 900 ohms in series with 2.16 microfarads and 4-wire ports are measured at 600 ohms resistive.

13.7.2

13.7.3 Trunk-to-Line (2-Wire or 4-Wire)

ERL - 24 dB, Minimum
SRL - 17 dB, Minimum

13.7.4 Line-to-Line or Line-to-Trunk (2-Wire or 4-Wire)

ERL - 18 dB, Minimum
SRL - 12 dB, Minimum

13.8 Longitudinal Balance

13.8.1 The minimum longitudinal balance, with dc loop currents of 20 to 70 mA, shall be 60 dB at all frequencies between 60 and 2000 Hz, shall be 55 dB at 2700 Hz and be 50 dB at 3400 Hz. The method of measurement shall be as specified in the IEEE Standard #455-1976, "Standard Testing Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band." Source voltage level shall be 10 volts RMS.

13.9 60 Hz Longitudinal Current Immunity (See Figure 1)

13.9.1 Under test conditions with 60 Hz, the system noise shall be no greater than 23 dBrncO.

13.10 Steady Noise (Idle Channel at 900 ohm Impedance)

13.10.1 Measure on terminated call.

Maximum - 23 dBrncO
Average - 18 dBrncO or less
3K Hz Flat - less than 35 dBrnO as an objective

13.11 Impulse Noise

13.11.1 The central office equipment shall be capable of meeting an impulse noise limit of not more than five counts exceeding 54 dBrnO voice band weighted in a 5-minute period on six such measurements made during the busy hour. A Northeast Electronics Company

TTS 58A Impulse Noise Counter, or equivalent, should be used for the measurements. The measurement shall be made by establishing a normal connection from the noise counter through the switching equipment in its off-hook condition to a quiet termination of 900 ohms impedance. Office battery and signaling circuit wiring shall be suitably segregated from voice and carrier circuit wiring, and frame talking battery filters provided, if and as required, in order to meet these impulse noise limits.

13.12 Crosstalk Coupling

13.12.1 Worst case equal level crosstalk is to be 75 dB minimum in the range 200 to 3400 Hz. This is to be measured between any two paths through the system connecting a 0 dBm0 level tone to the disturbing pair.

13.13 Quantizing Distortion

Input Level (dBm0) 1004 or 1020 Hz	Minimum Signal to Distortion With C-Message Weighting
0 to -30	33 dB
-30 to -40	27 dB
-40 to -45	22 dB

Due to the possible loss of the least significant bit on direct digital connections, a signal to distortion degradation of up to 2 dB may be allowed where adequately justified by the Bidder.

13.14 Absolute Delay

13.14.1 The absolute one-way delay through the switch, excluding delays associated with RST switching shall not exceed 1000 μsec. analog-to-analog measured at 1800 Hz.

13.15 Envelope Delay Distortion

13.15.1 On any properly established connection, the envelope delay distortion shall not exceed the following limits:

Band Widths (Hz)	Microseconds
1000 to 2600	190
800 to 2800	350
600 to 3000	500
400 to 3200	700

13.16 Digital Error Rate

13.16.1 The digital switch shall not introduce an error into digital connections which is worse than one error in 10^8 bits averaged over a 5-minute period, excluding the least significant bit.

13.17 Battery Noise

13.17.1 Noise across battery at power board distribution bus terminals shall not exceed 55 dBrnc during busy hour.

13.18 Radio and Television Interference

13.18.1 The central office equipment shall be so designed and installed that radiation of high frequency noise will be limited so as not to interfere with radio and television receivers.

14. TIMING INTERVALS

14.1 Type of Equipment Required

14.1.1 The equipment for providing the specified timing intervals shall be solid-state.

14.2 Tolerance

14.2.1 Where a range of time is specified as minimum and maximum, the lower limits shall be considered as controlling and the variation between this minimum and the actual maximum shall be kept as small as practicable. In no case shall the quoted upper limit be exceeded.

14.3 Permanent Signal Timing

14.3.1 Lockout shall be effected after an interval of 20 to 30 seconds after receipt of dial tone should a "permanent" condition occur prior to the transmission of dial pulses or pushbutton dialing signals. This interval may be reduced appreciably during periods of heavy traffic.

14.4 Partial Dial Timing: Partial dial timing shall be within 15 to 37 seconds. This may be reduced appreciably during periods of heavy traffic.

14.5 Charge Delay Timing: Charge delay timing shall be within two seconds.

14.6 "Don't Answer" Disconnect Timing: On revertive calls a "don't answer" disconnect feature shall be provided which shall operate within a period of two to four minutes should the called party not answer.

14.7 Called Party Disconnect Timing: Timed disconnect of a terminating path under control of the called party shall be 10 to 32 seconds.

14.8 Timing Intervals for Signals Involved in Distance Dialing: Timing intervals shall be provided to meet the requirements which have been established for distance dialing equipment in the current edition of "Notes on the Network." Some of the more important times which are specified are for:

Disconnect Signal
Wink Signal
Start Dialing Signal
Pulse Delay Signal
Go Signal
Digit Timing
Sender, Register and Link Attachment Timing

15. POWER REQUIREMENTS AND EQUIPMENT

15.1 Operating Voltage: The nominal operating voltage of the central office shall be 48 volts, dc, provided by a battery with the positive side tied to system ground.

15.2 Batteries

15.2.1 When battery cells of the lead antimony type are specified, the pasted plate type shall be considered adequate.

15.2.2 When lead calcium cells are specified, no cell shall differ from the average voltage of the string of fully charged cells by more than ± 0.03 volt when measured at a charging rate in amperes equivalent to 10 percent of the ampere hour capacity of the cells. Similarly when cells are fully charged and floating between 2.30 and 2.35 volts per cell, the cell voltage of any cell in a given string shall not differ more than ± 0.03 volt from the average. These requirements are for test purposes only and do not apply to operating conditions.

15.2.3 Voltage readings shall be corrected by a temperature coefficient of 0.0033 volt per degree F., whenever temperature variations exist between cells in a given string. This correction factor shall also be applied when comparing cell voltages taken at different times and at different temperatures. The correction factor shall be added to the measured voltage when the temperature is above 77°F and subtracted when the temperature is below 77°F.

15.2.4 The specific gravity readings of lead antimony cells at full charge shall be 1.210 ± .010 at 77°F at maximum electrolyte height.

15.2.5

15.2.6 When lead antimony batteries are specified, they shall be designed to last a minimum of 10 years when maintained on a full float operation between 2.15 and 2.17 volts per cell. When lead calcium batteries are specified, they shall be designed to last a minimum of 20 years when maintained on full float operation between 2.17 and 2.20 volts per cell. The battery shall be clearly designated as antimony or calcium by means of stencils, decals or other devices.

15.2.7 Each battery cell shall be equipped with an explosion control device.

15.2.8 The battery size shall be calculated in accordance with standard procedures. The battery in no case shall have a reserve capacity in ampere hours less than four times the current capacity of the largest charger.

15.3 Charging Equipment

15.3.1 Charging shall be on a full float basis. The rectifiers shall be of the full wave, self-regulating, constant voltage, solid-state type and shall be capable of being turned on and off manually.

15.3.2 When charging batteries, the voltage at the battery terminals shall be adjustable and shall be set at the value recommended for the particular battery being charged, providing it is not above the maximum operating voltage of the dial equipment. The voltage shall not vary more than plus or minus 0.02 volt per cell between 10 percent load and 100 percent load. Between 3 percent and 10 percent load the output voltage shall not vary more than plus or minus 0.04 volt per cell. Beyond full load current the output voltage shall drop sharply. The above output voltage shall be maintained with line voltage variations of plus or minus 10 percent. Provision shall be made to manually change the output voltage of the rectifier to 2.25 volts per cell to provide an equalization charge on the battery.

15.3.3 The charger noise when measured with a suitable noise measuring set and under the rated battery capacitance and load conditions as determined in Figure 2 shall not exceed 22 dBrnc.

15.3.4 The charging equipment shall be provided with means for indicating a failure of charging current whether due to ac power failure, an internal failure in the charger or to other circumstances which might cause the output voltage of the charger to drop below the battery voltage. Where a supplementary constant current charger is used, an alarm shall be provided to indicate a failure of the charger.

15.3.5 Audible noise developed by the charging equipment shall be kept to a minimum. Acoustic noise resulting from operation of the rectifier shall be expressed in terms of dB indicated on a sound level meter conforming to American National Standards Institute S1.4, and shall not exceed 65 dB (A-weighting) measured at any point five feet (152.4 cm) from any vertical surface of the rectifier.

15.3.6 The charging equipment shall be designed so that neither the charger nor the central office equipment is subject to damage in case the battery circuit is opened for any value of load within the normal limits.

15.3.7 The charging equipment shall have a capacity to meet the requirements of central office size and special requirements of the Owner in Part III of this specification.

15.3.8 Minimum equipment requirement for chargers is one of the following:

(a) Two chargers either capable of carrying the full office load as specified in item 7 of Part III.

(b) Three chargers each capable of carrying half the office load as specified in item 7 of Part III.

(c) One charger capable of carrying the full office load as specified in item 7 of Part III.

NOTE: Operation of 1900 ohm loops with a minimum of 21 milliamps shall be maintained until battery reaches final discharge voltage when only one charger is supplied.

15.4 Miscellaneous Voltage Supplies

15.4.1 Any power supply required for voltages other than the primary battery voltage, except for that required to operate input/output devices, shall be either a solid-state dc-to-dc converter or dc-to-ac inverter, operating from the central office battery or from a separate battery and charger. These power supplies shall meet the noise limit specified for chargers in paragraph 15.3.3, except the capacitor "C" shall be eliminated and the resistive load "R" shall be determined by the nominal output voltage in volts divided by the full load current rating in amperes.

15.5 Ringing Equipment

15.5.1 The ringing supply may be limited to one frequency. Ringing generators supplied on an ancillary basis shall meet the requirements of REA Specification PE-40, "Ringing Generator Equipment," and shall be selected from REA Bulletin 344-2, "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers." Ringing power generated integrally to the switching system must still meet the required output voltages, voltage regulation, cross ring requirements, and frequency stability specified in PE-40. The output requirements in watts for ringing generation shall be the responsibility of the Bidder for the size system specified by the Owner.

15.5.2 Provision shall be made for the ringing equipment to be available at least 99.99% of the time.

15.5.3 Terminals must be provided to test the frequency and voltage of the ringing power generated.

15.6 Interrupter Equipment

15.6.1 The interrupter shall be an integral part of the switching system and shall be controlled by any call processor.

15.6.2 The ringing cycle provided by the interrupter equipment shall not exceed six seconds in length. The ringing period should be two seconds.

15.7 Power Panels

15.7.1 Battery and charger control switches, dc voltmeters, dc ammeters, fuses and circuit breakers, supervisory and timer circuits shall be provided as required. Portable or panel mounted frequency meters or voltmeters shall be provided as specified by the Owner.

15.7.2 Power panels, cabinets and shelves, and associated wiring shall be designed initially to handle the exchange when it reaches its ultimate capacity as specified by the Owner.

15.7.3 The power panel shall be of the "dead front" type.

16. DISTRIBUTING FRAMES

16.1 Main Distributing Frame

16.1.1 The main distributing frame shall provide terminals for terminating all incoming cable pairs. Arresters shall be provided for all incoming cable pairs, or for a smaller number of pairs if specified, provided an acceptable means of temporarily grounding all terminated pairs which are not equipped with arresters is furnished.

16.1.2 The current carrying capacity of each arrester and its associated mounting shall be such as to coordinate with a #22 gauge copper conductor without causing a self-sustaining fire or permanently damaging other arrester positions. Where all cable pairs entering the central office are #24 gauge or finer, the arresters and mountings need only coordinate with #24 gauge cable conductors. Item 8.11 of Part III designates the gauge of the cable conductors serving the office.

16.1.3 Central office protectors shall be mounted and arranged so that outside cable pairs may be terminated on the left side of protectors (when facing the vertical side of the MDF) or on the back surface of the protectors. Means for easy identification of pairs shall be provided.

16.1.4 Protectors shall have a "dead front" (either insulated or grounded) whereby live metal parts are not readily accessible.

16.1.5 Protectors shall be provided with an accessible terminal of each incoming conductor which is suitable for the attachment of a temporary test lead. They shall also be constructed so that auxiliary test fixtures may be applied to open and test the subscriber's circuit in either direction. Terminals shall be tinned or plated and shall be suitable for wire wrapped or connectorized connections.

16.1.6 If specified in Part III, each protector group shall be furnished with a factory assembled tip cable for splicing to the entrance cable, the tip cable to be 20 feet in length unless otherwise specified.

16.1.6.1 Factory assembled tip cables shall have #22 gauge insulated tinned copper conductors conforming to ASTM Specification B-33, individually insulated with polyethylene with polyvinyl chloride covering, and a polyvinyl chloride outer jacket. Cables having other kinds of insulation and jackets which have equivalent resistance to fire and which produce less smoke and toxic fumes may be used if specifically approved. The tip cable shall have a shield between core and jacket. The shield shall be 8 mil aluminum with a coating so that it will be bonded to the cable outer jacket. A suitable core wrapper shall be used over the cable core to insure adequate insulation between the insulated conductors of the core and shield. The metal shield shall be bonded to the main frame ground bus. Refer to PE-87, "Terminating Tip Cable."

16.1.7 Protectors shall be mounted on vertical supports, with centers not exceeding nine inches. The space between protector units shall be adequate for terminating conductors.

16.1.8 Cable supporting framework shall be provided between the cable entrance and the MDF when overhead cable entrance is specified in Item 9.33 of Part III.

16.1.9 The main distributing frame shall be equipped with a copper ground bus bar having the conductivity of a #6 AWG copper conductor or a greater conductivity, or may consist of another metal if specifically approved, provided it has adequate cross sectional area to provide conductivity equivalent to, or better than, bare copper. A guardrail or equivalent shall also be furnished.

16.1.10 Other features not specified above may be required at the option of the Owner, if checked in Item 8.4 of Part III.

16.1.11 Main frame protector makes and types shall be selected only from REA Bulletin 344-2, "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers." Protectors shall be capable of easy removal.

17. ELECTRICAL PROTECTION

17.1 Surge Protection

17.1.1 Adequate electrical protection of central office equipment shall be included in the design of the system. The characteristics and application of protection devices must be such that they enable the central office equipment to withstand, without damage or excessive protector maintenance, the dielectric stresses and currents that are produced in line-to-ground and tip-to-ring circuits through the equipment as a result of induced or conducted lightning or power system fault-related surges. All wire terminals connected to outside plant wire or cable pairs shall be protected from voltage and current surges.

17.1.2 Electrical protection requirements for central office equipment can be summarized briefly as follows:

17.1.2.1 Equipment must pass laboratory tests, simulating the hostile electrical environment, before being placed in the field for the purpose of obtaining field experience. There are five basic types of laboratory tests which must be applied to exposed terminals in an effort to determine if the equipment will survive. Figure 4 summarizes these tests and the minimum acceptable levels of protection for equipment to pass them.

17.1.3 Briefly, the categories of tests include:

1) Current surge tests, which simulate the stress to which a relatively low impedance path may be subjected before main frame protectors break down. Paths with a 100 Hz impedance of 50 ohms or less shall be subjected to current surges, employing a 10 x 1000 μs waveshape as defined in Figure 5. (Note: For the purpose of determining this impedance, arresters which are mounted within the equipment are to be considered zero impedance.) The crest current shall not exceed 500A; however, depending on the impedance of the test specimen this value of current may be lower. The crest current through the sample, multiplied by the sample's 100 Hz impedance shall not exceed 1000 V. Where sample impedance is less than 2Ω, crest current shall be limited to 500A as shown in Figure 3.

2) Sixty Hertz (60 Hz) current carrying tests should be applied to simulate an ac power fault which is conducted to the unit over the cable pairs. The test should be limited to 10 amperes rms of 60 Hz ac for a period of 11 cycles (0.1835 seconds) and should be applied longitudinally from line to ground. See Figure 4.

3) AC power service surge voltage tests should be applied to the power input terminals of ac powered devices to simulate switching surges or lightning-induced transients on the ac power system. The test shall employ a 1.2 x 50 μs waveshape with a crest voltage of 2,500 V. Communications line protectors may be left in place for this test.

4) Voltage surge tests which simulate the voltage stress to which a relatively high impedance path may be subjected before primary protectors break down and protect the circuit. To assure coordination with the primary protection while reducing testing to the minimum, voltage surge tests should be conducted at a 1000 volts with primary arresters removed for devices protected by carbon blocks, or the +3 σ dc breakdown of other primary arresters. Surge waveshape should be 10 x 1000 µs.

5) Arrester response delay tests are designed to stress the equipment in a manner similar to that caused by the delayed breakdown of gap type arresters when subjected to rapidly rising voltages. Arresters shall be removed for these tests, the peak surge voltage should be the +3 σ breakdown of the arrester in question on a voltage rising at 100 V/µs and the time for the surge to decay to half voltage shall equal at least the delay time of the tube, as explained in Figure 6.

17.1.4 Tests should be conducted in the following sequence. As not all tests are required in every application, nonapplicable tests should be omitted.

1) Current Impulse Test
2) Sixty Hertz (60 Hz) Current Carrying Test
3) AC Power Service Impulse Voltage Test
4) Voltage Impulse Test
5) Arrester Response Delay Test

17.1.4.1 Five applications of each polarity for the surge tests and three for the 60 Hz Current Carrying Test are the minimum required. All tests should be conducted with not more than 1 minute between consecutive applications in each series of three or five to a specific configuration so that heating effects will be cumulative.

17.1.5 Tests should be applied between each of the following terminal combinations for all line operating conditions:

1) Line tip to ring.
2) Line ring to ground.
3) Line tip to ground.
4) Line tip and ring tied together to ground.

17.2 Dielectric Strength

17.2.1 Arresters shall be removed for all dielectric strength tests.

17.2.1.1 Direct current potentials shall be applied between all line terminals and equipment chassis and between these terminals and grounded equipment housings in all instances where the circuitry is (1) dc open circuit from the chassis, or (2) connected to the chassis through a capacitor. The duration of all dielectric strength tests shall be at least 1 second. The applied potential shall equal or exceed the plus 3 sigma DC breakdown voltage of the arrester, provided by the COE manufacturer.

17.2.1.2 Insulation Resistance - Following the dielectric tests, the insulation resistance of the installed electrical circuits between wires and ground, with the normal equipment grounds removed, shall not be less than 10 megohms at 500 volts, dc at approximately room temperature (68°F) and at a relative humidity of approximately 50 percent. The measurement shall be made after the meter stabilizes, unless the requirement is met sooner. Arresters shall be removed for these tests.

17.3 <u>Self-Protection</u>

17.3.1 All components shall be of the self-protecting type, capable of being continuously energized at rated voltage without injurious results.

17.3.2 The unit equipment shall not be permanently damaged by accidental short circuits of any duration across either the central office side tip and ring or the line side tip and ring. A test is to be made with the unit energized at the highest recommended voltages.

17.4 <u>Static Discharge</u>

Assemblies subject to damage by static discharge should be identified and special handling instructions must be supplied.

18. MISCELLANEOUS

18.1 <u>Office Wire:</u> All office wire shall be of soft annealed tinned copper wire meeting the requirements of ASTM Specification B-33 and of suitable cross-section to provide safe current carrying capacity and mechanical strength. The insulation of installed wire, connected to its equipment and frames, shall be capable of withstanding the same insulation resistance and dielectric strength requirements as given in paragraphs 17.2.1.1 and 17.2.1.2 at a temperature of 120°F and a relative humidity of 90 percent.

18.2 <u>Wire Wrapped Terminals:</u> These terminals are preferred and where used shall be tinned, or of a material suitable for wire wrapping. The connections to them shall be made with a wire wrapping tool with the following minimum number of successive nonoverlapping turns of bare tinned copper wire in contact with each terminal:

6 turns of 30 gauge
6 turns of 26 gauge
6 turns of 24 gauge
5 turns of 22 gauge

18.3 Protection Against Corrosion: All metal parts of equipment frames, distributing frames, cable supporting framework and other exposed metal parts shall be constructed of corrosion resistant materials or materials plated or painted to render them adequately corrosion resistant.

18.4 Screws and Bolts: Screw threads for all threaded securing devices shall be of American National form in accordance with National Bureau of Standards Handbook H-28, unless exceptions are granted to the manufacturer of the switching equipment. All bolts, nuts, screws, and washers shall be of nickel-copper alloy, steel, brass or bronze.

18.5 Temperature and Humidity Range: The supplier shall furnish the operating temperature and humidity ranges of the equipment being provided in order that adequate heating and cooling may be supplied. See Items 5.21 and 5.22, Part IV.

18.6 Stenciling: Equipment units and terminal jacks shall be adequately designated and numbered. They shall be stenciled so that identification of equipment units and leads for testing or traffic analysis can be made without unnecessary reference to prints or descriptive literature.

18.7 Equipment Frame Design: For newly designed systems consideration should be given to the desirability of providing frames which can be installed in rooms of normal ceiling height (up to 8 feet) and moved through doorways 30" wide and 78" high. Where feasible, frames and equipment units shall be designed for ready portability and/or high salvage value.

18.8 Quantity of Equipment Bays

18.8.1 Consistent with system arrangements and ease of maintenance, space shall be provided on the floor plan for an orderly layout of future equipment bays that will be required for anticipated traffic when the office reaches its ultimate size. Readily accessible terminals will be provided for connection to interbay and frame cables to future bays. All cables, interbay and intrabay (excluding power), if technically feasible, shall be terminated at both ends by use of connectors.

19.1 Line Concentrator

19.1 The line concentrator (LC) is a device placed at a subordinate wire center to connect subscriber lines to the central office via a transmission path(s) of selected capacity (often multiple T1 span lines using a DS1X interface). The central office shall be arranged to work with the LC via a direct digital interface or multiple VF circuits. See PE-60 for a description of the span line and REA Form 397g for a description of the line concentrator.

20. RESPONSIBILITY

20.1 Central Office Layout

20.1.1 The successful Bidder shall furnish tentative floor plan layout drawings showing the arrangement of the equipment and the dimensions of major equipment units. These drawings shall include minimum door and ceiling heights required for installation, maintenance and ventilation. If requested by the Owner, the floor plan shall be such that the battery, charger, power board, main distributing frame and wire chief's test equipment are isolated from the other equipment by a partition.

20.1.2 The layout drawings shall also show provision for the ultimate capacity of the central office as specified by the Owner.

20.1.3 After approval by the Owner of the tentative floor plan, and within ten calendar days after approval of the contract by the Administrator, the Owner shall furnish the Bidder the necessary data on the actual floor plan. Within 20 calendar days after receiving the necessary building data, the Bidder shall then supply floor plan drawings showing exact locations of all equipment, both initial and ultimate, including points where connection to commercial power are required, with voltage and wattage indicated at each point. Within 20 calendar days after receiving the floor plan drawings from the Bidder, the Owner shall approve these drawings or take the necessary steps to have the drawings changed to meet his approval. The layout planning must be so coordinated between the Owner and the Bidder as not to delay scheduled equipment installation date.

20.2 <u>Shipment of MDF</u>

20.2.1 The Bidder shall ship the main distributing frame equipment, with all necessary instructions to permit its installation by the Owner, at the time requested by the Owner in writing, provided such time is not earlier than 90 days prior to the date specified for the shipment of the rest of the central office equipment. If the Owner or his agent installs the main distributing frame, the Owner shall assume the responsibility and the expense of proper installation according to information furnished by the Bidder.

20.3 <u>Drawings and Printed Material</u>

20.3.1 The Bidder shall supply instructional material for each exchange involved at the time of delivery of the equipment. It is not the intent of this specification to require system documentation necessary for the repair of individual circuit boards.

Three complete sets of legible drawings, each set to include all of the following:

Floor Plan	- Showing exact dimensions and location of each equipment frame or item to a convenient scale.
Switching Diagram	- Block schematic drawing showing the various equipment components in the system, their identifying circuit number (e.g., MDF, line circuits, memory, trunks, etc.)
Equipment Layout Drawings	- Drawings of major equipment items such as frames with the location of major component items of equipment shown therein.

Descriptions	-	An explanation of the operation of each circuit down to a circuit package level.
Wiring Diagrams (or equivalent)	-	Drawings indicating the wiring used on each item of equipment and the interconnection between items of equipment.
Software Documentation	-	Drawings showing principal aspects of the software architecture. Sufficient documentation shall be provided to maintain and service the system.
Maintenance Drawings	-	Individual item drawings covering each equipment item that contains replaceable parts, appropriately identifying each part by name and part number. If individual item drawings are not provided, complete ordering instructions shall be furnished for all replaceable parts.
Job Drawings	-	Included in this category are all drawings that are individual to the particular office involved, such as main frame, power panel, test board, etc.

20.3.2 The following information shall also be furnished:

Complete index of the required drawings.

Explanation of electrical principles of operation of overall switching system.

List of tests which can be made with each piece of test equipment furnished and explanation of method of making each test.

Sample of each form recommended for use in keeping records of tests.

Criteria for analyzing results of tests and determining appropriate corrective action.

General notes on the methods of isolating equipment faults to specific printed circuit cards in the equipment.

List of typical troubles which might be encountered, together with general indications as to the probable location of each trouble.

Special office grounding requirements.

20.4 Distributing Frame Wire

20.4.1 The Bidder shall provide sufficient tinned copper conductor distributing frame wire for the initial installation. The insulation of this wire shall be such that it will not support combustion, will have good abrasion resistance and cut-through properties, exhibit good solder heat resistance and be suitable for wire wrap connections.

20.5 Technical Assistance Service

20.5.1 A technical assistance service shall be made available to assist the Owner and its maintenance personnel on a 24-hour, 7 days a week basis. There is to be assistance available for both hardware and software problems. The necessary interface shall be supplied by the Bidder. The Supplier is to define to the Owner the conditions when additional payment for this service will be required.

20.6 Spare Parts

20.6.1 Lists of spare parts and maintenance tools as recommended by the Bidder shall be provided. The cost of such tools and spare parts shall be indicated and shall not be included in the base price. The Owner may accept any or all of the suggested items as alternate bids for spare parts or maintenance tools, to be based on individual unit prices to be obtained from the Bidder.

20.7 Environmental Requirements

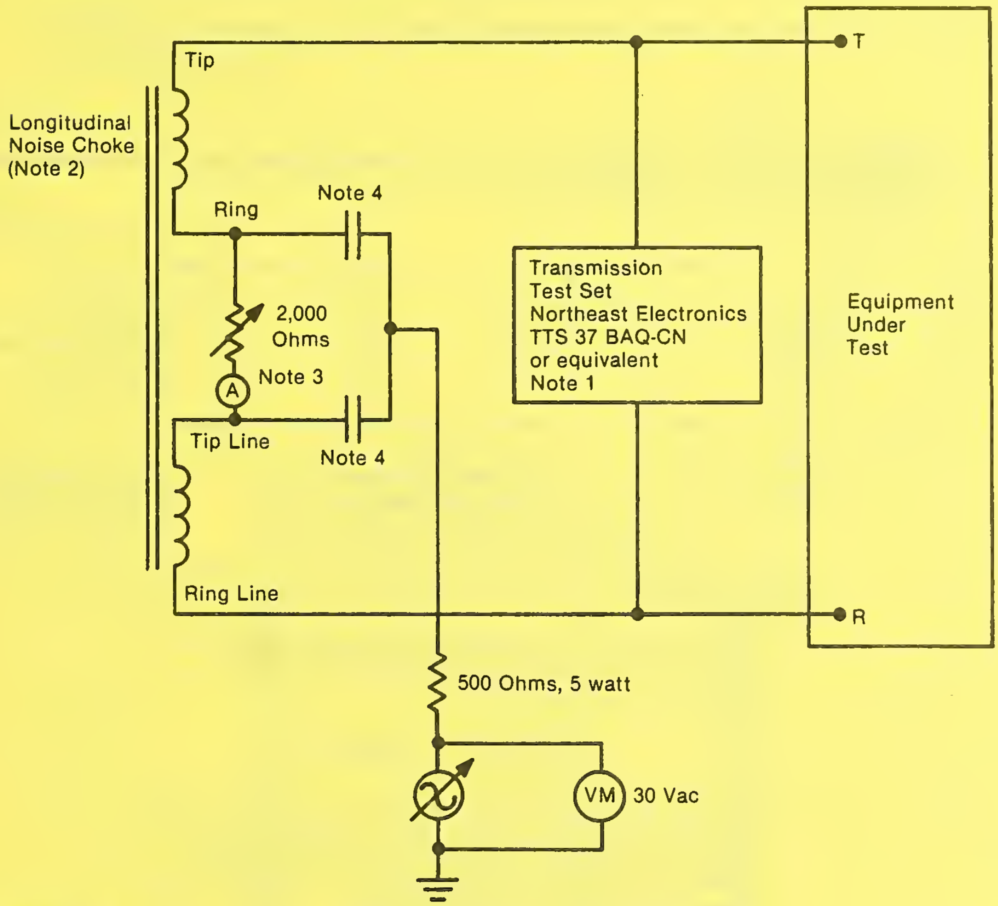
20.7.1 The Bidder shall specify the environmental conditions necessary for safe storage and satisfactory operation of his equipment. If requested, he shall assist the Owner in planning how to provide the necessary environment for the equipment. (See paragraph 1.4.22.)

20.8 Unit Costs for Cost Separation Purposes

The successful Bidder will present a cost breakdown of the central office equipment on a discrete element basis 90 days after installation completion. This will include the various frames, switching and transmission components, and software.

Figure 1

Measuring the Effects of Low Frequency Induction

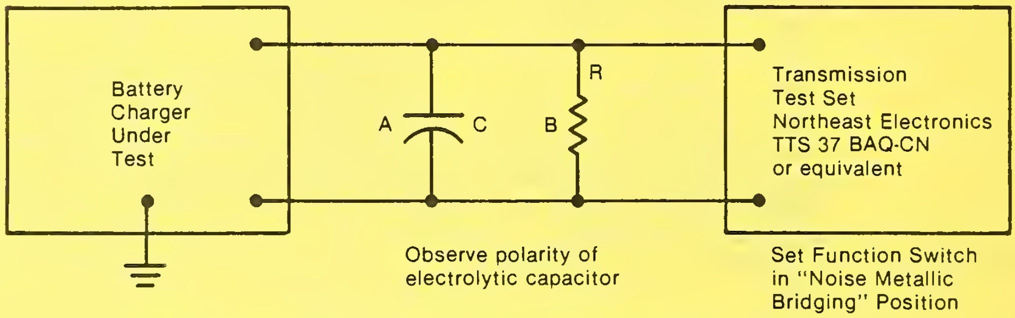


Notes:

1. 900 ohm termination, C message weighting, hold coil off
2. SNC Noise Choke 35 W, or equivalent
3. Test at 0.020 A and 0.070 A dc
4. 2 ± 0.001 microfarad, 150 Vdc

Figure 2

Charger Noise Test



Where the manufacturer so elects the capacitor C may be eliminated from the measurement.

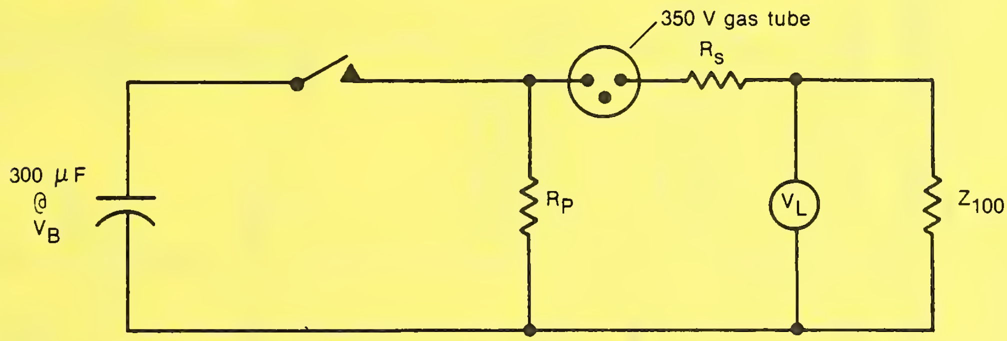
A. Capacitance in μF = 30,000 μF per ampere-hour per cell. (For example, 25 cells at 100 ampere-hour would be equivalent to a capacitance of:)

$$\frac{30{,}000 \times 100}{25} = 120{,}000\ \mu F$$

B. The value of the resistive load R is determined by the nominal battery voltage in volts divided by the full load rating in amperes. For example, for a 48-volt battery and a full load current of 24 amperes, the load resistance R is 48/24 = 2 ohms of appropriate power handling capacity.

Figure 3

Current Surge Test



V_L = Not to exceed 1000V
V_B = Charging Voltage
Z_{100} = Test Specimen Impedance to be measured at 100 Hz.
R_p = Parallel Resistance (Waveshape)
R_s = Series Resistance (Current Limiting)

Z_{100}	R_s	R_p	V_B
"0"	5	∞	2500
1	4	∞	2500
2	3	∞	2500
3	2	∞	1670
4	1	∞	1250
5	0	∞	1000
7.5	0	15	1000
10	0	10	1000
15	0	7.5	1000
20	0	6.7	1000
25	0	6.25	1000
30	0	6	1000
40	0	5.7	1000
50	0	5.5	1000

FIGURE 4

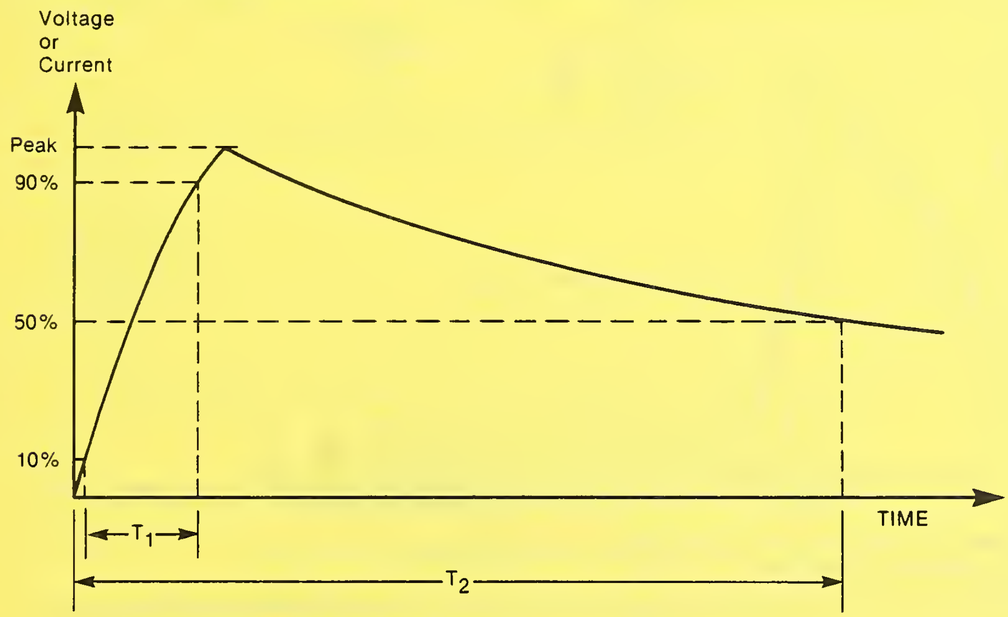
Summary of Electrical Requirements and Tests

Test	Application Criteria	Peak Voltage or Current	Surge Waveshape	No. of Applications & Max. Time Between	Comments
Current Surge	Low Impedance Paths Exposed to Surges	500A or Lesser Current (See Fig. 3)	10x1000 μs	5 each Polarity at 1 minute intervals	
60 Hz Current Carrying	High or Low Impedance Paths Exposed to Surges	10A rms or Lesser Current (See Fig. 7)	11 Cyles of 60 Hz (0.183 Sec.)	3 each at 1 minute intervals	
AC Power Service Surge Voltage	AC Power Service Connection	2500V or +3 σ clamping V of arrester employed at 10kV/μs	1.2x50 μs	5 each Polarity at 1 minute intervals	AC arrester, if used, must be removed. Communications line arresters, if used, remain in place.
Voltage Surge	High Impedance Paths Exposed to Surges	1000V or +3 σ dc breakdown of arrester employed	10x1000 μs	Same	All primary arresters, if used, must be removed.
Arrester Response Delay	Paths protected by arresters, such as gas tubes, with breakdown dependent on V. rate of rise.	+3 σ breakdown of arrester employed at 100V/μs of rise	100V/μs rise decay to ½ V. in tube's delay time	Same	Same

REA Form 52

Figure 5

Explanation of Surge Waveshape



Surge Waveshape is defined as follows:

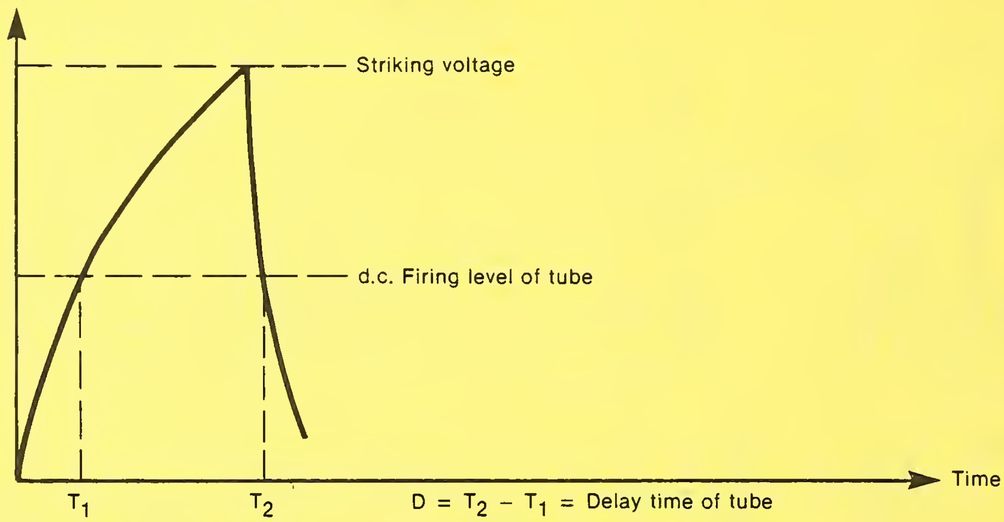
Rise Time X Time to Decay to Half Crest Value for Example: 10 x 1000 μs

Notes: T_1 = Time to determine the rate of rise. The rate of rise is determined as the slope between 10% and 90% of peak voltage or current.

T_2 = Time to 50% of peak voltage (decay to half value).

Figure 6

Explanation of Arrester Response Delay Time

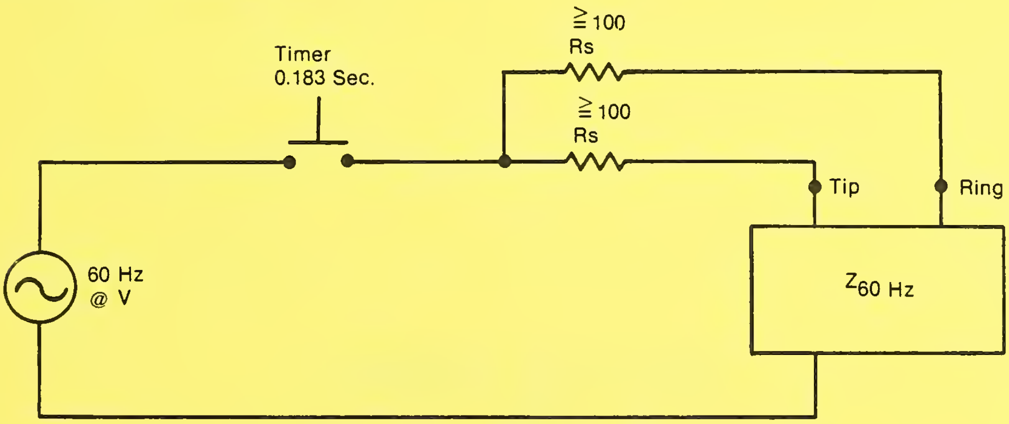


$D = T_2 - T_1$ = Delay time of tube

That period of time when the potential across an arrester exceeds its d.c. firing level is considered delay time.

Figure 7

60 Hz Current Surge Test



V – 700 Volts RMS (Approximately 1000V Peak).
Z_{60} – Test specimen impedance to be measured at 60 Hz.
Rs – Series Resistance (current limiting) in each side of line. (Source impedance never less than 50Ω longitudinal.)

$Z_{60\ Hz}$	R_s
0	140
10	120
20	100
50	100
Over 50	100

UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

PERFORMANCE SPECIFICATION

FOR

LINE CONCENTRATORS

REA Form 397g

DRAFT REVISION
JUNE 1983

PERFORMANCE SPECIFICATION
FOR
LINE CONCENTRATORS

CONTENTS

PART IV - BIDDER SUPPLIED INFORMATION (NOT INCLUDED; STILL UNDER PREPARATION)

FIGURES

PART I

PERFORMANCE SPECIFICATION FOR LINE CONCENTRATORS

1. GENERAL

1.1 The Line Concentrator (LC) shall operate in accordance with the manufacturer's specifications. Reliability shall be of prime importance to the design, manufacture and installation of the equipment. The equipment shall provide for terminating subscriber lines at a location remote from the home central office, concentrating them over a few transmission and supervisory paths to the home central office, then terminating them there without loss of individual identity. This shall be accomplished automatically. The aforementioned subscriber lines shall have essentially the same services as a subscriber connected directly to the central office. Intra unit calling among connected subscribers may be provided.

1.2 There are two types of requirements listed in this specification as discussed in the following two paragraphs.

1.2.1 Fixed Requirements.

Unless otherwise indicated, the requirements listed herein are considered to be fixed requirements.

1.2.2 Optional Requirements.

In some cases, requirements are listed for features which may not be needed for every application. Such features are identifiable by the inclusion in the requirements of some such phrase as "when specified by the Owner" or "as specified by the Owner."

1.2.3 In some cases where an optional feature will not be required by an Owner, either now or in the future, a system which does not provide this feature shall be considered to be in compliance with the specification for the specific installation under consideration, but not in compliance with the entire specification.

1.2.4 The Owner may properly request bids from any supplier whose system provides all the features which will be required for a specific installation.

1.3 <u>Reliability</u>

1.3.1 Quality control and burn-in procedures shall be sufficient so that the failure rate of printed circuit boards does not exceed an average of 2.0 percent per month of all equipped cards in the central office and remote terminals during the first 3 months after cutover, and an average of 1.0 percent per month of all equipped cards in the terminals during the second 3-month period. The failure rate for the equipment shall be less than 0.5 percent per month of all equipped cards after 6 months. A failure is considered to be the failure of a component on the PC board which requires it to be repaired or replaced.

1.3.2 The line concentrator terminal units shall be designed such that there will be no more than four hours of total outages in 20 years.

1.4 System Type Acceptance Tests

1.4.1 General test results will be required on each system type. Any installation of a system provided in accordance with this specification shall be capable of meeting any requirement herein on a spot-check basis.

1.5 Features Required

1.5.1 The network control equipment and peripheral equipment shall be comprised of solid-state and integrated circuitry components as far as practical and in keeping with the state-of-the-art and economics of the subject system.

1.5.2 When subscriber loops that exceed the resistance and voice frequency gain range of the line concentrator equipment are required, external loop extenders and voice frequency repeaters or LE/VFR combination must be of a type accepted by REA.

1.5.3 When specified by the Purchaser, party line service shall be supplied. The number of parties per line is intended to be no more than four.

2. SUBSCRIBER LINES

2.1 The remote unit shall operate satisfactorily with subscriber lines which meet all of the conditions under the Seller's specifications and all the requirements of this specification. This specification recognizes that the loop limit of the line concentrator is dependent upon the transmission facility between the LC central office termination and the LC remote unit. When voice frequency (physical) circuits are used, the central office switching equipment's loop limit of 1900 ohms (including the telephone set) shall not be substantially reduced. When electronically derived circuits (carrier, lightwave, etc.) are used, the loop limits of the electronic system will control. The Seller shall identify the loop limits of the equipment to be supplied.

2.1.1 It shall be possible for subscribers on the same party line to call each other in systems providing party line service when connected to central office equipment arranged to provide reverting party line service.

2.1.2 For the purpose of this specification, the input impedance of all subscriber loops served by the equipment is arbitrarily considered to be 900 ohms in series with a 2 microfarad capacitor at voice frequencies.

2.1.3 There should be provisions for such types of lines as ground start, loop start, regular subscriber, pay stations, etc.

2.2 Dialing

2.2.1 The line concentrator remote and central office terminal equipment shall satisfactorily transmit dialing information when used with subscriber dials having a speed of operation between 8 and 12 impulses per second and a break period of 55 to 65 percent of the total impulse period.

2.2.2 Subscriber Dial Interdigital Time: The remote and central office equipment shall permit satisfactory operation when used with subscriber rotary dial interdigital times of 200 milliseconds minimum, and pushbutton dialing with 50 milliseconds minimum.

2.2.3 Subscriber Line Pushbutton Dialing Frequencies: The frequency pairs assigned for pushbutton dialing shall be as listed below, with an allowable variation of ± 1.5 percent:

Low Group Frequencies (Hz)	High Group Frequencies (Hz)			
	1209	1336	1477	1633
697	1	2	3	Spare
770	4	5	6	Spare
852	7	8	9	Spare
941	*	0	#	Spare

3. RINGING

3.1 When ringing is regenerated at the remote end it shall be automatic and intermittent and shall be cut off from the called line immediately upon removal of the handset at the called station during ringing or silent period.

3.2 Where ringing is generated at the remote end, the ringing system shall provide sufficient ringing on a bridged basis over the voltage and temperature limits of this specification and over subscriber drops within the limits stated by the manufacturer. The manufacturer shall state the minimum number (not less than two) of main station ringers that can be used for each ringing option available.

4. TRAFFIC

4.1 The minimum grade of service for the carriage of traffic in the line concentrator shall be B=.005 using the Erlang B tables. When intra unit calling is included to meet the required grade of service, traffic assumptions and calculations for the particular application being implemented shall be supplied by the Seller.

4.2 Traffic and Plant Registers: Traffic measurements consist of three types - peg count, usage and congestion. A peg count register scores one count per call attempt per circuit group such as trunks, digit receivers, senders, etc. Usage counters measure the traffic density in networks, trunks and other circuit groups. Congestion registers score the number of calls which fail to find an idle circuit in a trunk group or to find an idle path through the switching network when attempting to connect two given end points. These conditions constitute "network blocking."

4.3 When required, traffic data will be stored in electronic storage registers or block of memory consisting of one or more traffic counters for each item to be measured. The Bidder shall indicate what registers are to be supplied, their purpose and the means for displaying the information locally (or at a remote location when available).

5. TRANSMISSION REQUIREMENTS

5.1 General

5.1.1 Transmission requirements for line concentrators will be described in three groups: Common Requirements, Analog System Requirements and Digital System Requirements. Unless otherwise stated, the requirements are in terms of analog measurements made from Main Distributing Frames (MDF) to MDF terminals excluding cabling loss.

5.2 Requirements Common to Both Analog and Digital Line Concentrators

5.2.1 Telephone Transmitter Battery Supply: A minimum of 21 milliamperes, dc, shall be provided for the transmitter of the telephone set at the subscriber station under all loop conditions specified by the Supplier, except in the case of physical trunks to the central office.

5.2.2 Impedance - Subscriber Loops: For the purpose of this specification, the input impedance of all subscriber loops served by the equipment is arbitrarily considered to be 900 ohms in series with a 2 microfarad capacitor at voice frequencies.

5.2.3 Battery Noise: Noise across remote terminal battery at power panel distribution bus terminals shall not exceed 35 dBrnC during busy hour.

5.2.4 Stability: The long-term allowable variation in loss through the line concentrator system shall be ± 0.5 dB from the loss specified by the Bidder.

5.2.5 Return Loss: The specified return loss values are determined by the service and type of port at the measuring end. Two-wire ports are measured at 900 ohms in series with 2.16 microfarads, and 4-wire ports are measured at 600 ohms resistive.

Line-to-Line or Line-to-Trunk (2-Wire)

Echo Return Loss (ERL) - 18 dB, Minimum
Singing Return Loss (SRL) - 12 dB, Minimum

5.2.6 Longitudinal Balance: The minimum longitudinal balance, with dc loop currents of 20 to 70 mA, shall be 60 dB at all frequencies between 60 and 2000 Hz, shall be 55 dB at 2700 Hz and be 50 dB at 3400 Hz. The method of measurement shall be as specified in the IEEE Standard #455-1976, "Standard Testing Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band." Source voltage level shall be 10 volts RMS where conversation battery feed originates at the remote end.

5.2.7 60 Hz Longitudinal Current Immunity: Under test conditions with 60 Hz, the system noise shall be no greater than 23 dBrnC. See Figure 1, Measuring the Effects of Low Frequency Induction.

5.2.8 Steady Noise (Idle Channel at 900 ohm Impedance): Measure on terminated call.

Maximum	- 23 dBrnC
Average	- 18 dBrnC or Less
3K Hz Flat	- Less than 35 dBrnC as an Objective

5.2.9 Impulse Noise: The central office terminal equipment shall be capable of meeting an impulse noise limit of not more than five counts exceeding 54 dBrnC voice band weighted in a 5-minute period on six such measurements made during the busy hour. A Northeast Electronics Company TTS 58A Impulse Noise Counter, or equivalent, should be used for the measurements. The measurement shall be made by establishing a normal connection from the noise counter through the switching equipment in its off-hook condition to a quiet termination of 900 ohms impedance. Office battery and signaling circuit wiring shall be suitably segregated from voice and carrier circuit wiring, and frame talking battery filters provided, if and as required, in order to meet these impulse noise limits.

When used with a SxS or other electro-mechanical telephone switchboard, a measurement shall be made of the impulse noise performance of the termination before connecting the line concentrator. The number of impulse noise counts shall not increase by more than five counts in a 5-minute period when the line concentrator is connected to the electro-mechancial switchboard.

5.2.10 Crosstalk Coupling: Worst case equal level crosstalk is to be 65 dB minimum in the range 200 to 3400 Hz. This is to be measured between any two paths through the system connecting a 0 dBm0 level tone to the disturbing pair.

5.3 Requirements for Analog Line Concentrators

5.3.1 Insertion Loss: The insertion loss, in decibels, of the various paths in the analog line concentrator shall not exceed the following values:

Frequency (Hz)	Capacitor Coupled	Repeating Coil Coupled
300	1.0 dB	1.5 dB
500	0.5	1.0
1000	0.5	0.5
3400	0.5	0.5

5.4 Requirements for Digital Line Concentrators

5.4.1 Digital Error Rate: The digital line concentrator shall not introduce an error into digital connections which is worse than one error in 10^8 bits averaged over a 5-minute period, excluding the least significant bit.

5.4.2 Quantizing Distortion:

Input Level (dBm0) 1004 or 1020 Hz	Minimum Signal to Distortion With C-Message Weighting
0 to -30	33 dB
-30 to -40	27 dB
-40 to -45	22 dB

Due to the possible loss of the least significant bit on direct digital connections, a signal to distortion degradation of up to 2 dB may be allowed where adequately justified by the Bidder.

5.4.3 Overload Level: The overload level at 900 ohm impedance shall be +3 dBm0.

5.4.4 Gain Tracking (Linerarity): 1004 Hz reference at 0 dBm0.

Input Signal Level	Maximum Gain Deviation
+3 to -37 dBm0	$\pm$0.5 dB
-37 to -50 dBm0	$\pm$1 dB

5.4.5 Frequency Response (Loss Relative to 1004 Hz): Here, (-) means less loss and (+) means more loss.

Line-to-Line (Via Trunk Group or Intra-Link)

Frequency (Hz)	Loss at 0 dBm0 Input
60	20 dB Min.*
300	-1 to +3 dB
600 to 2400	±1 dB
3400	-1 to +3 dB

*Transmit End

5.4.6 Envelope Delay Distortion: On any properly established connection, the envelope delay distrotion shall not exceed the following limits:

Band Widths (Hz)	Microseconds
1000 to 2600	190
800 to 2800	350
600 to 3000	500
400 to 3200	700

5.4.7 Absolute Delay: The absolute one-way delay through the line concentrator, excluding delays associated with the central office equipment switching shall not exceed 1000 microseconds analog-to-analog measured at 1800 Hz.

5.5 Detailed Requirements for Direct Digital Connections

5.5.1 The following covers the detailed requirements for the provision of interface units which will permit direct digital connection between the host central office and line concentrator subscriber terminals over digital facilities. The digital transmission system shall be compatible with T1 type span lines using a DS1 interface and other digital interfaces that may be specified by the Owner. The REA specification for the span line equipment is PE-60. Other span line techniques may also be used.

5.5.2 Each interface circuit will connect approximately 24 voice channels from a 1.544 megabit per second DS1 bit stream. The DS1 bit stream entering or exiting the system will be in the D3 format and the voice signals will be encoded in 8 bit mu = 255 PCM. The format and processing of the bit stream must be compatible with characteristics of the D3 channel bank. Examples are alarm and maintenance characteristics. Loss of receive signal (DS1) or frame synchronization shall be detected and execute the equivalent of a carrier group alarm in 2.5 $\pm$ 0.5 seconds.

5.5.3 Signaling will be by means of MF or DP and the system which is inherent in the A and B bits of the D3 format. In the case where A and B bits are not used for signaling, these bits shall only be used for normal voice and data transmission.

5.5.4 When a direct digital interface between the span line and the host central office equipment is to be implemented, the following requirements shall be met.

5.5.4.1 The span line is terminated in a central office repeater and the DS1 bit stream is connected to a digital interface port on the central office equipment.

5.5.4.2 The digital central office equipment is programmed to support the operation of the digital port with the line concentrator subscriber terminal.

5.5.4.3 The line concentrator subscriber terminal used with a direct digital interface shall be interchangeable with the subscriber terminal used with a central office terminal.

6. ALARMS

6.1 General

6.1.1 The system shall have alarms such as blown fuse, blocked controls, power failure in remote, etc., with its own indication and dry relay contract closures or solid-state equivalent for connection to the associated central office alarm circuits. Sufficient system alarm points shall be provided from the remote LC to report conditions to the central office LC alarm system. The alarms shall be transmitted from the remote LC to the central office terminal as long as any part of the connecting link is available for this transmission. Fuses shall be of the alarm and indicator type, and their rating designated by numerals or color code on fuse positions.

7. ELECTRICAL PROTECTION

7.1 General

7.1.1 Adequate electrical protection of line concentrator equipment shall be included in the design of the system. The characteristics and application of protection devices must be such that they enable the line concentrator equipment to withstand, without damage or excessive protector maintenance, the dielectric stresses and currents that are produced in line-to-ground and tip-to-ring circuits through the equipment as a result of induced or conducted lightning or power system fault-related surges. All wire terminals connected to outside plant wire or cable pairs shall be protected from voltage and current surges.

7.1.2 Equipment must pass laboratory tests, simulating the hostile electrical environment, before being placed in the field for the purpose of obtaining field experience. There are five basic types of laboratory tests which must be applied to exposed terminals in an effort to determine if the equipment will survive. Figure 4, Summary of Electrical Requirements and Tests, identifies the tests and their application.

7.1.3 Electrical protection requirements for line concentrator equipment can be summarized briefly as follows.

7.1.3.1 Current surge tests, which simulate the stress to which a relatively low impedance path may be subjected before main frame protectors break down. Paths with a 100 Hz impedance of 50 ohms or less shall be subjected to current surges, employing a 10 x 1000 microsecond waveshape as defined in Figure 5, Surge Waveshape. (Note: For the purpose of determining this impedance, arresters which are mounted within the equipment are to be considered zero impedance.) The crest current shall not exceed 500A; however, depending on the impedance of the test specimen this value of current may be lower. The crest current through the sample, multiplied by the sample's 100 Hz impedance, shall not exceed 1000 V. Where sample impedance is less than 2 ohm, crest current shall be limited to 500A as shown in Figure 3, Current Surge Test.

7.1.3.2 Sixty Hertz (60 Hz) current carrying tests should be applied to simulate an ac power fault which is conducted to the unit over the cable pairs. The test should be limited to 10 amperes rms of 60 Hz ac for a period of 11 cycles (0.1835 seconds) and should be applied longitudinally from line to ground.

7.1.3.3 AC power service surge voltage tests should be applied to the power input terminals of ac powered devices to simulate switching surges or lightning-induced transients on the ac power system. The test shall employ a 1.2 x 50 microsecond waveshape with a crest voltage of 2500V. Communications line protectors may be left in place for this test.

7.1.3.4 Voltage surge tests which simulate the voltage stress to which a relatively high impedance path may be subjected before primary protectors break down and protect the circuit. To assure coordination with the primary protection while reducing testing to the minimum, voltage surge tests should be conducted at a 1000 volts with primary arresters removed for devices protected by carbon blocks, or the +3 sigma dc breakdown of other primary arresters. Surge waveshape should be 10 x 1000 microseconds.

7.1.3.5 Arrester response delay tests are designed to stress the equipment in a manner similar to that caused by the delayed breakdown of gap type arresters when subjected to rapidly rising voltages. Arresters shall be removed for these tests, the peak surge voltage should be the +3 sigma breakdown of the arrester in question on a voltage rising at 100 V per microsecond and the time for the surge to decay to half voltage shall equal at least the delay time of the tube as explained in Figure 6, Arrester Response Delay Time.

7.1.4 Tests should be conducted in the following sequence. As not all tests are required in every application, non-applicable tests should be omitted.

1) Current Impulse Test
2) Sixty Hertz (60 Hz) Current Carrying Test
3) AC Power Service Impulse Voltage Test
4) Voltage Impulse Test
5) Arrester Response Delay Test

7.1.5 Five applications of each polarity for the surge tests and three for the 60 Hz Current Carrying Test are the minimum required. All tests should be conducted with not more than 1 minute between consecutive applications in each series of three or five to a specific configuation so that heating effects will be cumulative. See Figure 7, 60 Hz Current Surge Test.

7.1.6 Tests should be applied between each of the following terminal combinations for all line operating conditions:

1) Line tip to ring.
2) Line ring to ground.
3) Line tip to ground.
4) Line tip and ring tied together to ground.

7.2 Dielectric Strength

7.2.1 Arresters shall be removed for all dielectric strength tests.

7.2.2 Direct current potentials shall be applied between all line terminals and equipment chassis and between these terminals and grounded equipment housings in all instances where the circuitry is (1) dc open circuit from the chassis, or (2) connected to the chassis through a capacitor. The duration of all dielectric strength tests shall be at least 1 second. The applied potential shall equal or exceed the plus 3 sigma dc breakdown voltage of the arrester, provided by the line concentrator manufacturer.

7.3 Insulation Resistance

7.3.1 Following the dielectric tests, the insulation resistance of the installed electrical circuits between wires and ground, with the normal equipment grounds removed, shall not be less than 10 megohms at 500 volts, dc at approximately room temperature (68°F) and at a relative humidity of approximately 50 percent. The measurement shall be made after the meter stabilizes, unless the requirement is met sooner. Arresters shall be removed for these tests.

7.4 Components

7.4.1 Insofar as possible, all components shall be capable of being continuously energized at rated voltage without injurious results. Insofar as possible, design precautions must be taken to prevent damage to other equipment and components when a particular component fails.

7.4.2 Printed circuit boards or similar equipment employing electronic components shall be self-protecting against external grounds applied to the connector terminals, where feasible. Board components and coatings applied to finished products shall be of such material or so treated that they will not support combustion.

7.4.3 Every precaution shall be taken to protect electro-statically sensitive components from damage during handling. This shall include written instructions and recommendations.

8. MISCELLANEOUS

8.1 Interconnect Wire: All interconnect wire shall be of soft annealed tinned copper wire meeting the requirements of ASTM Specification B-33 and of suitable cross-section to provide safe current carrying capacity and mechanical strength. The insulation of installed wire, connected to its equipment and frames, shall be capable of withstanding the same insulation resistance and dielectric strength requirements as given in paragraphs 7.2 and 7.3 at a temperature of 120°F and a relative humidity of 90 percent.

8.2 Wire Wrapped Terminals: These terminals are preferred and where used shall be tinned, or of a material suitable for wire wrapping. The connections to them shall be made with a wire wrapping tool with the following minimum number of successive non-overlapping turns of bare tinned copper wire in contact with each terminal:

6 turns of 30 gauge
6 turns of 26 gauge
6 turns of 24 gauge
5 turns of 22 gauge

8.3 Protection Against Corrosion: All metal parts of equipment frames, distributing frames, cable supporting framework and other exposed metal parts shall be constructed of corrosion resistant materials or materials plated or painted to render them adequately corrosion resistant.

8.4 Screws and Bolts: Screw threads for all threaded securing devices shall be of American National form in accordance with National Bureau of Standards Handbook H-28, unless exceptions are granted to the manufacturer of the switching equipment. All bolts, nuts, screws, and washers shall be of nickel-copper alloy, steel, brass or bronze.

8.5 Environmental Requirements: The Bidder shall specify the environmental conditions necessary for safe storage and satisfactory operation of his equipment. If requested, he shall assist the Owner in planning how to provide the necessary environment for the equipment.

8.5.1 To the extent practicable, the following temperature range objectives shall be met.

8.5.1.1 For equipment mounted in central office and subscriber buildings, the carrier equipment shall operate satisfactorily within an ambient temperature range of 0° to $49^{\circ}C$ and at 80 percent relative humidity between 10° and $38^{\circ}C$.

8.5.1.2 Equipment mounted outdoors in normal operation (with cabinet doors closed) shall operate satisfactorily within an ambient temperature range (external to cabinet) of -40° to $60^{\circ}C$ and at 95 percent relative humidity between 10° to $38^{\circ}C$. As an alternative to the $60^{\circ}C$ requirement, a maximum ambient temperature of $49^{\circ}C$ with equipment (cabinet) exposed to direct sunlight may be substituted.

8.6 Stenciling: Equipment units and terminal jacks shall be adequately designated and numbered. They shall be stenciled so that identification of equipment units and leads for testing or traffic analysis can be made without unnecessary reference to prints or descriptive literature.

8.7 Equipment Frame Design: For newly designed systems, consideration should be given to the desirability of providing frames which can be installed in rooms of normal ceiling height (up to 8 feet). Where feasible, frames and equipment units shall be designed for ready portability and/or high salvage value.

8.8 Quantity of Equipment Bays: Consistent with system arrangements and ease of maintenance, space shall be provided on the floor plan for an orderly layout of future equipment bays. Readily accessible terminals will be provided for connection to interbay and frame cables to future bays. All cables, interbay and intrabay (excluding power), if technically feasible, shall be terminated at both ends by use of connectors.

9. RADIO AND TELEVISION INTERFERENCE

9.1 Measures shall be employed by the manufacturers to limit the radiation of radio frequency noise voltages generated by the equipment so as not to interfere with radio, television receivers, or other sensitive equipment.

10. HOUSING

10.1 When housing is supplied by the Bidder, it should follow the general requirements of REA Specification PE-69, "REA Specification for Electronic Equipment Housings," insofar as possible.

10.2 When housed in a building supplied by the Owner, a complete floor plan including ceiling height, power outlets, cable entrances, equipment entry and travel, type of construction, and other pertinent dimensions shall be supplied with this specification.

10.3 In order to control corrosion, all metal parts of the housing and mounting frames shall be constructed of suitable corrosion resistant materials or materials protectively coated to render them adequately resistant to corrosion under the climatic and atmospheric conditions existing in the area in which the housing is to be installed.

11. DISTRIBUTING FRAME

11.1 The line concentrator terminal equipment located at the central office shall be protected by the central office main distribution frame. The Seller may supply additional protection capability as he finds it appropriate.

11.2 The line concentrator remote terminal equipment shall be equipped with protectors mounted in a distribution frame.

11.2.1 The distributing frame shall provide terminals for terminating all incoming cable pairs. Arresters shall be provided for all incoming cable pairs, or for a smaller numer of pairs if specified, provided an acceptable means of temporarily grounding all terminated pairs which are not equipped with arresters is furnished.

11.2.2 The current carrying capacity of each arrester and its associated mounting shall be such as to coordinate with a #22 gauge copper conductor without causing a self-sustaining fire or permanently damaging other arrester positions. Where all cable pairs entering the housing are #24 gauge or finer, the arresters and mountings need only coordinate with #24 gauge cable conductors.

11.2.3 Remote terminal protectors may be mounted and arranged so that outside cable pairs may be terminated on the left side of protectors (when facing the vertical side of the MDF) or on the back surface of the protectors. Means for easy identification of pairs shall be provided.

11.2.4 Protectors shall have a "dead front" (either insulated or grounded) whereby live metal parts are not readily accessible.

11.2.5 Protectors shall be provided with an accessible terminal of each incoming conductor which is suitable for the attachment of a temporary test lead. They shall also be constructed so that auxiliary test fixtures may be applied to open and test the subscriber's circuit in either direction. Terminals shall be tinned or plated and shall be suitable for wire wrapped or connectorized connections.

11.2.6 If specified, each protector group shall be furnished with a factory assembled tip cable for splicing to the outside cable; the tip cable to be 20 feet in length unless otherwise specified.

11.2.7 Protector makes and types shall be selected only from REA Bulletin 344-2, "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers." Protectors shall be capable of easy removal.

12. POWER EQUIPMENT

12.1 When specified, batteries and charging equipment shall be supplied for the remote terminal of the line concentrator.

12.2 Operating Voltage

12.2.1 The nominal operating voltage of the central office and remote terminal shall be 48 volts dc, provided by a battery with the positive side tied to system ground.

12.2.1.1 Where equipment is dc powered, it must operate satisfactorily over a range of 50 volts ± 6 volts dc.

12.2.1.2 Where equipment is ac powered, it must operate satisfactorily over a range of 117 ± 10% volts or 220 ± 10% volts ac.

12.3 Batteries

12.3.1 Unless specified otherwise by the Purchaser, sealed batteries shall be supplied for the remote line concentrator terminal.

12.3.2 The batteries shall have an ampere hour load capacity of no less than 8 busy hours. When an emergency ac supply is available, the battery reserve may be reduced to 3 busy hours.

12.3.3 The batteries shall be sealed when they are mounted in the cabinet with the concentrator equipment.

12.3.4 Battery heaters shall be supplied in Bidder furnished housing whenever climatic conditions require.

12.4 Charging Equipment

12.4.1 One charger capable of carrying the full dc power load of the remote terminal shall be supplied unless otherwise specificed by the Purchaser.

12.4.2 Charging shall be on a full float basis. The rectifiers shall be of the full wave, self-regulating, constant voltage, solid-state type and shall be capable of being turned on and off manually.

12.4.3 When charging batteries, the voltage at the battery terminals shall be adjustable and shall be set at the value recommended for the particular battery being charged, providing it is not above the maximum operating voltage of the dial equipment. The voltage shall not vary more than plus or minus 0.02 volt per cell between 10 percent load and 100 percent load. Between 3 percent and 10 percent load, the output voltage shall not vary more than plus or minus 0.04 volt per cell. Beyond full load current the output voltage shall drop sharply. The above output voltage shall be maintained with line voltage variations of plus or minus 10 percent. Provision shall be made to manually change the output voltage of the rectifier to 2.25 volts per cell to provide an equalization charge on the battery.

12.4.4 The charger noise when measured with a suitable noise measuring set and under the rated battery capacitance and load conditions shall not exceed 22 dBrnC. See Figure 2, Charger Noise Test.

12.4.5 The charging equipment shall be provided with means for indicating a failure of charging current whether due to ac power failure, an internal failure in the charger or to other circumstances which might cause the output voltage of the charger to drop below the battery voltage. Where a supplementary constant current charger is used, an alarm shall be provided to indicate a failure of the charger.

12.4.6 Audible noise developed by the charging equipment shall be kept to a minimum. Acoustic noise resulting from operation of the rectifier shall be expressed in terms of dB indicated on a sound level meter conforming to American National Standards Institute S1.4, and shall not exceed 65 dB (A-weighting) measured at any point five feet (152.4 cm) from any vertical surface of the rectifier.

12.4.7 The charging equipment shall be designed so that neither the charger nor the central office equipment is subject to damage in case the battery circuit is opened for any value of load within the normal limits.

12.5 Power Panel

12.5.1 Battery and charger control switches, dc voltmeters, dc ammeters, fuses and circuit breakers, supervisory and timer circuits shall be provided as required. Portable or panel mounted frequency meters or voltmeters shall be provided as specified by the Owner.

12.5.2 Power panels, cabinets and shelves, and associated wiring shall be designed initially to handle the line concentrator terminal when it reaches its ultimate capacity as specified by the Owner.

12.5.3 The power panel shall be of the "dead front" type.

12.6 Ringing Equipment

12.6.1 The ringing system shall provide sufficient ringing on a bridged basis over the voltage and temperature limits of this specification and over subscriber drops within the limits stated by the manufacturer. The ringing system shall be without operational problems such as bell tapping during dialing. The manufacturer shall state the minimum number (not less than two) of main station ringers that can be used for each ringing option available.

12.7 Interrupter Equipment

12.7.1 The interrupter may be an integral part of the system or may be part of the associated central office equipment connected to the line concentrator central office terminal.

13. FUSING REQUIREMENTS

13.1 General

13.1.1 The equipment shall be completely wired and equipped with fuses, trouble signals, and all associated equipment for the wired capacity of the frames or cabinets provided.

13.1.2 Design precautions shall be taken to prevent the possibility of equipment damage arising from the insertion of an electronic package into the wrong connector or the removal of a package from any connector or improper insertion of the correct card in its connector.

13.2 Fuses

13.2.1 Fuses and circuit breakers shall be of an alarm and indicator type, except where the fuse or breaker location is indicated on the alarm printout. Their rating shall be designated by numerals or color codes on the fuse or the panel, where feasible.

14. TROUBLE LOCATION AND TEST

14.1 Equipment

14.1.1 Trouble indications in the system may be displayed in the form of lights on the equipment units or printed circuit boards.

14.1.2 When required, a jack or other connector shall be provided to connect a fault or trouble recorder (printer or display).

14.2 Maintenance System

14.2.1 The maintenance system shall monitor and maintain the system operation without interruption of call processing except for major failures.

14.2.2 The maintenance system shall be arranged to provide the ability to determine trouble to an individual card, functional group of cards or other equipment unit.

15. SPARE PARTS

15.1 Lists of spare parts and maintenance tools as recommended by the Bidder shall be provided. The cost of such tools and spare parts shall be indicated and shall not be included in the base price.

16. DRAWINGS AND PRINTED MATERIAL

16.1 The Bidder shall supply instructional material for each exchange involved at the time of delivery of the equipment. It is not the intent of this specification to require system documentation necessary for the repair of individual circuit boards.

Three complete sets of legible drawings, each set to include all of the following:

Equipment Layout Drawings	-	Drawings of major equipment items such as frames with the location of major component items of equipment shown therein.
Wiring Diagrams (Or Equivalent)	-	Drawings indicating the specific method of wiring used on each item of equipment and interconnection wiring between items of equipment.
Maintenance Drawings	-	Individual item drawings covering each equipment item that contains replaceable parts, appropriately identifying each part by name and part number. If individual item drawings are not provided, complete ordering instructions shall be furnished for all replaceable parts.
Job Drawings	-	Included in this category are all drawings that are individual to the particular line concentrator application involved.

16.2 The following information shall also be furnished:

1) Complete index of the required drawings.

2) Explanation of electrical principles of operation of overall switching system.

3) List of tests which can be made with each piece of test equipment furnished and explanation of method of making each test.

4) Sample of each form recommended for use in keeping records of tests.

5) Criteria for analyzing results of tests and determining appropriate corrective action.

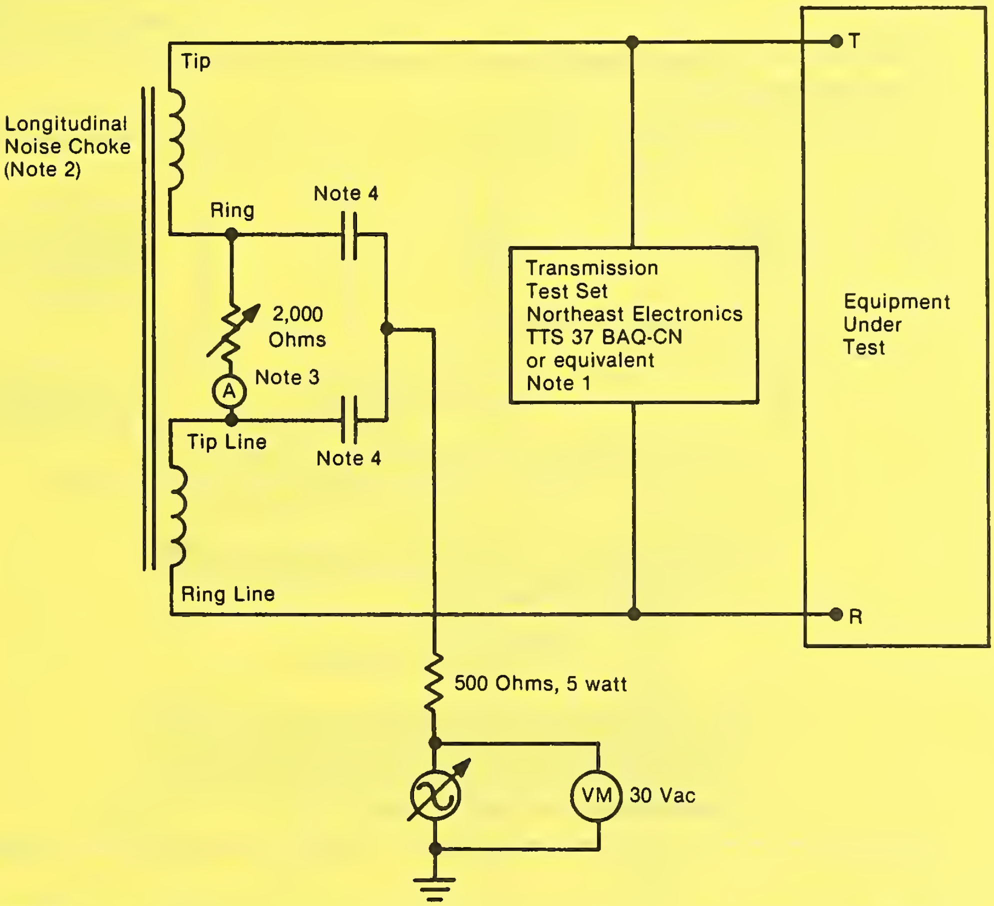
6) General notes on the methods of isolating equipment faults to specific printed circuit cards in the equipment.

7) List of typical troubles which might be encountered, together with general indications as to the probable location of each trouble.

8) Special line concentrator system grounding requirements.

Figure 1

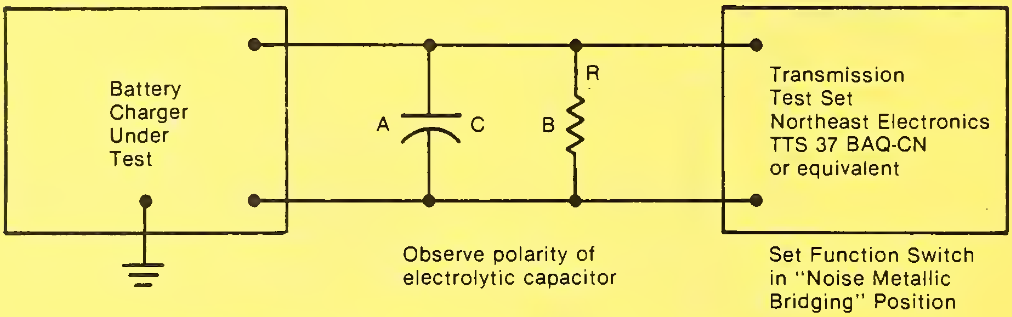
Measuring the Effects of Low Frequency Induction



Notes:
1. 900 ohm termination, C message weighting, hold coil off
2. SNC Noise Choke 35 W, or equivalent
3. Test at 0.020 A and 0.070 A dc
4. 2 ± 0.001 microfarad, 150 Vdc

Figure 2

Charger Noise Test



Where the manufacturer so elects the capacitor C may be eliminated from the measurement.

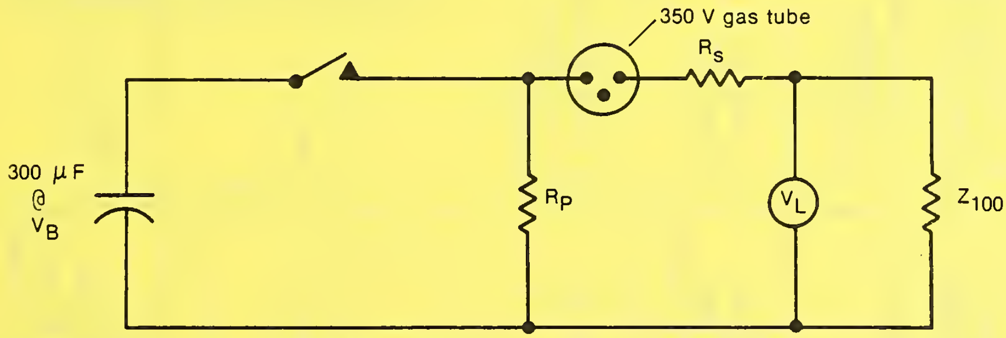
A. Capacitance in μF = 30,000 μF per ampere-hour per cell. (For example, 25 cells at 100 ampere-hour would be equivalent to a capacitance of:)

$$\frac{30{,}000 \times 100}{25} = 120{,}000\ \mu F$$

B. The value of the resistive load R is determined by the nominal battery voltage in volts divided by the full load rating in amperes. For example, for a 48-volt battery and a full load current of 24 amperes, the load resistance R is 48/24 = 2 ohms of appropriate power handling capacity.

Figure 3

Current Surge Test



V_L = Not to exceed 1000V
V_B = Charging Voltage
Z_{100} = Test Specimen Impedance to be measured at 100 Hz.
R_p = Parallel Resistance (Waveshape)
R_s = Series Resistance (Current Limiting)

Z_{100}	R_s	R_p	V_B
"0"	5	∞	2500
1	4	∞	2500
2	3	∞	2500
3	2	∞	1670
4	1	∞	1250
5	0	∞	1000
7.5	0	15	1000
10	0	10	1000
15	0	7.5	1000
20	0	6.7	1000
25	0	6.25	1000
30	0	6	1000
40	0	5.7	1000
50	0	5.5	1000

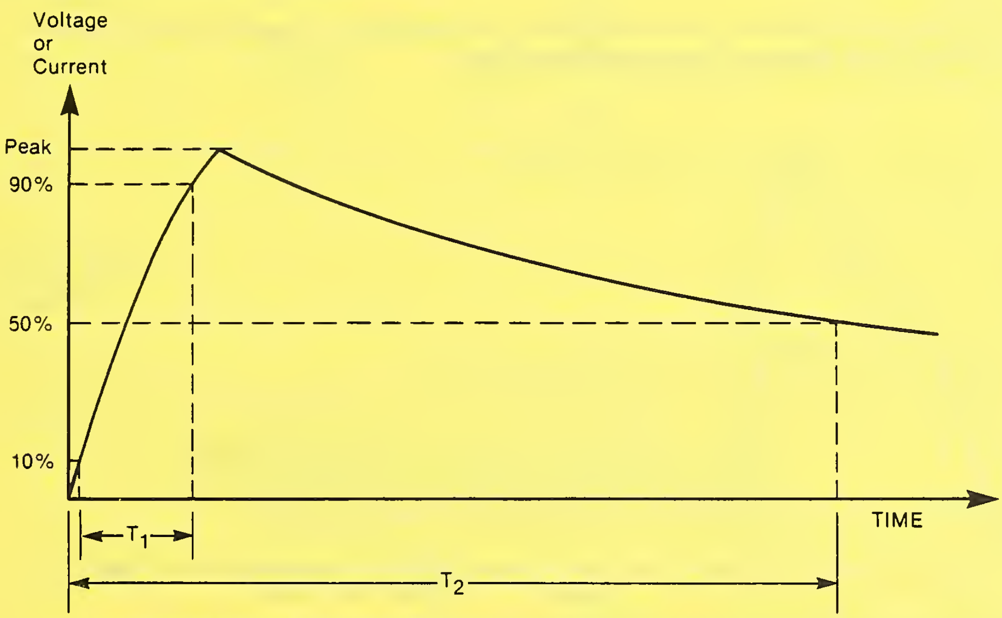
FIGURE 4

Summary of Electrical Requirements and Tests

Test	Application Criteria	Peak Voltage or Current	Surge Waveshape	No. of Applications & Max. Time Between	Comments
Current Surge	Low Impedance Paths Exposed to Surges	500A or Lesser Current (See Fig. 3)	10x1000 μs	5 each Polarity at 1 minute intervals	
60 Hz Current Carrying	High or Low Impedance Paths Exposed to Surges	10A rms or Lesser Current (See Fig. 7)	11 Cyles of 60 Hz (0.183 Sec.)	3 each at 1 minute intervals	
AC Power Service Surge Voltage	AC Power Service Connection	2500V or +3 σ clamping V of arrester employed at 10kV/μs	1.2x50 μs	5 each Polarity at 1 minute intervals	AC arrester, if used, must be removed. Communications line arresters, if used, remain in place.
Voltage Surge	High Impedance Paths Exposed to Surges	1000V or +3 σdc breakdown of arrester employed	10x1000 μs	Same	All primary arresters, if used, must be removed.
Arrester Response Delay	Paths protected by arresters, such as gas tubes, with breakdown dependent on V. rate of rise.	+3 σ breakdown of arrester employed at 100V/μs of rise	100V/μs rise decay to ½ V. in tube's delay time	Same	Same

Figure 5

Explanation of Surge Waveshape



Surge Waveshape is defined as follows:

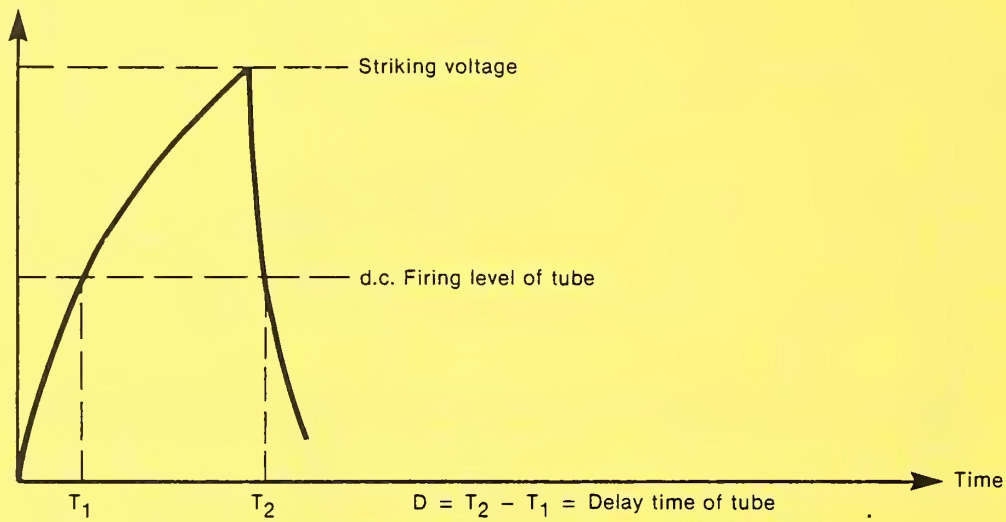
Rise Time X Time to Decay to Half Crest Value for Example: 10 x 1000 μs

Notes: T_1 = Time to determine the rate of rise. The rate of rise is determined as the slope between 10% and 90% of peak voltage or current.

T_2 = Time to 50% of peak voltage (decay to half value).

Figure 6

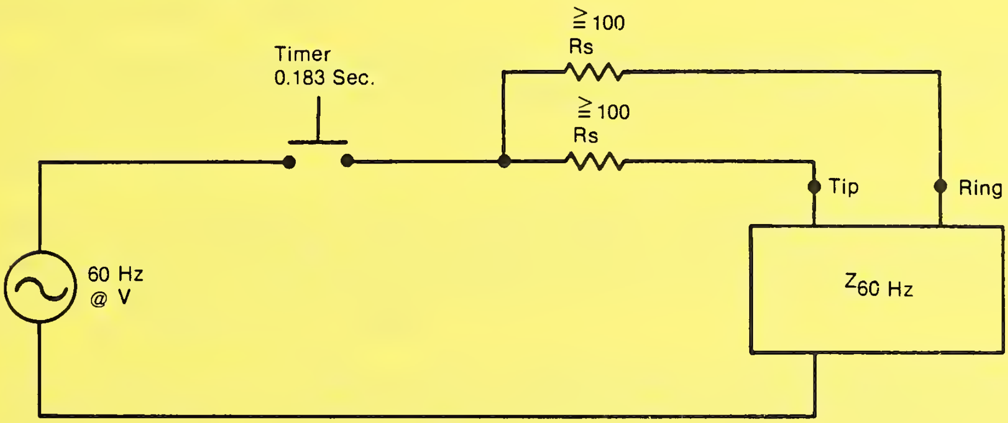
Explanation of Arrester Response Delay Time



That period of time when the potential across an arrester exceeds its d.c. firing level is considered delay time.

Figure 7

60 Hz Current Surge Test



V – 700 Volts RMS (Approximately 1000V Peak).
Z_{60} – Test specimen impedance to be measured at 60 Hz.
Rs – Series Resistance (current limiting) in each side of line.
(Source impedance never less than 50 Ω longitudinal.)

$Z_{60\ Hz}$	R_s
0	140
10	120
20	100
50	100
Over 50	100

PART II

INSTALLATION AND ACCEPTANCE

1. GENERAL

1.1 These specifications cover the general requirements for the installation of line concentrator equipment by the Bidder and outline the general conditions to be met by the Owner in connection with such installation work.

2. RESPONSIBILITIES OF OWNER

2.1 The following responsibilities apply in both the central office installation and remote terminal installations, unless otherwise noted.

2.2 The Owner shall:

2.2.1 During the progress of the installation, allow the Bidder and its employees free access to the premises and facilities at all hours. Likewise, the Owner and its representatives shall be allowed access to all parts of the buildings at all times.

2.2.2 Take such action as necessary to ensure that the premises are dry and free from dust and in such condition as not to be hazardous to the installation personnel or the material to be installed. Not required when remote terminal is not installed in a building.

2.2.3 Provide heat or air-conditioning when required and general illumination in rooms in which work is to be performed or materials stored.

2.2.4 Provide suitable openings in buildings to allow material to be placed in position. Not required when remote terminal is not installed in a building.

2.2.5 Provide the necessary conduit and commercial and DC-AC inverter output power to the locations shown on the approved floor plan drawings; provide 110 volts, 60 Hz commercial power equipped with a secondary arrester and a reasonable number of outlets for test, maintenance and installation equipment; provide suitable openings or channels and ducts for cables and conductors, from floor to floor and from room to room; and provide suitable ground leads, as designated by the Bidder. Not required when remote terminal is not installed in a building.

2.2.5.1 Provide the necessary wiring central office grade ground and commercial power service, with a secondary arrester, to the location of an exterior remote terminal installation. The voltage and load requirements are to be furnished by the Supplier.

2.2.6 Test at its own expense all lines and trunks for continuity, leakage and loop resistance and ensure that all lines and trunks shall be suitable for operation with the central office and remote terminal equipment specified.

2.2.7 Make alterations and repairs to buildings necessary for proper installation of material, except to repair damage for which the Bidder or its employees are responsible.

2.2.8 Connect outside cable pairs on the distributing frame and run all line and trunk jumpers (those connected to protectors).

2.2.9 Furnish all line, class of service assignment and party assignment information to permit Bidder to program the data base memory within a reasonable time prior to final testing.

2.2.10 When possible, release for the Bidder's use such portions of the existing plant as are necessary for the proper completion of such tests as require coordination with existing facilities. This includes facilities for T1 span lines with properly installed repeaters between the central office and the remote terminal installations.

2.2.11 Promptly make such inspections as it deems necessary when notified by the Bidder that the equipment, or any part thereof, is ready for acceptance.

2.2.12 Provide adequate fire protection apparatus at remote terminal, including one or more fire extinguishers or fire extinguishing systems of the gaseous type that has low toxicity and effect on equipment.

2.2.13 If underfloor cabling is selected, to provide necessary access ports for cable.

2.2.14 Equipment and accessory plant devices mounted external to the central office building and external to the repeater and other outside housings will be installed by the Owner. These include filters, repeater housings, splicing of repeater cable stubs, externally mounted protective devices and other such accessory devices. The Seller will provide instructions for the Owner to properly install the accessory and plant equipment. The instructions will be in written form.

2.2.15 The Owner shall make all cross connections (at the MDF or IDF) between the physical trunk or carrier equipment and the central office equipment unless otherwise specified in Part IIIA.

3. RESPONSIBILITIES OF BIDDER

3.1 The Bidder shall:

3.1.1 Obtain the Owner's permission before proceeding with any work necessitating cutting into or through any part of the building structure such as girders, beams, concrete or tile floors, partitions or ceilings. This does not apply to the installation of lag screws, expansion bolts, and similar devices used for fastening equipment to floors, columns, walls and ceilings.

3.1.2 Be responsible for and repair all damage to the building due to carelessness of his workmen, and exercise reasonable care to avoid any damage to the Owner's switching equipment or other property. It will report to the Owner any damage to the building which may exist or may occur during its occupancy of the building.

3.1.3 Consult with the Owner before cutting into or through any part of the building structure in all cases where the fireproofing or moisture proofing may be impaired.

3.1.3.1 Take necessary steps to ensure that all fire fighting apparatus is accessible at all times. Flammable materials shall be kept in suitable places outside the building.

3.1.3.2 Not use gasoline, benzene, alcohol, naptha, carbon tetrachloride or turpentine for cleaning any part of the equipment.

3.1.4 Install the equipment in accordance with the specifications for the line concentrator.

3.1.5 All leads brought out to terminal blocks on the MDF (or IDF if stated in Part IIIA) and the blocks shall be identified and permanently labeled by the Bidder.

3.1.5.1 Separate shielded type leads or TIP cables meeting REA cable cross-talk requirements shall be used for carrier frequencies inside the central office. The shields shall be grounded at one end only unless specified by the Purchaser or Bidder.

3.1.5.2 The cables shall be grouped to separate carrier frequency, voice frequency, signaling and power leads.

3.1.5.3 The Bidder will make the necessary power and ground connections to the Purchaser's power terminals and ground bus unless stated otherwise in Part IIIA. The location of these connections are shown in Part IIIA. The ground wire shall be 6 AWG unless stated otherwise.

3.1.6 Place the battery in service in compliance with the recommendations of the battery manufacturer.

3.1.7 Make final charger adjustments using the manufacturer's recommended procedure.

3.1.8 Run all jumpers, except line and trunk jumpers (those connected to protectors).

3.1.9 Establish and update all data base memories with subscriber information as supplied by the Owner until an agreed turnover time.

3.1.10 Permit the Owner or its representative to conduct tests and inspections after installation has been completed in order that the Owner may be assured the requirements for installation are met. The Bidder's installer shall give the Owner notice of completion of the installation at least one week prior to completion.

3.1.11 Upon request, before turnover, allow access by the Owner or its representative to the test equipment which is to be turned over as a part of the delivered equipment, to permit the checking of the circuit features which are being tested and to permit the checking of the amount of connected equipment to which the test circuits have access.

3.1.12 Promptly notify the Owner of the completion of work of the central office terminals, remote terminals or such portions thereof as are ready for inspection.

3.1.13 Promptly correct all defects for which the Bidder is responsible.

4. INSTALLATION REQUIREMENTS

4.1 All work shall be done in a neat, workmanlike manner. Equipment frames or cabinets shall be correctly located, carefully aligned, anchored and firmly braced. Cables shall be carefully laid with sufficient radius of curvature and protected at corners and bends to ensure against damage from handling or vibration. Exterior cabinet installations for remote terminals shall be made in a permanent, eye pleasing manner.

4.2 All multiple and associated wiring shall be continuous, free from crosses, reverses and grounds and shall be correctly wired at all points.

4.3 An inspection shall be made by the Owner or its representatives prior to performing operational and performance tests on the equipment, but after all installing operations which might disturb apparatus adjustments have been completed. The inspection shall be of such character and extent as to disclose with reasonable certainty any unsatisfactory condition of apparatus or equipment. Where any of the following conditions are observed either during above inspections, or inspections for apparatus adjustments, or wire connections, or in testing of equipment, sufficiently detailed examination shall be made throughout the portion of the equipment within which such condition is observed, or is likely to occur, to disclose the full extent of its existence.

4.3.1 Failure to supply in quantity and type the equipment specified for the installation.

4.3.2 Apparatus or equipment units damaged or incomplete.

4.3.3 Apparatus or equipment affected by rust, corrosion or marred finish.

4.3.4 Other adverse conditions resulting from failure to meet generally accepted standards of good workmanship.

5. OPERATIONAL TESTS

5.1 Operational tests shall be performed on all circuits and circuit components to ensure their proper functioning in accordance with appropriate explanation of the operation of the circuit.

5.2 All equipment shall be tested to ensure proper operation with all components connected in all possible combinations and each line shall be tested for proper ring, ring trip and supervision.

5.3 All fuses shall be verified for continuity and correct rating. Alarm indication shall be demonstrated for each equipped fuse position. An already failed fuse compatible with the fuse position may be used.

5.4 Each alarm or signal circuit shall be checked for correct operation.

5.5 A sufficient quantity of locally originating and incoming calls shall be made to demonstrate the function of the line concentrator including all equipped transmission paths. When intra-link calling is supplied, all intra-link transmission paths shall be demonstrated.

6. ACCEPTANCE TESTS AND DATA REQUIRED

6.1 Data shall be supplied to the Purchaser by the Bidder in writing as a part of the final documents in closing out the contract as follows:

6.1.1 A detailed cross connect drawing of alarm to power board, central office battery to physical trunks or carrier system, wiring options used in terminals channels, filters, repeaters, etc., shall be marked in the Purchaser's copy of the equipment manual or supplied separately.

6.1.2 The measured central office supply voltages applied to the equipment terminals or repeaters at the time the jack and test point readings are made and ac supply voltages where equipment is powered from commercial ac sources.

6.1.3 A list of all instruments, including accessories, by manufacturers and type number, used to obtain the data.

6.1.4 The measurements at all jack or test points recommended by the manufacturer, including carrier frequency level measurements at all carrier terminals and repeaters where utilized.

6.2 Data in the form of a checklist or other notations shall be supplied showing the results of the operational tests.

6.3 Furnish the Owner with a record of the cell voltages made at the completion of the installation of the switching system and before it is placed in commercial service.

7. JOINT INSPECTION REQUIREMENTS

7.1 The Bidder shall notify the Purchaser in writing at least one week before the date equipment will be ready for inspection and tests. A joint inspection shall be made by the Seller and Purchaser (or Purchaser's engineer) to determine that the equipment installation is acceptable. The inspection shall include physical inspection, a review of acceptance test data, operational tests and sample measurements.

7.1.1 The Purchaser shall review the acceptance test data and compare it to the requirements of this specification.

7.1.2 Sample measurements shall be made on all systems installed under this contract. Test methods should follow procedures described in Part I.

7.1.3 A check of measured test point and jack readings for compliance with the manufacturer's specifications. This applies also to channels, terminals, carrier frequency repeaters and fault locating circuits.

7.2 Statements

7.2.1 In the event that the measured data or operational tests show that equipment fails to meet the requirements of this specification, the deficiencies are to be resolved as set forth in Article II of this contract. The reports of the Seller and Purchaser should be detailed as to deficiencies, causes, corrective action necessary, corrective action to be taken, completion time, etc.

POWER REQUIREMENTS FOR COMMUNITY DIAL CENTRAL OFFICE EQUIPMENT

CONTENTS

1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. It discusses, in particular, the methods used in calculating the power requirements for dial central offices. It provides means to calculate the required capacities of the storage batteries and charging equipment for particular applications.

1.2 This revision replaces REA TE&CM 302, Issue No. 4, dated April 1975. It is being reissued to include power calculation methods for various digital, stored program controlled central office equipment.

1.3 Paragraphs 17.0 and 18.0, respectively, of Part III, REA Form 558c, "Detailed Central Office Equipment Requirements," paragraphs 8.1 and 8.2, respectively, of Part III, REA Form 524c, "Specification for Common Control Central Office Equipment Detailed Equipment Requirements," and paragraphs 7.1 and 7.2, respectively, of Part III, REA Form 522, "Specification for Digital, Stored Program Controlled Central Office Equipment," cover the general specifications governing the supply, by the manufacturer, of storage battery and charging equipment for use with an REA borrower's proposed dial central office (CDO). Based upon these general specifications, determination of the required capacities of the battery and charger is made by the manufacturer.

1.4 Appendix A includes the power requirement computations for the direct control and common control electromechanical switching systems.

2. BASIS FOR CALCULATIONS

2.1 The charging equipment furnished with a dial central office must have sufficient capacity to supply the dc power necessary for the satisfactory operation of the office during the busy hour. This includes the dc requirements for carrier, loop extenders, voice frequency repeaters, ANI, and dc-dc converters or dc-ac inverters to operate input/output devices.

2.1.2 Determination of the requirements for emergency generating and charging equipment is covered in REA TE&CM 320, "Emergency Generating and Charging Equipment."

2.2 Charging equipment for common control offices should be provided on one of the following bases:

(a) Two chargers either capable of carrying the full office load, or

(b) Three chargers each capable of carrying half the office load, or

(c) One charger capable of carrying the full office load.

Arrangement (a) may be used in any central office power system. Arrangement (b) may be used and offers potential cost savings when applied to large power requirements such as digital, stored program controlled offices. Arrangement (c) may be applicable to smaller class 5 offices and remote switching terminals or line concentrators.

2.3 Storage Battery

2.3.1 The storage battery furnished with a dial central office must have sufficient capacity to supply the dc power necessary to sustain satisfactory operation of the exchange for the period specified. See paragraph 1.3 for location of specific requirements in the various central office equipment specifications. This includes appropriate allowances for any equipment which is normally ac operated but arranged for dc operation in case of a power failure.

2.3.2 During battery discharge, the minimum usable voltage to be delivered to the central office equipment is determined by the COE manufacturer's design criteria. When power flows from the battery through the power board to the equipment, a voltage drop (IR loss) is experienced as a result of the resistance of the current carrying conductors. In many cases the equipment design is based on 44 volts being available at the power entry to the bay. Performance of the COE at voltages less than 44 volts becomes unpredictable. The electromechanical systems used earlier were capable of operation at voltages below 40 volts.

The voltage drop to the equipment bay is controlled by allocation as follows:

Battery to Power Board	0.5
Power Board to Equipment Bay	0.5
Minimum Equipment Voltage	44.0
Total	45V dc

In the case of a 24-cell battery (45 ÷ 24=) 1.88 volts per cell becomes the minimum operating voltage.

2.3.3 The computation of battery size to meet the site power requirement is described in Figure 9 - Estimating Telephone Battery Sizes. This method permits computation with differing numbers of hours of reserve and number of cells in the battery string. The computation is applicable to lead acid batteries - either lead antimony or lead calcium - using liquid, gelled or immobilized electrolyte (see manufacturer's data for capacity, dimensions, etc.).

2.3.4 Battery capacities are generally given in terms of ampere hour (AH) rating, when discharged to 1.75 volts per cell, in an 8-hour period. Since many REA systems are equipped with emergency generators, the period of discharge of their batteries is reduced to 3 hours. When a battery is discharged at a rate faster than 8 hours, the ampere hour rating is effectively reduced, e.g., at 3 hours approximately 75% of the 8-hour rating is available. The net effect of the 3-hour discharge is to require a battery of approximately half the size required to carry the same load for 8 hours (3 X load in amps ÷ 0.75 = 4 hrs. equivalent vs. 8-hour rating).

2.3.5 The selection of the battery capacity to be supplied is based on the power outages experienced at the site and the evaluation of the future performance of the ac power system. Another consideration is the size of the dc load to be supplied. Small electromechanical switching systems have a limited amount of fixed power consuming devices while a large part of the system only requires power when in use. This gave rise to considering the power required in the "busy hour." Industry usage considered 8 busy hour battery capacity appropriate for most small installations. The expectation of 8 consecutive busy hours of usage following a power interruption was nil, resulting in battery power being usable for longer than the 8-hour period. Power consumption in digital switching equipment is almost constant whether or not calls are being processed. In addition, the total power consumed by the digital switch is greater than the electromechanical systems. The concept of "busy hour drain" has lost its impact in digital offices where the operating drain represents the constant load. The solution most often used is to provide an emergency generator to supply power on a long-term basis and to install a battery with up to 3 hours capacity to avoid short running periods on the emergency generator.

3. CALCULATIONS

3.1 The following sample calculations describe the procedure to determine the power requirements for digital, stored program controlled central office equipment. Sample calculations are included for the following switching equipment types:

Manufacturer	System Designation
Figure 1 - GTE	GTD No. 5 EAX
Figure 2 - ITT	1210/32,/64
Figure 3 - NEC America	NEAX-61K
Figure 4 - Northern Telecom	DMS-100,-10,-10M
Figure 5 - Stromberg-Carlson	DCO
Figure 6 - CIT-Alcatel	E10-FIVE
Figure 7 - Western Electric	5ESS

3.2 Figure 8: Lists various power requirements for loop extenders, voice frequency repeaters, carrier equipment and other equipment.

3.3 Figure 9: Illustrates the method used in determining the capacity of the storage battery required for a particular application. This exhibit also illustrates, in Example 2, a method used to calculate the ampere hour reserve of existing batteries when the current requirement of the central office equipment is changed as a result of equipment additions, higher than anticipated calling rates, etc.

3.4 Figure 10: Illustrates the method used in determining charger capacity required for a particular application. In connection with the calculation of the required capacity of the charger, a 10% allowance is made, i.e., if 110% of the rated output of the charger is equal to or greater than the calculated charger dc current requirement, the charger supplied shall be considered as satisfactorily meeting the specification requirements. Three solutions in terms of the number of chargers and their capacity are included.

3.5 In some cases specialized equipment requires power at a voltage different from the -48V dc central office battery. DC-DC converters can be supplied at ±24V dc, ±48V dc, ±130V dc and other values. These other voltages are used to supply radio and carrier equipment operated at -24 volts, coin collect circuits at ±130 volts and other equipment. The power required by the dc-dc converters must be included in the total load to be carried by the central office dc power system.

3.6 When Automatic Number Identification is installed as a separate equipment system in a central office, the additional current drain on the dc supply is calculated as follows:

Two amperes for the common equipment, and 0.3 amperes for each interoffice trunk associated with the ANI equipment.

3.7 It should be kept in mind that the calculation methods shown in this section are to provide estimates only. Engineering judgment must be used for each individual application. It is, therefore, recommended that the manufacturer of the system be consulted for specific applications.

4. LONG-TERM COST CONSIDERATIONS

4.1 The long-term cost of supplying power to central office equipment (switching and transmission equipment) can represent a significant expenditure for the operating telephone company. The costs for power are high because:

Switch is operated continuously.
Power is required at each COE location.
Power is required continuously for air conditioning system.
Equipment is added during service life of COE.
Cost per kwh continues to increase.

The factors other than power that must be considered in evaluating COE are beyond the scope of this section.

4.2 The cost of power supplied by an emergency engine generator, during an interruption to the commercial ac system, can be expected to be high. The frequency and duration of interruptions to the commercial ac supply may require extended operation time of the emergency generator. Efforts to encourage the improvement in reliability of the commercial ac system should be continued to reduce the running time on the emergency generator.

Figure 1 GTE, GTD NO. 5 EAX

DC DRAIN

1. Number of Lines __________ X 0.036 = __________ Amps

2. Add 85 Amps ____85____ Amps

3. Customer Drain __________ Amps

4. Total DC Drain (1 + 2 + 3) __________ Amps

HEAT DISSIPATION

Heat Dissipation (Watts) = 50.019 X Total DC Drain________

= __________ Watts

EXAMPLE

Figure 1 GTE, GTD NO. 5 EAX

1,000 Lines, 3.2 CCS/L

DC DRAIN

1. Number of Lines 1,000 X 0.036 = 36 Amps
2. Add 85 Amps 85 Amps
3. Customer Drain 20 Amps
4. Total DC Drain (1 + 2 + 3) 141 Amps

HEAT DISSIPATION

Heat Dissipation (Watts) = 50.019 X Total DC Drain 141

= 7,053 Watts

Figure 2 ITT 1210/32, 1210/64

DC DRAIN

1210 HOST

____________	Lines at 3 CCS X .032	=	____________	Amps
____________	Lines at 4 CCS X .035	=	____________	Amps
____________	Lines at 5 CCS X .038	=	____________	Amps
	Add 60 Amps	=	60	Amps
	Add Customer DC Requirements	=	____________	Amps
	Total DC Drain	=	____________	Amps

1210 REMOTE LINE SWITCH

____________	Lines at 3 CCS X .026	=	____________	Amps
____________	Lines at 4 CCS X .030	=	____________	Amps
____________	Lines at 5 CCS X .034	=	____________	Amps
	Add 7 Amps	=	7	Amps
	Add Customer DC Requirements	=	____________	Amps
	Total DC Drain	=	____________	Amps

1210 REMOTE SWITCHING UNIT

____________	Lines at 3 CCS X .033	=	____________	Amps
____________	Lines at 4 CCS X .036	=	____________	Amps
____________	Lines at 5 CCS X .039	=	____________	Amps
	Add 22 Amps	=	22	Amps
	Add Customer DC Requirements	=	____________	Amps
	Total DC Drain	=	____________	Amps

HEAT DISSIPATION

Total DC Drain X 51.8 Volts	=	____________	Watts

EXAMPLE

Figure 2 ITT 1210/32, 1210/64

DC DRAIN

1210 HOST   1,000 Lines

1,000	Lines at 3 CCS X .032 =	32	Amps
	Lines at 4 CCS X .035 =		Amps
	Lines at 5 CCS X .038 =		Amps
	Add 60 Amps =	60	Amps
	Add Customer DC Requirements =		Amps
	Total DC Drain =	92	Amps

1210 REMOTE LINE SWITCH   2,100 Lines

2,100	Lines at 3 CCS X .026 =	55	Amps
	Lines at 4 CCS X .030 =		Amps
	Lines at 5 CCS X .034 =		Amps
	Add 7 Amps =	7	Amps
	Add Customer DC Requirements =		Amps
	Total DC Drain =	62	Amps

1210 REMOTE SWITCHING UNIT   6,000 Lines

6,000	Lines at 3 CCS X .033 =	198	Amps
	Lines at 4 CCS X .036 =		Amps
	Lines at 5 CCS X .039 =		Amps
	Add 22 Amps =	22	Amps
	Add Customer DC Requirements =		Amps
	Total DC Drain =	220	Amps

HEAT DISSIPATION

Total DC Drain X 51.8 Volts = 92 x 51.8 = 4766 Watts

Figure 3 NEC AMERICA NEAX-61K

DC DRAIN

	Quantity	Multiply By	Amps
Idle Switch Drain			50
Time Switch Frames (1)	____	24	____
Digital Transmission Interface (2)	____	1.3	____
Line & Trunk Frames (3)	____	14	____
Analog Trunks	____	0.02	____
Total Busy Hour Traffic (CCS)	____	0.001	____
Customer Drain			____
Total DC Drain			____

NOTES:

(1) 1 per 2880 ports.

(2) 1 per 5 T1 span lines.

(3) 1 per 720 lines or 1 per 360 lines + 144 analog trunks, typical. Maximum 16 modules.

HEAT DISSIPATION

Heat Dissipation (Watts) = 52.7 X DC Drain ____________

= ____________ Watts

EXAMPLE

Figure 3 NEC AMERICA NEAX-61K

1,000 Lines, 50 Digital Trunks, 50 Analog Trunks, 3.2 CCS/L

DC DRAIN

	Quantity	Multiply By	Amps
Idle Switch Drain			50
Time Switch Frames(1)	1	24	24
Digital Transmission Interface(2)	1	1.3	1.3
Line & Trunk Frames(3)	2	14	28
Analog Trunks	50	0.02	1
Total Busy Hour Traffic (CCS)	3,200	0.001	3.2
Customer Drain			20
Total DC Drain			127.5

NOTES:

(1) 1 per 2880 ports.

(2) 1 per 5 T1 span lines.

(3) 1 per 720 lines or 1 per 360 lines + 144 analog trunks, typical. Maximum 16 modules.

HEAT DISSIPATION

Heat Dissipation (Watts) = 52.7 X DC Drain 127.5

= 6,719 Watts

Figure 4-1 NORTHERN TELECOM DMS-100

DC DRAIN

1.	Basic	51.5
	CC Frame E/W 4 Memory Shelves I/O Frame E/W 2 Disk + 1 Mag Tape	
2.	No. of PDC ______ X 6.5 Amps	______
3.	LAMA or CAMA, 10 Amps	______
4.	Combined Network ______ X 24	______
5.	DCM's ______ X 2.28	______
6.	MTM's ______ + TM's ______ = ______ X 1.8	______
7.	Line Circuits	
	Basic Drain per Line: No. of Lines X .014	______
	Active Drain per Line: No. of Lines X .0012 ______ X ______ CCS/L:	______
	Sub Total	______

Additional Drains ______	______
Customer Drains ______	______
DMS Current Total	______

CC - Central Control
PDC - Power Distribution Center
DCM - Digital Carrier Module
MTM - Maintenance Trunk Module
TM - Trunk Module, Analog Trunks

EXAMPLE

Figure 4-1 NORTHERN TELECOM DMS-100

1,000 Lines, 50 Digital Trunks, 50 Analog Trunks, 3.2 CCS/L

DC DRAIN

1.	Basic	51.5
	CC Frame E/W 4 Memory Shelves I/O Frame E/W 2 Disk + 1 Mag Tape	
2.	No. of PDC 1 X 6.5 Amps	6.5
3.	LAMA or CAMA, 10 Amps	-
4.	Combined Network 1 X 24	24.0
5.	DCM's 1 X 2.28	2.28
6.	MTM's 4 + TM's 1 = 5 X 1.8	9.0
7.	Line Circuits	
	Basic Drain per Line: No. of Lines X .014	14.0
	Active Drain per Line: No. of Lines X .0012 1.2 X 3.2 CCS/L:	3.84
	Sub Total	111.12
	Additional Drains -	-
	Customer Drains 20	20
	DMS Current Total	131.12

CC - Central Control
PDC - Power Distribution Center
DCM - Digital Carrier Module
MTM - Maintenance Trunk Module
TM - Trunk Module, Analog Trunks

Figure 4-2 NORTHERN TELECOM DMS-100

HEAT DISSIPATION

Type of Frame	Quantity	Heat Dissipation Per Frame (Watts/Hr)	Total Heat Dissipation
Central Control Complex	______	1716	______
Input/Output Frame e/w 1 Mag Tape and 2 Disks	______	566	______
Miscellaneous Equipment Frame	______	220	______
Network Module Frame (Combined)	______	1380	______
Trunk Module Equipment Frame e/w 1 Maintenance Trunk Module and 4 Analog Trunk Modules (Maximum)	______	565	______
Power Distribution Center	______	200	______
Line Module Equipment Frame (2-Bay)	______	1100	______
Digital Carrier Equipment Frame	______	584	______
Total Watts/Hour			______

EXAMPLE

Figure 4-2 NORTHERN TELECOM DMS-100

1,000 Lines, 50 Digital Trunks, 50 Analog Trunks, 3.2 CCS/L

HEAT DISSIPATION

Type of Frame	Quantity	Heat Dissipation Per Frame (Watts/Hr)	Total Heat Dissipation
Central Control Complex	1	1716	1716
Input/Output Frame e/w 1 Mag Tape and 2 Disks	1	566	566
Miscellaneous Equipment Frame	1	220	220
Network Module Frame (Combined)	1	1380	1380
Trunk Module Equipment Frame e/w 1 Maintenance Trunk Module and 4 Analog Trunk Modules (Maximum)	2	565	1130
Power Distribution Center	1	200	200
Line Module Equipment Frame (2-Bay)	1	1100	1100
Digital Carrier Equipment Frame	1	584	584
Total Watts/Hour			6896

Figure 4-3 NORTHERN TELECOM DMS-10, DMS-10M

DC DRAIN

1. Common Equipment ________Amps

   1 Group System = 20 Amps
   2 Group System = 30 Amps
   3 Group System = 40 Amps
   4 Group System = 50 Amps

2. Peripheral Equipment ________Amps

   Lines _______ X 0.02 = _______Amps

   *DCM Shelves _______ X 4 = _______Amps
   144 (24 X 6) Digital Trunks

   *SCM Shelves _______ X 4.5 = _______Amps
   252 Line RCT Interface (2 Spans)

   *OCM Shelves _______ X 4.5 = _______Amps
   420 Line REM Interface (4 Spans)

   *Optional Equipment

3. Customer Drain ________Amps

   Total DC Drain ________Amps

HEAT DISSIPATION

Total DC Drain ________ X 51.3 = ________Watts

DCM - Digital Carrier Module
SCM - Subscriber Carrier Module
OCM - Office Carrier Module
RCT - Remote Concentrator Terminal (DMS-1)
REM - Remote Equipment Module (Remote DMS-10)

EXAMPLE

Figure 4-3 NORTHERN TELECOM DMS-10, DMS-10M

DMS-10: 1,000 Lines, 144 Trunks, 1 RCT, 1 REM, 3.2 CCS/L

DC DRAIN

1. Common Equipment ___20___ Amps

1 Group System = 20 Amps
2 Group System = 30 Amps
3 Group System = 40 Amps
4 Group System = 50 Amps

2. Peripheral Equipment ___33___ Amps

Lines ___1,000___ X 0.02 = ___20___ Amps

*DCM Shelves ___1___ X 4 = ___4___ Amps
144 (24 X 6) Digital Trunks

*SCM Shelves ___1___ X 4.5 = ___4.5___ Amps
252 Line RCT Interface (2 Spans)

*OCM Shelves ___1___ X 4.5 = ___4.5___ Amps
420 Line REM Interface (4 Spans)

*Optional Equipment

3. Customer Drain ___-___ Amps

Total DC Drain ___53___ Amps

HEAT DISSIPATION

Total DC Drain ___53___ X 51.3 = ___2,719___ Watts

DCM - Digital Carrier Module
SCM - Subscriber Carrier Module
OCM - Office Carrier Module
RCT - Remote Concentrator Terminal (DMS-1)
REM - Remote Equipment Module (Remote DMS-10)

EXAMPLE

Figure 4-3 NORTHERN TELECOM DMS-10, DMS-10M

DMS-10M: 600 Lines, 144 Trunks, 1 RCT, 1 REM, 3.2 CCS/L

DC DRAIN

1. Common Equipment ___20___ Amps

1 Group System = 20 Amps
2 Group System = 30 Amps
3 Group System = 40 Amps
4 Group System = 50 Amps

2. Peripheral Equipment ___25___ Amps

Lines ___600___ X 0.02 = ___12___ Amps

*DCM Shelves ___1___ X 4 = ___4___ Amps
144 (24 X 6) Digital Trunks

*SCM Shelves ___1___ X 4.5 = ___4.5___ Amps
252 Line RCT Interface (2 Spans)

*OCM Shelves ___1___ X 4.5 = ___4.5___ Amps
420 Line REM Interface (4 Spans)

*Optional Equipment

3. Customer Drain ___-___ Amps

Total DC Drain ___45___ Amps

HEAT DISSIPATION

Total DC Drain ___45___ X 51.3 = ___2,309___ Watts

DCM - Digital Carrier Module
SCM - Subscriber Carrier Module
OCM - Office Carrier Module
RCT - Remote Concentrator Terminal (DMS-1)
REM - Remote Equipment Module (Remote DMS-10)

Figure 5 STROMBERG-CARLSON DCO

DC DRAIN

Equipment	Quantity	Multiply By	Amps
Lines	____	0.0045 X CCS/Line	____
Lines	____	0.0016	____
Line Groups (90 Lines)*	____	1.3	____
Line Switch (1080 Lines)*	____	7.1	____
Tl Group (8 Spans)	____	1.3	____
Tl Spans	____	0.37	____
Analog Trunks	____	0.05	____
Matrix (1000 Lines)*	____	1.4	____
Common (1st 8000 Lines)	1	19.7	19.7
Each Add'l 8000 Lines	____	15.4	____
Add	1	9.6	9.6
AMA	____	6.7	____
		Customer Drain	____
		Total DC Drain	____

(*) Round to next higher integer.

HEAT DISSIPATION (WATTS) = 55.7 X TOTAL DC DRAIN = ______ WATTS

EXAMPLE

Figure 5 STROMBERG-CARLSON DCO

1,000 Lines

DC DRAIN

Equipment	Quantity	Multiply By	Amps
Lines	1,000	0.0045 X CCS/Line (3.2)	14.4
Lines	1,000	0.0016	1.6
Line Groups (90 Lines)*	12	1.3	15.6
Line Switch (1080 Lines)*	1	7.1	7.1
T1 Group (8 Spans)	1	1.3	1.3
T1 Spans	5	0.37	1.9
Analog Trunks		0.05	
Matrix (1000 Lines)*	1	1.4	1.4
Common (1st 8000 Lines)	1	19.7	19.7
Each Add'l 8000 Lines		15.4	
Add	1	9.6	9.6
AMA		6.7	
		Customer Drain	
		Total DC Drain	72.6

(*) Round to next higher integer.

HEAT DISSIPATION (WATTS) = 55.7 X TOTAL DC DRAIN = 4,044 WATTS

Figure 6 CIT-ALCATEL E10-FIVE

Equipment	Quantity	Multiplier	Watts
PCU (Peripheral Control Unit)	____	123.7	____
TCU (Telephony Control Unit)	____	97.2	____
TCU Shelves	____	11.4	____
Alarm:			
Subsystem	____	57.2	____
No. of Frames	____	5.4	____
D120 (Disc Drive)	____	145	____
Matrix (RCX), 4 Planes:			
32 X 32 Ports	____	263	____
64 X 64 Ports	____	576	____
96 X 96 Ports	____	949	____
128 X 128 Ports	____	1380	____
RIT:			
System Bus (Groups of 8)	____	2.15	____
Clock	____	45.8	____
Conference:			
Base	____	68.6	____
Bridges (Groups of 16)	____	11.4	____
Cards	____	10.4	____
AUMU (DTMF/MF Aux.)	____	89.4	____
Recorded Announcement:			
GTUANN (Shelf)	____	11.2	____
ARATU (Card)	____	11.2	____
TAA, Test Access:			
Base	____	11.2	____
1/2 GTU (Group Terminal Unit)	____	33.6	____
Select Switch Cards	____	11.2	____
Trunks:			
DT24 Shelves	____	11.2	____
DT24 Terminal Unit	____	44.8	____
Lines:			
No.	____	1.1	____
No. X CCS/Line	____	.09	____
GTU's	____	29.5	____
GTU's X CCS/Line	____	.09	____
Subtotal			____
Other Equipment			____
TOTAL (Watts)			____

Total Amps (Watts ÷ 52) = ____________ Amperes

Heat Dissipation (Watts X 3.41) = ____________ BTU/Hour

EXAMPLE

Figure 6 CIT-ALCATEL E10-FIVE

3,000 Lines @ 3.2 CCS/L

Equipment	Quantity	Multiplier	Watts
PCU (Peripheral Control Unit)	2	123.7	247.4
TCU (Telephony Control Unit)	7	97.2	680.4
TCU Shelves	3	11.4	34.2
Alarm:			
Subsystem	1	57.2	57.2
No. of Frames	18	5.4	97.2
D120 (Disc Drive)	2	145	290
Matrix (RCX), 4 Planes:			
32 X 32 Ports		263	
64 X 64 Ports	1	576	576
96 X 96 Ports		949	
128 X 128 Ports		1380	
RIT:			
System Bus (Groups of 8)	17	2.15	36.6
Clock	1	45.8	45.8
Conference:			
Base	1	68.6	68.6
Bridges (Groups of 16)	3	11.4	34.2
Cards	3	10.4	31.2
AUMU (DTMF/MF Aux.)	1	89.4	89.4
Recorded Announcement:			
GTUANN (Shelf)	1	11.2	11.2
ARATU (Card)	3	11.2	33.6
TAA, Test Access:			
Base	1	11.2	11.2
1/2 GTU (Group Terminal Unit)	1	33.6	33.6
Select Switch Cards	3	11.2	33.6
Trunks:			
DT24 Shelves	4	11.2	44.8
DT24 Terminal Unit	13	44.8	582.4
Lines:			
No.	3,000	1.1	3300
No. X CCS/Line	3,000 x 3.2	.09	864
GTU's	19	29.5	560.5
GTU's X CCS/Line	19 x 3.2	.09	5.5
Subtotal			7768.6
Other Equipment			-
TOTAL (Watts)			7768.6

Total Amps (Watts ÷ 52) = 150 Amperes

Heat Dissipation (Watts X 3.41) = 26,491 BTU/Hour

Figure 7 WESTERN ELECTRIC 5ESS

	Quantity	Multiply By	Total
Up to 83,400 CCS (≈ 26,000 Lines @ 3.2 CCS):			
Base		110	
CCS		.0087	
Total Amps			______
83,400 CCS to 200,000,000:			
Base		201	
CCS		.0076	
Total Amps			______
Heat Dissipation -			
Up to 15,000 Lines:			
Base		4,050	
No. of Lines		1.86	
Total Watts			______
15,000 to 40,000 Lines:			
Base		18,860	
No. of Lines		0.87	
Total Watts			______

EXAMPLE

Figure 7 WESTERN ELECTRIC 5ESS

500 Lines @ 3.2 CCS

	Quantity	Multiply By	Total
Up to 83,400 CCS (≈ 26,000 Lines @ 3.2 CCS):			
Base	1	110	110
CCS	500 @ 3.2	.0087	14
Total Amps			124
83,400 CCS to 200,000,000:			
Base		201	
CCS		.0076	
Total Amps			______
Heat Dissipation -			
Up to 15,000 Lines:			
Base	1	4,050	4,050
No. of Lines	500	1.86	930
Total Watts			4,980
15,000 to 40,000 Lines:			
Base		18,860	
No. of Lines		0.87	
Total Watts			______

EXAMPLE

Figure 7 WESTERN ELECTRIC 5ESS

5,000 Lines @ 3.2 CCS

	Quantity	Multiply By	Total
Up to 83,400 CCS (≈ 26,000 Lines @ 3.2 CCS):			
Base	*1*	110	*110*
CCS	*5,000 @ 3.2*	.0087	*139*
Total Amps			*249*
83,400 CCS to 200,000,000:			
Base		201	
CCS		.0076	
Total Amps			
Heat Dissipation -			
Up to 15,000 Lines:			
Base	*1*	4,050	*4,050*
No. of Lines	*5,000*	1.86	*9,300*
Total Watts			*13,350*
15,000 to 40,000 Lines:			
Base		18,860	
No. of Lines		0.87	
Total Watts			

Figure 8 TRANSMISSION ELECTRONICS CURRENT DRAIN

Equipment	48-Volt Battery Drain Amperes Per Unit
Loop Extenders	0.075
VF Repeaters	
1. Negative Impedance	0.035
2. Hybrid	0.035
3. Automatic Gain Control	0.080
4. Loop Extender/Repeater Combination	0.100
5. Automatic Gain Control Loop Extender/Repeater Combination	0.200
Carrier Systems	
1. D1 or D2	3.0
2. D3 (24 Channel)	0.7
3. D4 (24 Channel)	0.35
4. T1 Span Line	0.6
5. N1 or N2	1.8
6. N3 (24 Channel)	3.0
7. Station Carrier (1 Channel)	0.04
8. Station Carrier (Multi Channel) Per Chan.	0.1
9. Pair Gain Devices (Switching) (See Notes 1 & 2 for Office End)	
Echo Canceller	
1. VF (1 Channel)	0.075
2. Digital (24 Channel)	1.7
Remote Office Line Test	
1. Test Console (110V ac, 0.4A)	0.7
2. Remote Terminal	0.7

Maintenance and Control Center	120V, 60Hz Load Amperes Per Unit (Note 3)
Colocated with COE:	
Video Display (CRT)	0.5
Printer (1200 Band)	0.5
Remotely Located:	
Teletypwriter (e/w 300 Band Modem)	0.35

Notes:

1. Refer to the manufacturers' data sheets for specific current drain requirements.
2. Line concentrators or other pair gain devices incorporating switching functions are generally locally powered at remote site.
3. Voltage: 95 to 128V ac - Frequency: 48 to 65Hz

Figure 9 ESTIMATING TELEPHONE BATTERY SIZES

Number of Hours Reserve	8-Hour Ampere Hour Capacity Required for Each Ampere of Load — Final Cell Voltages 1.75	1.80	1.85	1.88	1.90	1.95
1	2.2	2.5	2.8	3.2	3.5	5.0
2	3.2	3.4	3.7	4.3	4.7	6.2
3	4.0	4.3	4.7	5.2	5.6	7.5
4	4.9	5.1	5.6	6.1	6.5	8.6
5	5.7	6.0	6.5	7.0	7.4	9.6
6	6.5	6.8	7.3	7.8	8.2	10.6
7	7.2	7.6	8.1	8.7	9.1	11.6
8	8.0	8.3	8.9	9.6	10.0	12.6
9	8.8	9.1	9.6	10.4	10.9	13.7
10	9.5	9.9	10.4	11.4	12.0	15.0
Voltage (24 Cells).	42	43.2	44.4	45.1	45.6	46.8

EXAMPLES:

1. Required: The capacity of a 24-cell battery to handle a 3-hour load of 34.0 amperes to a limiting voltage of 45 volts.

$$\frac{45}{24} = 1.88$$

From the above chart, each ampere of load requires 5.2 ampere hours of capacity.

Total capacity required = 5.2 X 34.0 = 177 ampere hours. Select the next larger catalog size.

2. Calculate the ampere hour reserve of an existing 24-cell, 480-ampere hour battery with the load increased to 69 amperes to a final voltage of 1.88 volts.

Formula: $K = \frac{B}{C}$

Where

K = 8-hour ampere hour capacity required for each ampere of load.
B = Ampere hour capacity of existing battery.
C = Actual current drain of all equipment.

$$K = \frac{480}{69} = 7.0$$

On the chart, locate 7.0 in the 1.88-volt column and to the left read 5 hours' reserve.

Figure 10 CHARGER CAPACITY

The battery charger must supply power for operation of the COE. Its capacity should be great enough to carry the entire load, including peak power requirements, to avoid taking power from the battery. Additional capacity is required to recharge the battery after a power service interruption.

EXAMPLE:

Drain	60 Amps
Battery Discharged for 3 Hours and Recharged in 12 Hours $3 \times 60 \div 12 =$	15 Amps
Total Charger Capacity	75 Amps

The charger capacity sizes commercially available include:

2 @ 75 Amps	- Traditional arrangement with load sharing between the two chargers.
3 @ 50 Amps	- Potential cost saving over buying two larger units. Potential operating cost saving by operating only two units.
1 @ 75 Amps	- Lowest capital cost, MTBF of approximately 20 years may permit significant capital recovery and operation costs during system life span.

APPENDIX A

POWER REQUIREMENTS FOR DIRECT CONTROL AND COMMON CONTROL ELECTROMECHANICAL SWITCHING SYSTEMS

1. GENERAL

1.1 The power requirements described in this appendix are for the older electromechanical switching systems that are still in use. These computations may be used in estimating power requirements associated with additions or rearrangements of the existing switching systems.

2. CALCULATIONS

2.1 Attached Exhibits A through N outline the procedures to be followed in calculating the power requirements (charger and battery) for dial central office equipment of the following types:

EXHIBIT A - Switch Type Equipment as Manufactured by Automatic Electric, ITT and Stromberg-Carlson

North Electric NX-2A Crossbar Equipment

Leich All-Relay Equipment

EXHIBIT B - Stromberg-Carlson ESC-1

EXHIBIT C - Stromberg-Carlson ESC-3

EXHIBIT D - ITT A-1

EXHIBIT E - ITT PC-32B

EXHIBIT F - Automatic Electric CXP-5

EXHIBIT G - Automatic Electric No. 1 EAX

EXHIBIT H - North Electric NX-1D

EXHIBIT I - North Electric NX-1E

EXHIBIT J - Northern Electric SP-1

EXHIBIT K - Nippon Electric NC-23, NC-400, and NC-460

EXHIBIT L - Stromberg-Carlson Toll Ticketing

EXHIBIT M - ITT Tel Touch

EXHIBIT N - Stromberg-Carlson Tone Dialing

EXHIBIT A

Busy Hour Current Drain Calculations
for Various Switchboards
(All Values in Amperes)

Type of Drain	Switch Type (XY, SxS)	North NX-2A Crossbar	Leich Dial (Linefinder-Selector-Connector)
Equipment Holding (See Note 1)	0.72/T.C.U.	0.6/T.C.U. (See Note 5)	1.17/T.C.U.
General Operating	0-100 Lines 1.0 101-200 Lines 1.5 201-400 Lines 2.0 401+ Lines 3.0	1st Line Group 1.0 Each Add'l. Line Group 0.5	4.0
Additional Equipment	-	-	0.3/100 Lines
Manual Toll Board	2.0/Position	2.0/Position	2.0/Position
DC Operated Ringing Generator (See Note 2)	0-100 Lines 2.0 101+ Lines 3.0	3.0	0-100 Lines 2.0 101+ Lines 3.0
Interoffice Trunk Circuit	0.35/2W & 1W Incoming Trunk 0.30/1W Outgoing Trunk (See Note 4)	0.25/Trunk (See Note 4)	1.08/T.T.C.U. (See Note 6)
Special Equipment (See Note 3)	As Required	As Required	As Required

EXHIBIT A NOTES

Notes:

1. A "Time Call" Unit is calculated as follows:

$$T.C.U. = \frac{\text{Unit Calls Per Line X Total Number of Lines}}{36}$$

2. When the primary ringing generator is ac operated, no provision need be made in the charger capacity to handle the standby ringing generator. The generator drain must be included when calculating battery capacity.

3. This includes the power requirements for carrier, loop extenders, voice frequency repeaters, ANI, etc. Where special equipment is normally ac operated and requires dc only for standby, no provision need be made in the charger capacity. The drain must be included when calculating battery capacity.

4. If the number of interoffice trunk groups equals four or more for switch type equipment (more than four for NX-2A), it is satisfactory to use three-quarters (3/4) of the total trunk circuit current drain.

5. When conversation time disconnect is equipped, add 0.2 amperes per T.C.U. to the holding drain.

6. A Trunk "Time Call" Unit (T.T.C.U.) is calculated as follows:

$$T.T.C.U. = \frac{\text{Unit Call Capacity of Trunk Group (P.01)}}{36}$$

7. If the total busy hour drain is not in excess of ten percent above a standard charger size, that charger may be used. If the above total exceeds ten percent, the next larger standard charger size should be used.

Examples:

The following office will be used in each of these examples. Assume a 360 line office has a calling rate of 2.0 unit calls per line with 6 two-way toll trunks and 8 two-way EAS trunks terminated on incoming selectors. Also assume that dc operated carrier and VF repeaters have a drain of 3 amperes. The primary ringing generator is ac operated in Examples 1 and 3.

$$T.C.U. = \frac{\text{2.0 UC/L X 360 Lines}}{36} = 20$$

Exhibit A Examples Continued

1. Switch Type Equipment:

Equipment Holding Drain = 20 X 0.72	= 14.4
General Operating Drain	= 2.0
No Toll Board	-
Primary Ringing Generator - AC Operated	-
Trunk Drain = 14 X 0.35	= 4.9
Special Equipment Drain	= 3.0
Total Drain	24.3 Amps

2. North NX-2A Crossbar:

Equipment Holding Drain = 20 X 0.6	= 12.0
General Operating Drain = 1.0 + $\frac{270}{90}$ X 0.5	= 2.5
Primary Ringing Generator - DC Operated	= 3.0
Trunk Drain = 14 X 0.25	= 3.5
Special Equipment Drain	= 3.0
Total Drain	24.0 Amps

3. Leich Dial:

Equipment Holding Drain = 20 X 1.17	= 23.4
General Operating Drain	= 4.0
Additional Equipment Drain = $\frac{360}{100}$ X 0.3	= 1.1
Primary Ringing Generator - AC Operated	-
Trunk Drain:	
6 Toll Trunks (P.01) will handle 64.4 UC	
Toll Group Drain = $\frac{64.4}{36}$ X 1.08	= 1.9
8 EAS Trunks (P.01) will handle 105 UC	
EAS Group Drain = $\frac{105}{36}$ X 1.08	= 3.2
Special Equipment Drain	= 3.0
Total Drain	36.6 Amps

The above total drains should be used in determining charger size. For calculating battery capacity three amperes should be added to Examples 1 and 3 to account for ringing generator current drain.

EXHIBIT B

Stromberg-Carlson ESC-1

Equipment	48-Volt Drain No. of Units	48-Volt Drain Amperes Per Unit	48-Volt Drain Total Current	8-Volt Drain No. of Units	8-Volt Drain Amperes Per Unit	8-Volt Drain Total Current
Common Control (Local) Cabinets (CCL) [1]	-	-	-		16	
4-Stage Trunk Link Network(TLN)		93		-	-	-
6-Stage Trunk Link Network(TLN)		102		-	-	-
Common Control(Trunk) Cabinets (CCT)		10			7	
Register Sender Cabinets(RS)		1			10	
Auxiliary Register Sender Cabinets (RSA)		3			10	
Translator Cabinets	-	5	5	-	42	42
TLN Cabinet(Control) (TLC)	1	10	10	1	8	8
Supervisory Cabinet (CSR)	1	6	6	1	12	12
Powerboard (1 Frequency)		7		-	-	-
(2 Frequencies)		9		-	-	-
(4 Frequencies)		15		-	-	-
Automatic Call Generator	1	3	3	1	5	5
DC-DC Converter (-24v) [2]		11		-	-	-
Loop Extender Power Supply[2]		4		-	-	-
Pre-Pay Power Supply		2		-	-	-
Tandem Trunks[3]		.015		-	-	-
Recording Trunks		Note 4			Note 4	
LAMA Cabinets		24			16	
CAMA Cabinets		13			7	
Maintenance Test Console		5			2	
Registers	-	-	-		1	
Senders	-	-	-		1	
Customer Drain		As Req'd.			As Req'd.	
Total Drain		48-Volt			8-Volt	

EXHIBIT B NOTES

Notes:

1. When the number of line units are odd, round off to next even number.

2. Do not include drain for redundant equipment.

3. Incoming Tandem Trunk CCS X .015 = Total Current

4.

Recording Trunks Equipped	Drain in Amperes 48-Volt	Drain in Amperes 8-Volt
1 - 50	7	57
51 - 100	8	68
101 - 150	9	79
151 - 200	10	90
201 - 250	11	102
251 - 300	13	113
301 - 350	14	124
351 - 400	15	136

5. When SCAMA-LAMA ticketing is required, the following drains should be added:

Ultimate DDD Trunk Capacity	8V Drain	48V Drain
50	57 amps	7 amps
100	68	8
150	79	9
200	90	10
250	111	11
300	113	13
350	124	14
400	136	15

6. When CAMA is required, the following drains should be added:

48V Drain - 24 amps
8V Drain - 16 amps

EXAMPLE

Stromberg-Carlson ESC-1
1500 Lines
5000 Directory Numbers

	48-Volt Drain			8-Volt Drain		
Equipment	No. of Units	Amperes Per Unit	Total Current	No. of Units	Amperes Per Unit	Total Current
Common Control (Local) Cabinets (CCL) [1]	-	-	-	1	16	16
4-Stage Trunk Link Network(TLN)	1	93	93	-	-	-
6-Stage Trunk Link Network(TLN)		102		-	-	-
Common Control(Trunk) Cabinets (CCT)	1	10	10	1	7	7
Register Sender Cabinets(RS)	1	1	1	1	10	10
Auxiliary Register Sender Cabinets (RSA)		3			10	
Translator Cabinets	-	5	5	-	42	42
TLN Cabinet(Control) (TLC)	1	10	10	1	8	8
Supervisory Cabinet (CSR)	1	6	6	1	12	12
Powerboard (1 Frequency)		7		-	-	-
(2 Frequencies)		9		-	-	-
(4 Frequencies)	1	15	15	-	-	-
Automatic Call Generator	1	3	3	1	5	5
DC-DC Converter (-24v) [2]	1	11	11	-	-	-
Loop Extender Power Supply[2]	2	4	8	-	-	-
Pre-Pay Power Supply	2	2	4	-	-	-
Tandem Trunks[3]	100 ccs	.015	1.5	-	-	-
Recording Trunks		Note 4			Note 4	
LAMA Cabinets		24			16	
CAMA Cabinets	1	13	13	1	7	7
Maintenance Test Console	1	5	5	1	2	2
Registers	-	-	-	80	1	80
Senders	-	-	-	20	1	20
Customer Drain		As Req'd.	15		As Req'd.	
Total Drain		48-Volt	200.5		8-Volt	209

EXHIBIT C

Stromberg-Carlson ESC-3

	48-Volt Drain			8-Volt Drain		
Equipment	No. of Units	Amperes Per Unit	Total Current	No. of Units	Amperes Per Unit	Total Current
Common Control Cabinet		23.8			48.6	
Translator		4.2			77.7	
Test Cabinet		3.7			10.0	
Power Supervisory		24.7		-	-	-
Register Common	-	-	-		12.0	
Call Generator		0.6			4.8	
MF Current Supply		2.8		-	-	-
Each Register (Max. 48)		0.2			1.3	
Each Sender (Max. 20)	-	-	-		1.0	
Each Tone Dial Detector		0.43		-	-	-
Each 1,000 Directory Numbers	-	-	-		5.6	
Each Toll MF Detector		0.5		-	-	-
+48v Message Registration		3.5		-	-	-
+48v Paystation Coin Control		1.5		-	-	-
Aux. Common Control Cabinet		6.8			16.6	
Aux. Line/Trunk Marker		4.2			14.0	
Each Line Unit (1350 CCS)		20.3		-	-	-
Each Line Unit (2000 CCS)		30.0		-	-	-
Loop Extender Power Supply (3 amps per 49 loops)		3.0		-	-	-
Customer Drain		As Req'd.			As Req'd.	
Total Drain	48-Volt			8-Volt		

EXAMPLE

Stromberg-Carlson ESC-3
500 Lines
1000 Directory Numbers

Equipment	48-Volt Drain No. of Units	48-Volt Drain Amperes Per Unit	48-Volt Drain Total Current	8-Volt Drain No. of Units	8-Volt Drain Amperes Per Unit	8-Volt Drain Total Current
Common Control Cabinet	1	23.8	23.8	1	48.6	48.6
Translator	1	4.2	4.2	1	77.7	77.7
Test Cabinet	1	3.7	3.7	1	10.0	10.0
Power Supervisory	1	24.7	24.7	-	-	-
Register Common	-	-	-	1	12.0	12.0
Call Generator	1	0.6	.6	1	4.8	4.8
MF Current Supply	1	2.8	2.8	-	-	-
Each Register (Max. 48)	8	0.2	1.6	8	1.3	10.4
Each Sender (Max. 20)	-	-	-	5	1.0	5.0
Each Tone Dial Detector		0.43		-	-	-
Each 1,000 Directory Numbers	-	-	-	1	5.6	5.6
Each Toll MF Detector		0.5		-	-	-
+48v Message Registration		3.5		-	-	-
+48v Paystation Coin Control		1.5		-	-	-
Aux. Common Control Cabinet		6.8			16.6	
Aux. Line/Trunk Marker		4.2			14.0	
Each Line Unit (1350 CCS)	1	20.3	20.3	-	-	-
Each Line Unit (2000 CCS)		30.0		-	-	-
Loop Extender Power Supply (3 amps per 49 loops)	1	3.0	3.0	-	-	-
Customer Drain		As Req'd.	10.0		As Req'd.	
Total Drain	48-Volt		94.7	8-Volt		174.1

EXHIBIT D

ITT A-1 Pentaconta

I. Speech Path Drain

CCS (Intraoffice)		x 0.007 =	
CCS (Outgoing)		x 0.007 =	
CCS (Incoming)		x 0.008 =	
		Total	

= Speech Path Drain

II. Register-Sender Drain

	BHC	RHT	BHCx RHT		
Intraoffice Calls				x 0.0008	
Outgoing Calls					
Assistance					
CAMA					
TSPS					
EAS					
Other					
Total Outgoing				x 0.0014 =	
Incoming Calls					
DDD					
EAS					
Other					
Total Incoming				x 0.0008 =	
				Total	

= R-S Drain

BHC = Number of Busy Hour Calls
RHT = Register-Sender Holding Time

Exhibit D - Continued

III. Marker Drain

BHC (Intraoffice)		x 0.0085 =	
BHC (Outgoing)		x 0.0026 =	
BHC (Incoming)		x 0.0057 =	
		Total	

= Marker Drain

IV. Connector Drain

Total Marker Drain		x 0.2 =	

= Connector Drain

V. Customer Equipment Drain

As Required

Total Current Drain equals sum of I through V.

EXHIBIT E

ITT PC-32B

I. Speech Path Drain

CCS (Intraoffice)		x 0.022 =	
CCS (Outgoing)		x 0.017 =	
CCS (Incoming)		x 0.017 =	
		Total	

= Speech Path Drain

II. Register-Sender Drain

	BHC	RHT	BHC x RHT		
Intraoffice Calls				x 0.00014 =	
Outgoing Calls					
Assistance					
CAMA					
TSPS					
EAS					
Other					
Total Outgoing				x 0.00021 =	
Incoming Calls					
DDD					
EAS					
Other					
Total Incoming				x 0.00056 =	
				Total	

= R-S Drain

BHC = Number of Busy Hour Calls
RHT = Register-Sender Holding Time

Exhibit E continued

III. Marker Drain

BHC (Intraoffice)				
BHC (Outgoing)				
BHC (Incoming)				
Total BHC		x 0.0019 =		= Marker Drain

IV. Customer Equipment Drain

As Required

Total Current Drain Equals Sum of I through IV.

ITT A-1 Pentaconta & PC-32B

Example

The following information is used to demonstrate the method used to calculate the current drain of the ITT A-1 and PC-32B systems.

2000 Lines
1.6 CCS/Line Originating

Outgoing Trunk Traffic		
Assistance	200 CCS	67 BHC
CAMA	400 CCS	167 BHC
EAS	800 CCS	533 BHC
Incoming Trunk Traffic		
DDD	600 CCS	250 BHC
EAS	800 CCS	533 BHC
Intraoffice Traffic	1800 CCS	1500 BHC

Register Holding Times	
Assistance	5 Seconds
CAMA	17 Seconds
Outgoing EAS	14 Seconds
DDD	7 Seconds
Incoming EAS	7 Seconds
Intraoffice	14 Seconds

Customer Equipment Drain 40 Amps

EXAMPLE

ITT A-1 Pentaconta

I. Speech Path Drain

CCS (Intraoffice)	1800	x 0.007 =	12.6
CCS (Outgoing)	1400	x 0.007 =	9.8
CCS (Incoming)	1400	x 0.008 =	11.2
		Total	33.6 = Speech Path Drain

II. Register-Sender Drain

	BHC	RHT	BHCx RHT		
Intraoffice Calls	1500	14	21,000	x 0.0008	16.8
Outgoing Calls					
Assistance	67	5	335		
CAMA	167	17	2839		
TSPS					
EAS	533	14	7462		
Other					
Total Outgoing	767		10,636	x 0.0014 =	14.9
Incoming Calls					
DDD	250	7	1750		
EAS	533	7	3731		
Other					
Total Incoming	783		5481	x 0.0008 =	4.4
				Total	36.1 = R-S Drain

BHC = Number of Busy Hour Calls
RHT = Register-Sender Holding Time

EXAMPLE - Continued

III. Marker Drain

BHC (Intraoffice)	1500	x 0.0085 =	12.8
BHC (Outgoing)	767	x 0.0026 =	2.0
BHC (Incoming)	783	x 0.0057 =	4.5
		Total	19.3

= Marker Drain

IV. Connector Drain

Total Marker Drain	19.3	x 0.2 =	3.9

= Connector Drain

V. Customer Equipment Drain

As Required 40 AMPS

Total Current Drain equals sum of I through V.

33.6 + 36.1 + 19.3 + 3.9 + 40.0 = 132.9 AMPS

From the above ampere drain it is seen that either two 150 amp chargers or three 75 amp chargers should be provided. For a three-hour reserve, a 660 ampere-hour battery is required. (From Exhibit P, a final cell voltage of 1.85 yields a factor of 4.7 for a three-hour reserve. Therefore, 4.7 X 132.9 = 625 AH. The next larger size is 660 AH.)

EXAMPLE

ITT PC-32B

I. Speech Path Drain

CCS (Intraoffice)	1800	x 0.022 =	39.6
CCS (Outgoing)	1400	x 0.017 =	23.8
CCS (Incoming)	1400	x 0.017 =	23.8
		Total	87.2 = Speech Path Drain

II. Register-Sender Drain

	BHC	RHT	BHC x RHT		
Intraoffice Calls	1500	14	21,000	x 0.00014 =	2.9
Outgoing Calls					
Assistance	67	5	335		
CAMA	167	17	2839		
TSPS					
EAS	533	14	7462		
Other					
Total Outgoing	767		10,636	x 0.00021 =	2.2
Incoming Calls					
DDD	250	7	1750		
EAS	533	7	3731		
Other					
Total Incoming	783		5481	x 0.00056 =	3.1
				Total	8.2 = R-S Drain

BHC = Number of Busy Hour Calls
RHT = Register-Sender Holding Time

EXAMPLE continued

III. Marker Drain

BHC (Intraoffice)	1500			
BHC (Outgoing)	767			
BHC (Incoming)	783			
Total BHC	3050	x 0.0019 =	5.8	= Marker Drain

IV. Customer Equipment Drain

As Required 40 AMPS

Total Current Drain Equals Sum of I through IV.

87.2 + 8.2 + 5.8 + 40.0 = 141.2 AMPS

EXHIBIT F

Automatic Electric CXP-5

Subscriber Lines x CCS/Line =

________ x ________ = ________

Delay Dial Trunks CCS = ________
Local Register-Sender CCS = ________
Non-Delay Dial Trunk Register-Sender CCS = ________

Total CCS = ________

0.037 x Total CCS = Peak BH Drain
0.037 x ________ = ________ (A)

Trunks (See Note)

Type	Number		Drain
1W Incoming DD	________	x 0.30 =	________
1W Incoming NDD	________	x 1.25 =	________
2W DD	________	x 0.15 =	________
2W NDD	________	x 0.62 =	________
CAMA or SATT	________	x 0.14 =	________
Coin Completion	________	x 0.35 =	________

Total Trunk Drain ________ (B)

Note: Do not include 1-way outgoing trunks other than CAMA or SATT.

DD = Delay Dial
NDD = Non-Delay Dial

Common Equipment

Common Control and General Office Drain 6.0
Ringing Generators (5 Freq. 15W-3A, 25W-5A, 50W-13A) ______
(1 Freq. 15W-0.6A, 25W-1A, 50W-1.8A)

Detection Equipment (Type 70A - 4 amps/system) ______
Customer Equipment (Carrier, loop extenders, etc.) ______

Total Common Equipment Drain ______ (C)

Total CXP-5 Drain = 0.8 x [A + B + C]
= 0.8 x ________ = ________

Automatic Electric
CXP-5

Example

The following information is used to demonstrate the method used to calculate the current drain of the Automatic Electric CXP-5 system.

2000 Lines
1.6 CCS/Line Originating
Delay Dial Trunks CCS 1000
Local Register Sender CCS 1800
Non-Delay Dial Trunk Register-Sender CCS 400
10 1W Incoming DD Trunks
5 1W Incoming NDD Trunks
20 2W DD Trunks
5 2W NDD Trunks
15 CAMA Trunks
5 Coin Completion
Ringing Generator - 5 Frequency - 25 Watt
One 70A System
40 amps Customer Equipment

EXAMPLE

Automatic Electric CXP-5

Subscriber Lines x CCS/Line =
2000 x 1.6 = 3200

Delay Dial Trunks CCS = 1000
Local Register-Sender CCS = 1800
Non-Delay Dial Trunk Register-Sender CCS = 400

Total CCS = 6400

0.037 x Total CCS = Peak BH Drain
0.037 x 6400 = 236.8 (A)

Trunks (See Note)

Type	Number		Drain
1W Incoming DD	10	x 0.30 =	3.0
1W Incoming NDD	5	x 1.25 =	6.3
2W DD	20	x 0.15 =	3.0
2W NDD	5	x 0.62 =	3.1
CAMA or SATT	15	x 0.14 =	2.1
Coin Completion	5	x 0.35 =	1.8

Total Trunk Drain 19.3 (B)

Note: Do not include 1-way outgoing trunks other than CAMA or SATT.

DD = Delay Dial
NDD = Non-Delay Dial

Common Equipment

Common Control and General Office Drain	6.0
Ringing Generators (5 Freq. 15W-3A, 25W-5A, 50W-13A) (1 Freq. 15W-0.6A, 25W-1A, 50W-1.6A)	5.0
Detection Equipment (Type 70A - 4 amps/system)	4.0
Customer Equipment (Carrier, loop extenders, etc.)	40.0
Total Common Equipment Drain	55.0 (C)

Total CXP-5 Drain = 0.8 x [A + B + C]
= 0.8 x 311.1 = 248.9

Exhibit G

Automatic Electric No. 1 - EAX

Line Drain

Number of lines x 0.027 amps/line (A)

Trunk Drain

Number of trunks x 0.15 amps/trunks (B)

Busy Hour Drain = A + B = (C)
Peak Busy Hour Drain = 1.33 x C = (D)

Common Control Drain

Up to 15,000 lines - 250 amps
More than 15,000 lines - 510 amps (E)

Customer Equipment Drain

As Required (F)

Total Busy Hour Drain = C + E + F

Total Peak Busy Hour Drain (Power Board) = D + E + F

Example: The following information is used to demonstrate the method for calculating the busy hour current drain of the Automatic Electric No. 1 - EAX:

4000 Lines -- 800 Trunks -- 100 Amps, Customer Equipment Drain

Calculation:

4000 lines x 0.027 amps/line	=	108 amps
800 trunks x 0.15 amps/trunk	=	120 amps
Busy Hour Drain		228 amps

Peak Busy Hour Drain = 1.33 x 228 = 303.2 amps

Common Control Drain = 250 amps
Customer Equipment Drain = 100 amps

Total Busy Hour Drain = 228+250+100 = 578 amps
Total Peak Busy Hour Drain = 303.2+250+100 = 653.2 amps

EXHIBIT H

North Electric NX-1D

Formula 1 for Class 5 offices - includes all trunks:

Average BH Current Drain =
Number of Lines x CCS per line x 0.025 amperes

__________ x __________ x 0.025 = __________

Customer Equipment Drain = __________

Total Drain = __________

Formulae for Class 4/5 offices or Class 5 offices with ticketing:

1. Line Group Drain =
   Number of Lines x CCS per line x 0.014 amperes
   __________ x __________ x 0.014 = __________
2. One-way trunk, excluding intertoll, Drain =
   Trunks CCS x 0.01 amperes
   __________ x 0.01 = __________
3. Two-way, and one-way intertoll, trunk Drain =
   Trunks CCS x 0.0174 amperes
   __________ x 0.0174 = __________
4. Toll Recording Trunk Drain =
   Trunks CCS x 0.05 amperes
   __________ x 0.05 = __________
5. TSD Equipment Drain =
   TSD CCS x 0.015 amperes
   __________ x 0.015 = __________
6. Customer Equipment Drain = __________

Total Drain = 1 + 2 + 3 + 4 + 5 + 6 = __________

Calculating drain for Group Selector, Translator and Number Group:

Group Selector and Translator
1.5 amps per frame

Number Group
1.0 amp per frame

EXHIBIT I

North NX-1E

The current drain for the electromechanical portion of the NX-1E is calculated in the same manner as the NX-1D. To calculate the drain of the electronic part of the NX-1E, the following figures should be used:

Uprights Fully Equipped	Average Drain Per Upright
Receiver-Sender Originating (RSO)	11 amps
RSO - Auxiliary	7
Receiver-Sender Incoming (RSI)	10
Key Call Receiver/MF Receiver (KCR/MFR) (Assume all MFR's)	4
KCR/MFR Auxiliary (Assume all MFR's)	4
KCR/MFR (Assume all KCR's)	6
KCR/MFR Auxiliary (Assume all KCR's)	7
Key Call/MF Receiver Link (MFL)	3
Trunk Register Link (TRL)	6
500-Line Group	Number of Lines x UC/L x 0.0075
3-Stage Group Selector	14
CPU Pair	17
Data Memory	15
Miscellaneous Data Transfer Unit	3
Tape Unit	5

North NX-1D and NX-1E

Example

The following data is used to demonstrate the method used to calculate the current drain of the North NX-1D and the electromechanical portion of the NX-1E. The necessary information to calculate the required drain of the NX-1E electronic circuits is shown in Exhibit I.

Class 5 Office		
2000 Lines		
2.0 CCS/Line Originating		
Customer Equipment Drain	40 Amps	
Class 5 Office with Ticketing		
2000 Lines		
2.0 CCS/Line Originating		
100 Two-Way Intertoll Trunks		2800 CCS
100 Two-Way EAS Trunks		2800 CCS
75 One-Way Toll Completing Trunks		2000 CCS
75 One-Way Intertoll Trunks		2000 CCS
125 Toll Recording Trunks		3600 CCS
12 TSD Positions		1200 CCS
Customer Equipment Drain	40 Amps	

EXAMPLE

North Electric NX-1D

Formula 1 for Class 5 offices - includes all trunks:

Average BH Current Drain =
Number of Lines x CCS per line x 0.025 amperes

2000 x 2.0 x 0.025 = 100
Customer Equipment Drain = 40
Total Drain = 140

Formulae for Class 4/5 offices or Class 5 offices with ticketing:

1. Line Group Drain =
   Number of Lines x CCS per line x 0.014 amperes
   2000 x 2.0 x 0.014 = 56.0
2. One-way trunk, excluding intertoll, Drain =
   Trunks CCS x 0.01 amperes
   2000 x 0.01 = 20.0
3. Two-way, and one-way intertoll, trunk Drain =
   Trunks CCS x 0.0174 amperes
   7600 x 0.0174 = 132.2
4. Toll Recording Trunk Drain =
   Trunks CCS x 0.05 amperes
   3600 x 0.05 = 180.0
5. TSD Equipment Drain =
   TSD CCS x 0.015 amperes
   1200 x 0.015 = 18.0
6. Customer Equipment Drain = 40.0

Total Drain = 1 + 2 + 3 + 4 + 5 + 6 = 446.2

EXHIBIT J

Northern Electric SP-1 (2 Wire)

I. Negative 48-Volt Current Consumption

Constant		125 amps
Total Busy Hour Calls x 1 amp / 1000 (Minimum 10 amperes)	=	
Incoming CCS x 0.01	=	
Outgoing CCS x 0.00925	=	
Originating Intraoffice CCS x 0.0145	=	________
Total Negative 48-Volt Current Drain	=	

Notes:

1. In offices with short loops, add 20 amperes per 10,000 lines. Where loops are long, subtract 20 amperes per 10,000 lines.

2. For offices with Centrex features, add 25 amperes.

II. Positive 24-Volt Current Consumption

A.	Common Equipment (CPU's, CCTC, PMC, etc.)	42.0 amps
B.	Call Stores:	
	Ferrite Sheet Memory, Basic 16K Words	10.8 amps
	, First Supplementary 8K Words	8.0 amps
	, Second Supplementary 8K Words	2.8 amps
	MOS Memory, Basic 16K Words	5.1 amps
	, Supplementary 8K Words	1.3 amps
C.	Program and Data Stores:	
	Piggyback Twister Memory, Basic 16K Words	5.2 amps
	, Supplementary 16K Words	2.2 amps
	MOS Memory, Basic 32K Words	13.8 amps
	, Supplementary 16K Words	5.2 amps
D.	Centrex Data Line Units (16 Data Lines)	8.0 amps
E.	LAMA	3.0 amps
F.	Per 1000 Line Appearances	1.0 amps

Northern Electric SP-1

Example

The following data is used to demonstrate the method of calculating the negative 48-volt current drain of the Northern Electric SP-1 system.

Total Busy Hour Calls (Originating and Terminating) 12,000 BHC
Incoming CCS 3000 CCS
Outgoing CCS 3000 CCS
Originating Intraoffice CCS 4000 CCS

The majority of subscriber loops are 1900 ohms or less.

EXAMPLE

Northern Electric SP-1 (2 Wire)

I. Negative 48-Volt Current Consumption

Constant			125 amps
Total Busy Hour Calls x 1 amp / 1000 (Minimum 10 amperes)	12,000 / 1000 x 1	=	12
Incoming CCS x 0.01	3000 x .01	=	30.0
Outgoing CCS x 0.00925	3000 x .00925	=	27.8
Originating Intraoffice CCS x 0.0145	4000 x .0.45	=	58.0
Total Negative 48-Volt Current Drain		=	252.8
Add for short loops			+ 20.0
			272.8

Notes:

1. In offices with short loops, add 20 amperes per 10,000 lines. Where loops are long, subtract 20 amperes per 10,000 lines.

2. For offices with Centrex features, add 25 amperes.

EXHIBIT K

Nippon Electric Crossbar Systems
(NC-10, NC-23, NC-400 and NC-460)

I. Negative 48-Volt Main Power Requirement

A. Average Current Drain

$$Iav = (A+B) \times C \times \frac{K}{36} \quad \text{where}$$

Iav = Average Current in Amperes
A = Originating CCS Per Line
B = Terminating CCS Per Line
C = Number of Lines
K = 0.41 for NC-10
K = 0.51 for NC-23
K = 0.53 for NC-400 and NC-460

B. Peak Current Drain

$$Ipk = Iav + 4.48\sqrt{Iav} \quad \text{where}$$

Ipk = Peak Current in Amperes
Iav = Average Current in Amperes

II. Positive 50-Volt Power Requirement

A. 0.58 amps per Dial Tone Marker (NC-400)

B. 1.42 amps per Completing Marker (NC-400)

C. 1.42 amps per Marker (NC-23, NC-460)

Nippon Electric Crossbar Systems

Example

The following data is used to demonstrate the method of calculating the current drain for the NC-10, NC-23, NC-400 and NC-460 systems.

Originating CCS Per Line	1.6 CCS/Line
Terminating CCS Per Line	1.6 CCS/Line
Number of Lines	2000 Lines
Dial Tone Markers (NC-400)	3
Completing Markers (NC-400)	3
Markers (NC-23, NC-460)	3

Negative 48-volt Main Power Requirement:

NC-10

$$Iav = (1.6 + 1.6) \times 2000 \times \frac{.41}{36} = 73 \text{ amps}$$

$$Ipk = 73 + 4.48\sqrt{73} = 111.3 \text{ amps}$$

NC-23

$$Iav = (1.6 + 1.6) \times 2000 \times \frac{.51}{36} = 90.7 \text{ amps}$$

$$Ipk = 90.7 + 4.48\sqrt{90.7} = 133.3 \text{ amps}$$

NC-400 and NC-460

$$Iav = (1.6 + 1.6) \times 2000 \times \frac{.53}{36} = 94.2 \text{ amps}$$

$$Ipk = 94.2 + 4.48\sqrt{94.2} = 137.7 \text{ amps}$$

Positive 50-volt Power Requirement:

NC-23 and NC-460

$$3 \times 1.42 = 4.26 \text{ amps}$$

NC-400

$$3 \times 0.58 + 3 \times 1.42 = 6 \text{ amps}$$

EXHIBIT L

Power Requirements for Stromberg-Carlson Toll Ticketing Equipment

The following busy hour current drains should be used when calculating power requirements for Stromberg-Carlson automatic toll ticketing equipment:

1.0 ampere per recorder
2.0 amperes per identifier (usually 1 identifier)
4.0 amperes per data register (1 register/3.5 trunks)
2.0 amperes per sender (1 sender/4 recorders)
4.0 amperes miscellaneous

<u>Example</u>:

An automatic toll ticketing system contains the following equipment: 17 recorders, 1 identifier, 4 data registers and 4 senders.

The following drains are totaled:

Recorders	17 x 1.0	=	17
Identifier	1 x 2.0	=	2
Data Registers	4 x 4.0	=	16
Senders	4 x 2.0	=	8
Miscellaneous			4
Total Drain			47 amperes

EXHIBIT M

ITT Tel Touch

The following formulae should be used to calculate the additional busy hour current drain when ITT Tel Touch (pushbutton dialing) equipment is installed:

1. Total Originating Call Drain

$$\frac{\text{Total Originating Traffic (UC)} \times 0.046}{36} = \_\_\_\_\_\_\_\_ \text{ amps}$$

2. Traffic to Register Drain*

$$\frac{\text{BHC} \times \text{Register Holding Time}}{3600} \times (\text{Register Current} + 0.04) = \_\_\_\_\_\_\_\_ \text{ amps}$$

$$\text{BHC} = \frac{\text{Unit Calls} \times 100}{\text{Call Holding Time}}$$

Register Holding Time (RHT) =
2.5 + (1.5 seconds/digit x number of digits)

*Repeat this calculation for each type of traffic to registers, i.e., local, toll, CAMA, EAS, etc.

Register Current Table

Number of Digits Handled	Current
1	1.2
2	1.2
3	1.5
4	1.5
5	1.65
6	1.65
7	2.0
8	2.0
9	2.3
10	2.3
11	2.55
12	2.55
13	2.8

Exhibit M Continued-2

3. Allotter Drain

Total BHC x 0.00047 = __________ amps

4. Peak Drain

Total Drain (1 + 2 + 3) x 1.03 = __________ amps

Example:

A 300-line office equipped with 100% Tel Touch has the following traffic parameters:

Total Originating Traffic = 300 lines x 1.4 UC/L = 420 UC
9 Toll Trunks = 126 UC ÷ 2 = 63 UC
7 EAS Trunks = 84 UC ÷ 2 = 42 UC

Equal traffic is assumed in both directions on 2-way trunks.

Total Local Originating Traffic = 420 - (63 + 42) = 315 UC

Assume 120 second holding time.

$$\text{Local Originating BHC} = \frac{315 \times 100}{120} = 263 \text{ BHC}$$

Toll holding time is assumed to be 270 seconds.

$$\text{Toll Originating BHC} = \frac{63 \times 100}{270} = 23 \text{ BHC}$$

EAS holding time is assumedto be 150 seconds.

$$\text{EAS Originating BHC} = \frac{42 \times 100}{150} = 28 \text{ BHC}$$

Local Traffic - 7 Digits
Toll Traffic - 1 Digit
EAS Traffic - 7 Digits

Register Holding Time (RHT) - Local and EAS = 2.5 + (1.5x7) = 13 seconds

Register Holding Time (RHT) - Toll = 2.5 + (1.5x1) = 4 seconds

Exhibit M Continued-3

The following shows the calculation of the busy hour current drain:

1. Total Originating Call Drain = $\frac{420 \times .046}{36}$ = .54 amps

2. Local Traffic to Register Drain = $\frac{263 \times 13}{3600} \times (2+.04)$ = 1.94 amps

   EAS Traffic to Register Drain = $\frac{28 \times 13}{3600} \times (2+.04)$ = .21 amps

   Toll Traffic to Register Drain = $\frac{23 \times 4}{3600} \times (1.2+.04)$ = .03 amps

3. Allotter Drain = (263 + 28 + 23) x .00047 = .15 amps

   Total Drain = 2.87

4. Peak Drain = 2.87 x 1.03 = 3.0 amps

EXHIBIT N

Stromberg-Carlson Tone Dialing

To calculate the current drain of Stromberg-Carlson tone dialing equipment, use one ampere for each converter.

To calculate the number of converters required, use the following formula:

$$\frac{\text{Number of Lines} \times \text{UC/L}}{\text{Avg. Call Holding Time}} \times \text{Average Converter Holding Time} = \text{UC to Converters}$$

Using the P.01 Table, find the number of converters required.

Example:

Given:
400 Lines
1.5 UC/L
Call Holding Time - 180 seconds
Converter Holding Time - 10 seconds

Find current drain of Tone Dialing equipment.

Using the above formula, the traffic to the converters is

$$\frac{400 \times 1.5}{180} \times 10 = 33.3 \text{ UC}$$

From the P.01 Table, 5 converters are required. Therefore, the current drain is

5 x 1 amp/converter = 5 amps

CONTENTS

Systems Engineering (blue sheets)

DIGITAL SWITCHING DESIGN ALTERNATIVES

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During the early years of conversion from electromechanical switches to digital in the late seventies, REA requested and reviewed a comparison of lump sum PWAC results as part of the area coverage design (ACD) criteria. From 1980 through most of 1982, REA examined cost studies and made recommendations by developing and judging time line diagrams of cumulative year-by-year PWAC amounts. As digital equipment became more established, more seasoned, and the existing E-M switches grew older and less commensurate with current technology, the formal requirement for economic studies was discontinued. A need became evident to accelerate the rate of conversion of 300 - 400 switches per year.

The change to new digital switches was linked to the age, type, and condition of the existing offices. The chosen time to convert was affected by the rate of subscriber growth and the need for expansion of the operating switches. Conversions were planned to coordinate with connecting company schedules of toll network revisions, introduction of CAMA, TSPS, T-span trunking, or the introduction of a variety of new services such as the custom calling features. Building space considerations have always been important, too.

The economic studies stimulated the preparation of design alternatives, not only as to the optimum time to modernize the telephone switching, but what arrangements might be better than others. The alternate designs compared changing all offices quickly or perhaps over a five-year period. Single offices---or groups of offices---were compared on an economic basis. System alternatives were often presented such as: partial replacement at chosen times, gradual replacement or the entire system at once.

Even though economic studies are not required, alternative designs are still valuable and should be developed to insure that the most effective solution was chosen. There should be a discussion of features. Reasons for selection of a particular plan should be presented from an engineering standpoint. Economic studies are optional. They still appear in a variety of formats--from first cost plant investment comparisons to PWFC or PWAC expressions.

There are always choices to be made. Why do a change or a major improvement now? Why do it this way or that way? The choice between alternative ways of doing the same thing is common to our engineering activity. If a design comes in with only one plan showing, plus a tabulation of dollar requirements for the proposed equipment, the reviewers wonder if the plan is really the best one and whether alternatives were considered.

TE&CM 205 in describing the preparation of designs states:

> Page 2, paragraph 2.03 - "The narrative shall evaluate the alternate plans of service considered during the design stage and indicate the reasons for selection of the recommended plans which have been developed in detail."
>
> Page 11, paragraph 12.1 - "Detailed engineering and economic studies made for various preliminary design approaches which were considered are not intended to be included in the ACD. Studies made by the engineer. . . are expected to be reviewed. . . to determine whether the best overall method of serving the area has been chosen."

One of the more important and far reaching alternatives for many systems to consider today is the choice between separate independent exchanges or a host/remote configuration . Many remotes have been installed over the last several years. Some of them replace existing offices. Others do not, but are installed and sometimes moved around to handle subscriber growth. Still other digitals are used to supplement existing operating switches.

> EXAMPLE I compares two designs. One of the designs recommends retaining eleven small independent switches with no consolidation. The second design (in an adjacent state) ompares features and costs of a host/remote arrangement in a rural system of six exchanges. The smaller system shows COE cost estimates 20 percent cheaper than the large one.
>
> EXAMPLE II consists of an analysis of one exchange area in which a digital switch unit hosting two types of remotes is used for growth and one-party upgrade, eliminating the need for extensive outside plant additions. Without including the outside plant considerations, the switch conversion becomes a more costly alternative. However, including the reduction of outside plant costs, the switch conversion plan produces the lowest total cost.
>
> EXAMPLE III compares the complete replacement of an existing switch or freezing it in size and keeping it in operation for a planned interval, and colocating a new digital switch for concurrent operation to handle growth requirements. Such an alternative has been successful for larger existing offices that are not very old and most likely not SxS. Building space is important.

Another alternative to consider of growing importance is the use of fiber optics for medium size trunk lines. Recent studies show an awareness of potential applications of the optical facilities. One design compared a lightwave linkage over 14 miles between two offices of less than 2000 lines each (plus several remotes). An economic advantage is claimed compared to the use of T-carrier/50 pair cable. It seems that after several years of development and usage confined to larger trunk groups that fiber optics are on the threshold of the mainstream of rural telephony and henceforth should be an alternative to appraise.

SUMMARY

Small telephone companies generated a flurry of digital changeouts as soon as the switches came on the market. Recent reports indicate that digital COE sales gained activity in 1982-83, with Class 5 replacements getting underway by Bell companies, and continuing conversion by the rural telcos.

After a brief lull for an assessment of divestiture effects, a sustained increase in the rate of conversion to digitals may be expected. There is a continual need to change out the old vintage machinery for expansion, to provide new services, and for increased reliability with less maintenance.

Depreciation rates have recently been somewhat liberalized. Soon there will be obsolete digitals as well as electromechanical switches. New digital versions will feature more advanced hardware and software. Distributed processing capability and constantly increasing versatility will maintain and expand the use of both "base" and remote" units.

Revenues are to have a new look in the emerging world of deregulation. For years, our engineers could design new telephone plant to include expanded services such as ticketing, consolidation of offices, more toll routes and ownership, modern digital trunking, etc., with an assurance of reasonable settlements following standard A, B, C schedules or Ozark cost formulas for the toll portions. Design directions and plant considerations now must be geared to new rate and income criteria and more of the revenue to be derived from users within the system. New rules of competition have been established.

Engineering economics---an appraisal of well chosen alternatives---is sure to maintain its importance in the emerging age of competitiveness.

EXAMPLE I

COMPARISON OF TWO SYSTEMS

(Independent Offices and Host/Remotes)

It is proposed to convert ten exchanges from E-M SxS switching to digital. No consolidation of offices or use of remotes is recommended. All offices are indicated to be converted in a time slot from August '84 to August '85.

The existing equipment is small switches serving mostly less than 500 subscribers as shown below:

GOW System	Subscribers Now/5 years	Existing COE Lines	Age	
Bar	159/163	200	15 years	
Box	228/236	300	19 years	
Chur	467/474	600	16 years	
Far	391/409	500	15 years	
Gow	709/711	1000	16 years	Note 1
Knim	110/116	200	15 years	
Lan	64/65	200	20 years	Note 2
Mor	284/296	300	16 years	
Pat	352/357	600	15 years	
PM	178/183	300	19 years	
Som	221/228	300	16 years	

Note 1 - Gow to become Class 4 serving 9 system exchanges plus 3 of an adjacent company.

Note 2 - New digital switch being installed currently (end of 1983).

We assume that many of these switches received one or more additions over their years in service so that the average age would be somewhat less than indicated above.

- - - - -

All new digital switching -- as proposed for the system -- is desirable because:

1. Current technologies are made available.

2. System can be kept uniform -- not ½ new services, ½ old services and equipment.

3. Replacement of serviceable but aged, slow speed switches requiring increased maintenance.

4. Increased reliability, speed, versatility resulting from the use of electronic switching and stored program control equipment.

5. Provide for 911 service, custom calling, etc.

6. Trunking advantages such as centralized toll arrangements, EAS calling area provisions. Establishment of LATA and equal access facilities.

Inter-LATA trunking will be established as this system straddles three LATA boundaries.

Subscriber growth is meager for all exchanges. Only one office shows exhaustion of line capacity.

FIGURE 1 compares the cost estimates for these new switches to a similar nearby rural system (except the second system has only six exchanges) proposing to install host/remotes. A difference in the estimated COE cost of about 20 percent is revealed --- $959 per subscriber versus $754 per subscriber. The offices have been paired in the columns to show those nearly equal in size. The host office is much higher per station than its independent counterpart (Gow), but the remotes generate net savings overall.

Both systems propose to update and revise trunking arrangements (FIGURES 2a, 2b, 3).

FIGURE 4 is a graphical analysis of PWAC values of a third system showing typical PWAC differences between accelerated initial replacement compared with gradual conversion of switches.

The economically timed replacement of all step-by-step switching and the proposed use of separate Class 5 offices for this project was recommended. All switches are small and are uniformly "rather old" vintage. There are cost additives, but this area leads in rural telephony due to natural advantages of terrain, density of subscribers, general economics and income. They were in the forefront of one-party service and weatherproof plant.

However, other considerations that could be explored are:

1. An alternative such as the initial replacement of the Gow office due to its increased trunking responsibilities, plus selected small switches might be evaluated.

2. Potential savings that might develop from a digital host and remote switching design.

3. Savings that are realizable (from the design cost estimates) for prepackaged small switches procured on a multiple basis over a reasonable production and delivery period.

FIGURE I

GOW SYSTEM				HOST/REMOTE SYSTEM			
Exchange	5 Yr Sub.	Total COE Estimate	COE Cost per Sub.	Exchange	5 Yr Sub.	Total COE Estimate	COE Cost per Sub.
Lan	65	$ 54,572					
Gow	711	$ 664,194	$ 934	*Host	254	$ 401,365	$1,580
Box	236	255,223	1,081				
Far	409	303,552	742	TG(RST)	308	175,881	571
Som	228	243,600	1,068				
P M	183	231,597	1,265 ↔	E(RST)	194	147,852	762
Pat	357	286,305	802 ↔	F(RST)	363	185,831	512
Knim	116	216,945	1,870				
Mo	296	271,613	918 ↔	S(RST)	316	175,994	557
Bar	163	228,468	1,401 ↔	M(RST)	160	116,880	731
Chur	474	309,740	653				
System	3173	$3,011,237	$ 949		1595	$1,203,803	$ 754

* includes LAMA, spare parts, 5% tax

NOTES

Extremely small COE (10 of 11 less than 600 lines).

Must buy new bigger standby chargers.

Hole and new door in back wall of each building.

More revenue?

Better for EAS trunking.

Reliability assured.

Need for dual access.

Need for smart remotes?

Could have movable type of remotes for fast localized growth coverage.

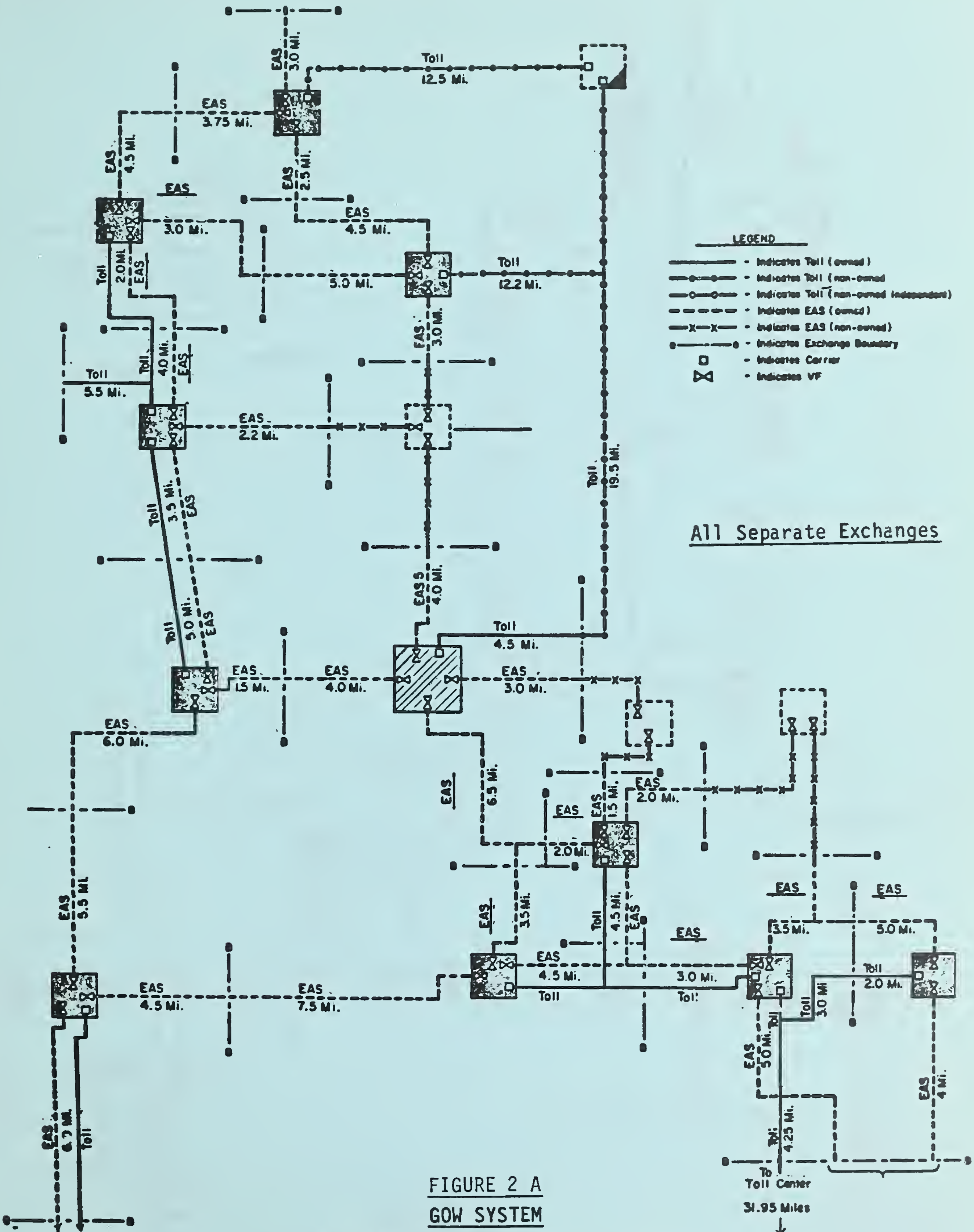


FIGURE 2 A

GOW SYSTEM

EXISTING TRUNKING DIAGRAM

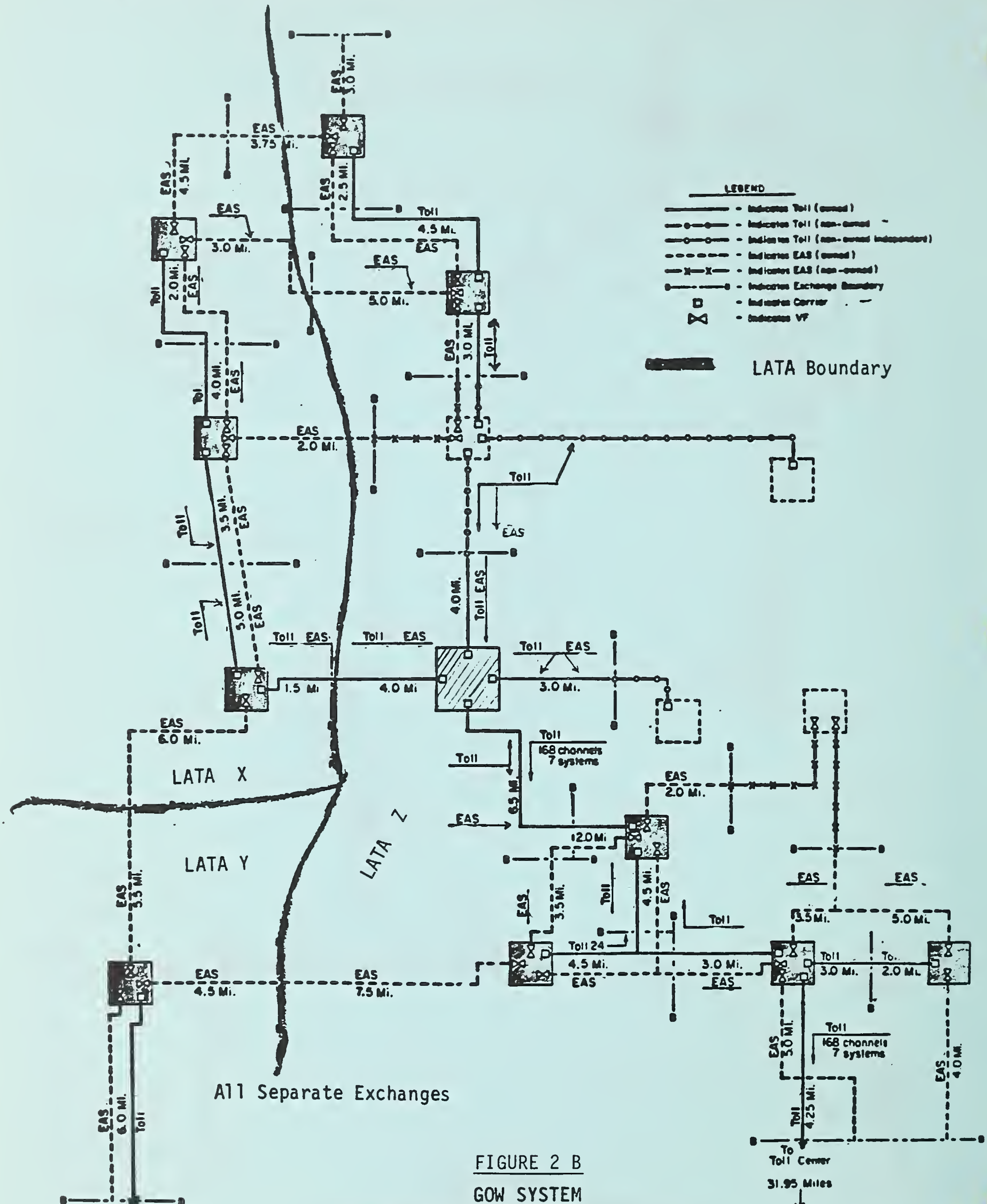


FIGURE 2 B

GOW SYSTEM

PROPOSED TRUNKING DIAGRAM

FIGURE 4

COE REPLACEMENT

ECONOMIC ANALYSIS

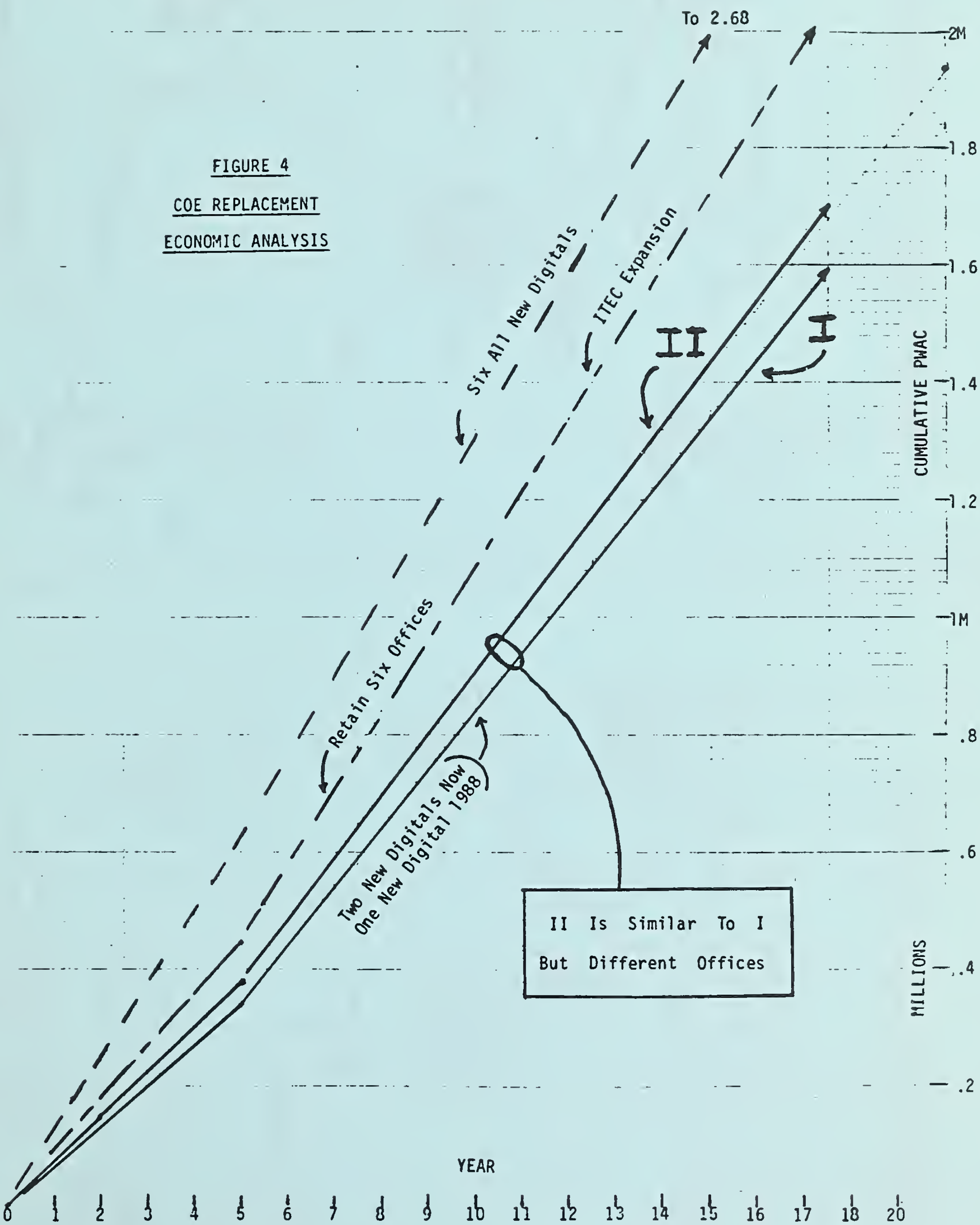
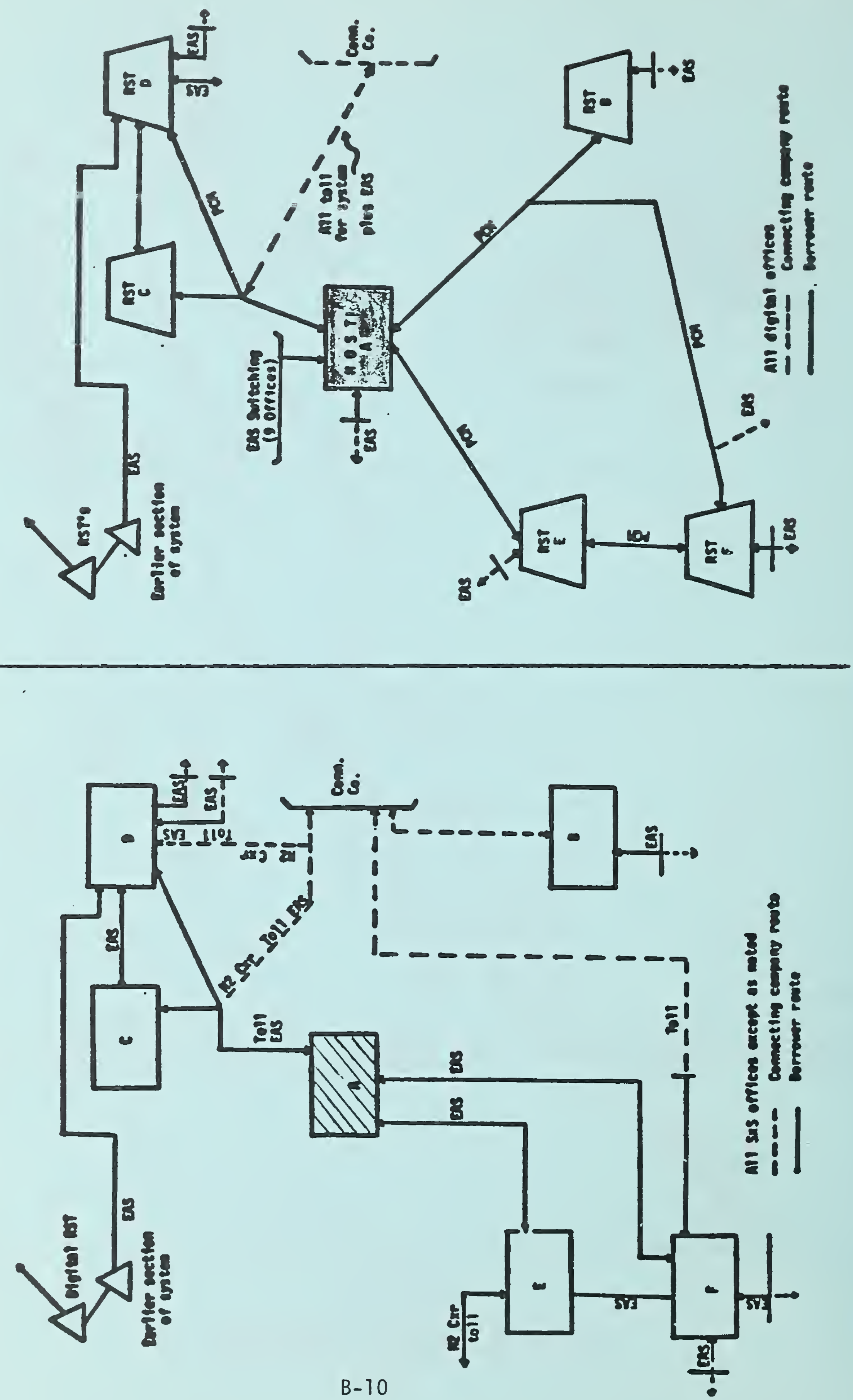


FIGURE 3

HOST/REMOTE SYSTEM - 'PROPOSED LAYOUT

HOST/REMOTE SYSTEM - PRESENT LAYOUT



EXAMPLE II

CONVERSION OF SWITCHING FOR OUTSIDE PLANT SAVINGS

1. System Description

1.1 General

1.1.1 Growth in an exchange area does not, by itself, automatically justify an economical conversion of an office to digital switching. But in this example a one-party upgrade consisting of sizable outside plant modifications and reinforcements is also proposed. The possibility of converting the office to digital switching and using remotes in lieu of reinforcing outside plant is being considered.

1.2 System Design Alternatives

1.2.1 PLAN I (control plan): expand the existing office (See TABLE I) and reinforce the outside plant for the growth and one-party upgrade using SAVE practices.

1.2.2 PLAN II: convert the central office to digital and install RST's (Remote Switching Terminals) and possible RLU's (Remote Line Units) in the outlying areas to the greatest extent possible to minimize outside plant additions.

1.3 Preparation of System Designs

1.3.1 Because the outside plant segment is of primary importance in both plans the first step should be to develop an accurate inventory of what plant needs to be replaced, modified, or retained.

1.3.2 The next step is to update outside plant maps showing present and future subscribers.

1.3.3 With these maps as the basis, serving areas can be selected. These same serving areas can then be used in both plans.

1.3.4 PLAN I type design is prepared using SAVE techniques. The most cost effective design, using both physical cable and subscriber carrier, should be developed.

1.3.5 For PLAN II, costs should be determined for the placement of compartmentalized cable (e.g., T-screen) and either RST's or RLU's to serve each serving area. (In many cases loading coils can be reduced or eliminated due to the shorter length VF circuits.)

1.3.6 The PLAN I and PLAN II costs can be compared for each serving area with the final design being a hybrid using RST's and RLU's where economical, and cable and carrier elsewhere.

1.3.7 Central office equipment costs can then be added to both plans to complete the designs.

1.3.8 Implementation plans (TABLES 2 and 3) may be prepared for use if PWAC studies are to be prepared.

1.3.9 PWAC study results, as summarized in TABLE 4, will help to determine when it is feasible to apply digital technology to the system in question. Details of the economic studies for EXAMPLE II are presented on pages 14 through 17. The time line graph of the cumulative PWAC values (FIGURE 1) shows both the (1) switching costs alone and (2) a comparison of results when the outside plant savings are included.

- - - - - - - - - - - - -

TABLE 1

EXISTING OFFICE
DATA AND LINE REQUIREMENTS

Central Office	Date Installed	Number of Lines Existing	5-Year	10-Year
Bakersburg	1974	2000	2600	3200

TABLE 2

IMPLEMENTATION PLAN - PLAN I

1. 1984 - 600-line, 400-terminal addition
   Outside plant additions
   Line treatment - existing COE
2. 1986 - Line treatment - existing COE
3. 1989 - 600-line, 500-terminal addition
   Building expansion
   Line treatment - COE
4. 1990 - Line treatment - COE
5. 1992 - Line treatment - COE

TABLE 3

IMPLEMENTATION PLAN - PLAN II

1. 1984 - Replace existing COE with 2200 line-digital.
   Provide remotes at three locations in exchange area, T-line repeaters. Land for remotes; three sites.
   New buildings at three locations
   Outside plant additions
   Retire existing equipment

2. 1985 - 100-line digital addition

3. 1986 - 150-line digital addition
   Line treatment

4. 1987 - 150-line digital addition

5. 1988 - 150-line digital addition
   Install wiring for 450 lines

6. 1989 - 100-line digital addition

7. 1990 - 100-line digital addition
   Line treatment

8. 1991 - 100-line digital addition

9. 1992 - 100-line digital addition
   Install wiring for 400 lines
   Line treatment

TABLE 4

PWAC RESULTS

	PLAN I	PLAN II
COE	$ 384,323	$1,153,716
Building	90,723	74,040
Outside Plant	3,090,096	2,096,645
Total PWAC	$3,565,142	$3,324,401
First Cost	$1,970,729	$2,087,238
First Cost COE Only	$212,758	$674,000
PWAC Value COE Only	$394,625	$761,028

EXAMPLE II - ECONOMIC STUDY - PLAN I

DESCRIPTION: Bakersburg - Retain COE and place physical outside plant

ITEM	YEAR	FIRST COST AMOUNT	ANNUAL COST %	ANNUAL COST AMOUNT	PRESENT WORTH OF ANNUAL COSTS PERIOD	FACTOR (p/a)n	AMOUNT
600L 400T Addition	1984	$ *(172,796)	.0619	$ 10,696	0-20	7.469	$ 79,888
600L 500T Addition	1988	*(178,831)	.0619	11,070	4-20	4.432	49,062
Building Addition	1988	100,000	.2047	20,470	4-20	4.432	90,723
Outside Plant Addition	1984	1,694,891	.2441	413,723	0-20	7.469	3,090,096
Line Treatment	1984	33,440	.2197	7,347	0-20	7.469	54,875
Line Treatment	1986	9,560	.2197	2,100	2-20	5.779	12,136
Line Treatment	1988	1,950	.2197	428	4-20	4.432	1,897
Line Treatment	1990	8,230	.2197	1,808	6-20	3.358	6,071
Line Treatment	1991	9,900	.2197	2,175	8-20	2.502	5,442
[1] Labor & material to install 600L 400 T	1984	46,460	.2730	12,684	0-20	7.469	94,737
[2] Labor & material to install 600L 500T	1988	66,298	.2730	18,099	4-20	4.432	80,215
TOTALS		$1,970,729					$3,565,142

EQUATED ANNUAL COSTS = (TOTAL PWAC AMOUNT) X ANNUITY FACTOR=$477,301
(a/p)n=.13388

Remarks: C/M = 12%, factor
*Note - Not a credit to first cost-these are original book costs used only to determine maintenance and ad valorem

1 Assumed intra-company reuse
2 Assumed inter-company reuse

PLAN I OF II

STUDY PERIOD 1984 - 2003
20 years

EXAMPLE II - ECONOMIC STUDY - PLAN II

BAKERSBURG EXCHANGE
DESCRIPTION

This plan provides the replacing of an existing central office with a digital switching system in 1984. Remote switching units will be utilized at three locations which will eliminate the need for approximately 20 miles of physical outside plant construction. Environmentally controlled buildings are included to house the remote switches. A total of 121 miles of new feeder and distribution cable are included.

In addition to cost savings this plan offers several other advantages over PLAN I as follows:

1. No central office building addition would be required.

2. Additional revenue potential (vertical services).

3. Maintenance savings.

4. Smaller investment in the high inflation technology of copper and labor.

5. More flexible and efficient use of outside plant by using remote switching units.

Line requirements for the remote line units through 1988 are as follows:

	Remote #1	Remote #2	Remote #3
1984	272	251	189
1985	287	286	204
1986	300	299	223
1987	313	313	241
1988	329	330	261

EXAMPLE II ECONOMIC STUDY - PLAN II

DESCRIPTION: Bakersburg - Replace CO with Digital - Remotes on leads 1 & 3 and Physical on leads 2 & 4

ITEM	YEAR	FIRST AMOUNT AMOUNT	ANNUAL COST %	ANNUAL COST AMOUNT	PRESENT WORTH OF ANNUAL COSTS PERIOD	FACTOR (p/a)n	AMOUNT
Replace CO 2200L digital	1984	$ 510,000	.2458	125,358	0-20	7.469	$ 936,299
Remotes (3) locations	1984	153,600	.2458	37,755	0-20	7.469	281,992
T Line repeaters	1984	55,574	.2458	13,660	0-20	7.469	102,027
Outside plant additions	1984	1,149,992	.2441	280,713	0-20	7.469	2,096,645
Line treatment	1984	3,610	.2197	793	0-20	7.469	5,923
Land for remotes (3) locations	1984	15,000	.2169	3,254	0-20	7.469	24,304
New buildings (3) locations	1984	32,532	.2047	6,659	0-20	7.469	49,736
100L digital addition	1985	11,000	.2458	2,704	1-20	6.577	17,784
Line treatment	1986	1,160	.2197	255	2-20	5.779	1,474
150L digital addition	1986	16,500	.2458	4,056	2-20	5.779	23,440
150L digital addition	1987	16,500	.2458	4,056	3-20	5.068	20,556
150L digital & wiring for 450L	1988	48,000	.2458	11,798	4-20	4.432	52,289
100L digital addition	1989	11,000	.2458	2,704	5-20	3.865	10,451
100L digital addition	1990	11,000	.2458	2,704	6-20	3.358	9,080
100L digital addition	1991	11,000	.2458	2,704	7-20	2.906	7,858
100L digital & wiring for 400L	1992	39,000	.2458	9,586	8-20	2.502	23,984
Line treatment	1990	1,590	.2197	349	6-20	3.358	1,172
Line treatment	1992	180	.2197	40	8-20	2.502	100
Retire E-M equipment $736,942	1984		.0619	(45,617)	0-20	7.469	(340,713)
TOTALS		$2,087,238					$3,324,401

EQUATED ANNUAL COSTS = (TOTAL PWAC AMOUNT) X ANNUITY FACTOR=$455,071
(a/p)n=.13388

Remarks: C/M = 12%, factor

PLAN II OF II

STUDY PERIOD 1984 - 2203
20 years

EXAMPLE II ECONOMIC STUDY - PLAN I
COE ONLY

DESCRIPTION: Bakersburg - Retain existing COE

ITEM	YEAR	FIRST COST AMOUNT	ANNUAL COST %	ANNUAL COST AMOUNT	PRESENT WORTH OF ANNUAL COSTS PERIOD	FACTOR (p/a)n	AMOUNT
600L 400T addition	1984	$*(172,796)	.0619	$10,696	0-20	7.469	$79,888
600L 500T addition	1986	*(178,831)	.0619	11,070	4-20	4.432	49,062
Building addition	1988	100,000	.2047	20,470	4-20	4.432	90,723
[1]Labor & material to install 600L 400T addition	1984	46,460	.2730	12,684	0-20	7.469	94,737
[2]Labor & material to install 600L 500T addition	1988	66,298	.2730	18,099	4-20	4.432	80,215
TOTALS		$212,758					$394,625

EQUATED ANNUAL COSTS = (TOTAL PWAC AMOUNT) X ANNUITY FACTOR=$52,832
(a/p)n=.13388

Remarks: C/M = 12%, factor
*Note - not a credit to first cost - these are original book costs used only to determine maintenance and ad valorem

[1]Assumed intra-company reuse
[2]Assumed inter-company reuse

PLAN I OF II

STUDY PERIOD 1984 - 2003
20 years

EXAMPLE II - ECONOMIC STUDY - PLAN II
COE ONLY

DESCRIPTION: Bakersburg - Replace CO with digital

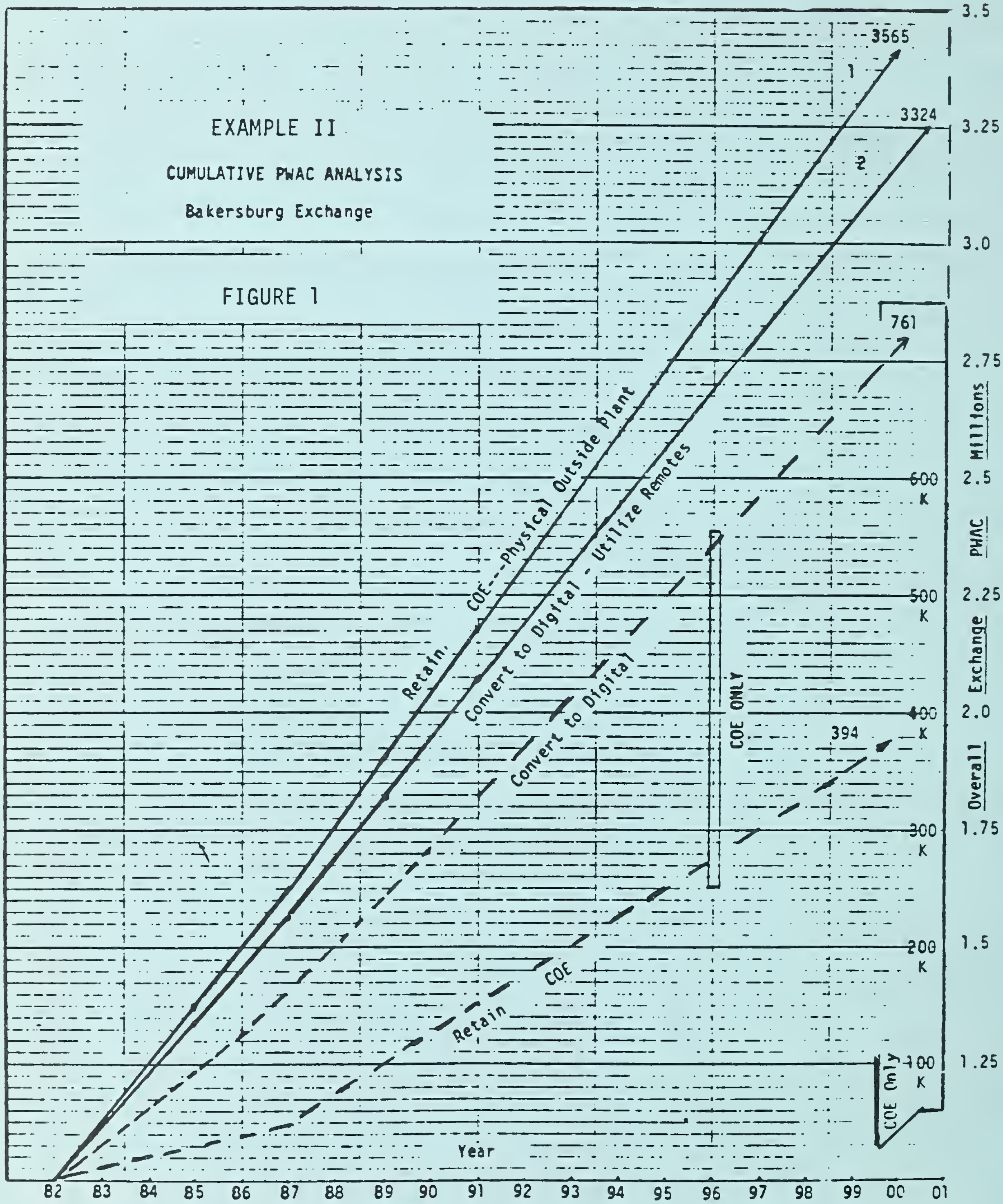
ITEM	YEAR	FIRST COST AMOUNT	ANNUAL COST %	ANNUAL COST AMOUNT	PRESENT WORTH OF ANNUAL COSTS PERIOD	FACTOR (p/a)n	AMOUNT
Replace CO 2200L digital	1984	$510,000	.2458	$125,358	0-20	7.469	$936,299
100L addition	1985	11,000	.2458	2,704	1-20	6.577	17,784
150L addition	1986	16,500	.2458	4,056	2-20	5.779	23,440
150L addition	1987	16,500	.2458	4,056	3-20	5.068	20,556
150L & wiring for 450L	1988	48,000	.2458	11,798	4-20	4.432	52,289
100L addition	1989	11,000	.2458	2,704	5-20	3.865	10,451
100L addition	1990	11,000	.2458	2,704	6-20	3.358	9,080
100L addition	1991	11,000	.2458	2,704	7-20	2.906	7,858
100L & wiring for 400L	1992	39,000	.2458	9,586	8-20	2.502	23,984
Retirement S x S $736,942			.0619	(45,617)	0-20	7.469	(340,713)
TOTALS		$674,000					$761,028

EQUATED ANNUAL COSTS = (TOTAL PWAC AMOUNT) X ANNUITY FACTOR=$101,886
(a/p)n=.13388

Remarks: C/M 12%, factor
No inflation added

PLAN II OF II

STUDY PERIOD 1984 - 2003
20 years



TIME LINE GRAPH

EXAMPLE III

USE OF A COLOCATED NEW DIGITAL SWITCH

1. System Description

1.1 An expansion of existing switching facilities with colocated digital equipment, while keeping the existing equipment (TABLE 1) in service, may be advantageous solution. Some reasons for doing this are:

1) Cost savings over complete conversion to digital.

2) Keeps existing switches in service until depreciated.

3) Advanced and custom features are made available to any subscriber at each colocated exchange.

4) Can serve remotes if needed.

5) Increased versatility for trunking and numbering requirements.

1.2 However, if two types of switches are to function essentially as one, maintenance and administration becomes more complex. Trunking is required between the switches. Procurement costs of the digital may be increased to facilitate dual operation with electromechanical apparatus.

2. Discussion of Example

2.1 The Kong central office is presently electromechanical equipment. Complex and conflicting EAS office codes preclude the use of 911 emergency service. Because of the overlapping codes, the subscribers are required to dial eight digits to reach one of the EAS locations. Traffic studies show that some of the line and terminal groups are becoming overloaded due to increased calling. To continue with E-M will require electronic register senders and a building space expansion. Several large businesses intend to relocate into the exchange area but the total effect cannot be accurately projected yet.

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TABLE 1

EXISTING OFFICE
DATA AND LINE REQUIREMENTS

Central Office	Date Installed	Number of Lines		
		Existing	5-Year	10-Year
Kong	1974 and later	4600	5800	6500

2.2 A time schedule for the three options is shown, TABLE II.

2.2.1 PLAN I retains and adds to the existing switch gear.

2.2.2 PLAN II provides for removal and partial reuse in other offices within the system of 1000 lines at the outset, 1000 lines to be retired during year four and again in year seven; 1600 lines are kept in service.

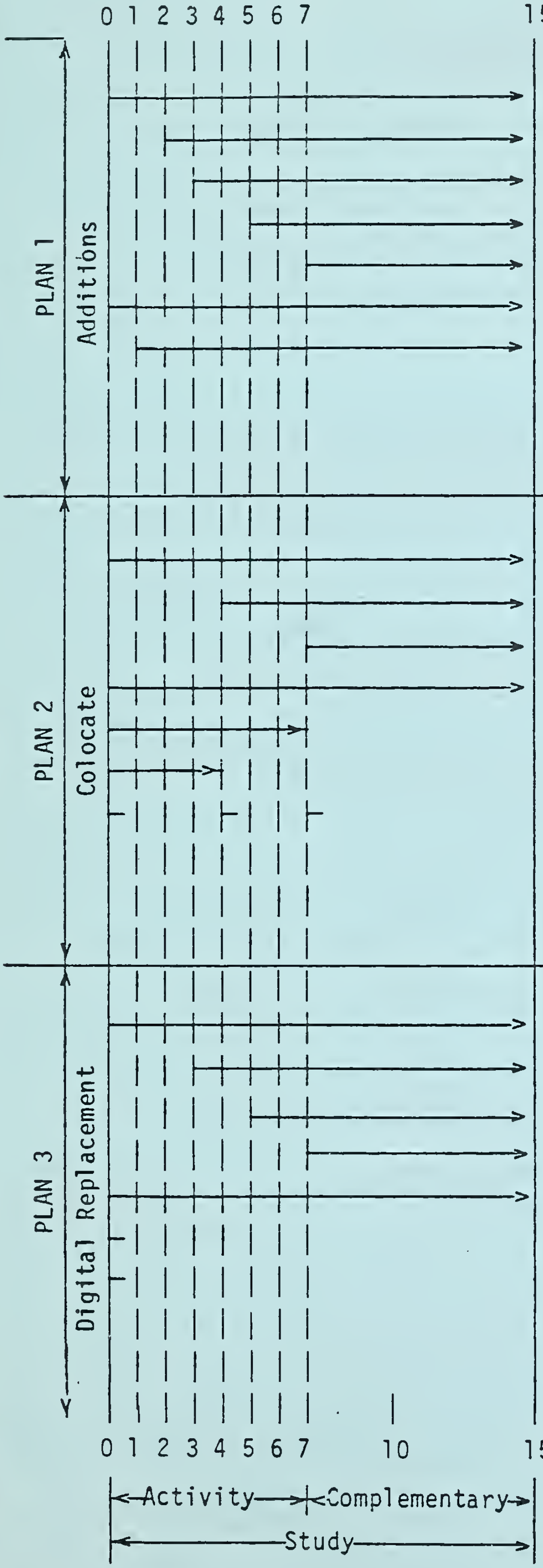
2.2.3 PLAN III consists of a complete digital replacement and retirement of all E-M equipment.

2.3 An economic study helps to determine the most practical means for providing acceptable service. (See pages 22-26.)

2.3.1 The partial replacement (colocated in the same building) proves to be a favorable option as shown by the comparative analysis summarized in TABLE III and the graphical cost comparison (FIGURE 1).

KONG TIME SCHEDULES

TABLE II



	EVENT	COST
PLAN 1 Additions	400 line/500 term.	$ 239,181
	400 line/700 term.	657,279
	400 line/400 term.	359,103
	500 line/500 term.	538,914
	200 line/300 term.	257,906
	Exist.equip.maint.& ad valorem	
	Building addition	199,650
		$2,252,033
PLAN 2 Colocate	2200 line startup	$ 929,134
	1300 line addition	393,191
	1362 line addition	508,894
	Exist.equip.mainte.& ad valorem	(1600L)
	" " " "	(1000L)
	" " " "	(1000L)
	Net salvage	-90,000
		$1,741,219
PLAN 3 Digital Replacement	5400 line startup	$1,491,433
	400 line addition	140,489
	400 line addition	189,830
	200 line addition	110,151
	Building addition	199,650
	Net salvage	-150,000
	Cutover charges	50,000
		$2,031,553

EXAMPLE III

KONG EXCHANGE
ALTERNATE PLAN DESCRIPTIONS
FOR ECONOMIC STUDIES

PLAN 1: Continue with the present type of equipment.

A. Addition to the present building.
B. Add sufficient quantities of E-M equipment to reduce overloaded groups and to satisfy main station growth.
C. Add Electronic Register Senders to eliminate eight-digit dialing and to provide 911 emergency service capabilities.

PLAN 2: Digital, partial replacement.

A. Install digital switch large enough to replace 1000 lines of the present switch and satisfy main station growth, thus providing space for future replacement of E-M equipment without a building addition.

PLAN 3: Digital, total replacement.

A. Addition to present building.
B. Install digital switch sufficient in size to totally replace the existing E-M equipment.

Annual charge factors for this example are as follows:

COE (15-year basis)

Year	S.F. Dep.	Inc. Tax	C/M	Ad Val. Tax	Total %
0	2.9	2.78	11	0.77	17.45
1	3.3	2.76	11	0.77	17.83
3	4.4	2.68	11	0.77	18.85
4	5.11	2.64	11	0.77	19.52
5	5.98	2.61	11	0.77	20.36
7	8.43	2.54	11	0.77	22.74
Building Addition (20-year basis)					
1	1.56	3.06	11	0.77	16.39

Maintenance Estimate

Existing switch	COE	$17.00 per line
New digital	COE	$15.50 per line

Building addition -- 1.8% of additional investment

Assumptions for PWAC Studies

A. Base dollars plus an annual compounded inflation rate of 11% per year for E-M equipment and 8.5% per year for digital equipment

B. Salvage dollars are equal to gross salvage less cost of removal.

C. Maintenance costs are expressed as units and are not inflated.

D. The life of the digital switch is assumed to be 15 years with "0" net salvage.

E. Year "0" is 1983.

Narrative of Recommended Plan II

A. Replace 1000 lines (approximately) of E-M equipment with 2000 lines of digital equipment.

B. Rehome all trunking in digital switch.

C. Add environmental controls to the building.

D. Reuse 800 lines in the other exchanges in the following years.

E. Lowest ultimate cost of three plans with only a small cost penalty over Plan 1 in the early study years.

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TABLE III

PWAC RESULTS

	PLAN I (Retain existing & expand)	PLAN II (partially new)	PLAN III (completely new)
COE	$2,284,786	$2,165,905	$2,755,047
Building	228,560		261,299
Outside Plant	--	--	--
	$2,513,346	$2,165,905	$3,016,346

TYPE OF STUDY PWAC

PLANT COST ANALYSIS

EXCHANGE Kong

PLAN 1 OF 3 SHEET 1 OF 1

ITEM X-Y	FIRST COST AMOUNT	FIRST COST YEAR	ANNUAL COSTS: TOTAL PCT. EXCL. MTCE.	TOTAL AMOUNT EXCL. MTCE.	MAINTENANCE UNIT	MAINTENANCE AMOUNT	TOTAL ANNUAL COST AMOUNT	PRESENT WORTH OF ANNUAL COSTS OVER 15 YEAR PERIOD: PERIOD OF YEARS	(p/a) FACTOR	AMOUNT
400 line/500 term.	$ 239,181	0	17.45	41,833	17.00	$ 6,800	$ 48,633	0-15	7.191	$ 349,720
400 line/700 term. ERS	657,279	1	17.83	105,579	17.00	6,800	112,379	1-15	6.290	706,864
400 line/400 term.	359,103	3	18.85	49,496	17.00	6,800	56,296	3-15	4.747	267,237
500 line/500 term.	538,914	5	20.36	65,120	17.00	8,500	73,620	5-15	3.495	257,302
200 line/300 term.	257,906	7	22.74	28,251	17.00	3,400	31,651	7-15	2.479	78,463
Exist.equip. 4600 lines	(1,135,305)		.77	8,742	17.00	78,200	86,942	0-15	7.191	625,200
Building addition	199,650	1	16.40	32,743	1.8	3,594	36,337	1-15	6.290	228,560
TOTALS	$2,252,033						$445,858*			$2,513,346

* After year 7

TYPE OF STUDY PWAC

PLANT COST ANALYSIS

EXCHANGE Kong

PLAN 2 OF 3 SHEET 1 OF 1

ITEM Digital (Partial Replacement)	FIRST COST AMOUNT	FIRST COST YEAR	ANNUAL COSTS: TOTAL PCT. EXCL. MTCE.	ANNUAL COSTS: TOTAL AMOUNT EXCL. MTCE.	MAINTENANCE UNIT	MAINTENANCE AMOUNT	TOTAL ANNUAL COST AMOUNT	PRESENT WORTH OF ANNUAL COSTS OVER 15 YEAR PERIOD: PERIOD OF YEARS	(p/a) FACTOR	AMOUNT
2200 line/300 trunks digital startup	$929,134	0	17.45	$162,134	15.50	$34,100	$196,234	0-15	7.191	$1,411,119
1300 line addition	393,191	4	19.52	50,556	15.50	20,150	70,706	4-15	4.089	289.117
1362 line addition	508,894	7	22.74	55,743	15.50	21,111	76,854	7-15	2.479	190,521
Exist. equip. 1600 lines**	(394,889)		.77	3,041	17.00	27,200	30,241	0-15	7.191	217,463
Exist. equip. 1000 lines**	(246,806)		.77	1,900	17.00	17,000	18,900	0-7	4.712	89,057
Exist. equip. 1000 lines**	(246,806)		.77	1,900	17.00	17,000	18,900	0-4	3.102	58,628
Salvage										(90,000)
TOTALS	$1,831,219						$411,835*			$2,165,905

* After year 7

** Existing equipment to be phased out. Maintenance and ad valorem taxes are shown for year equipment is to be in service.

TYPE OF STUDY PWAC

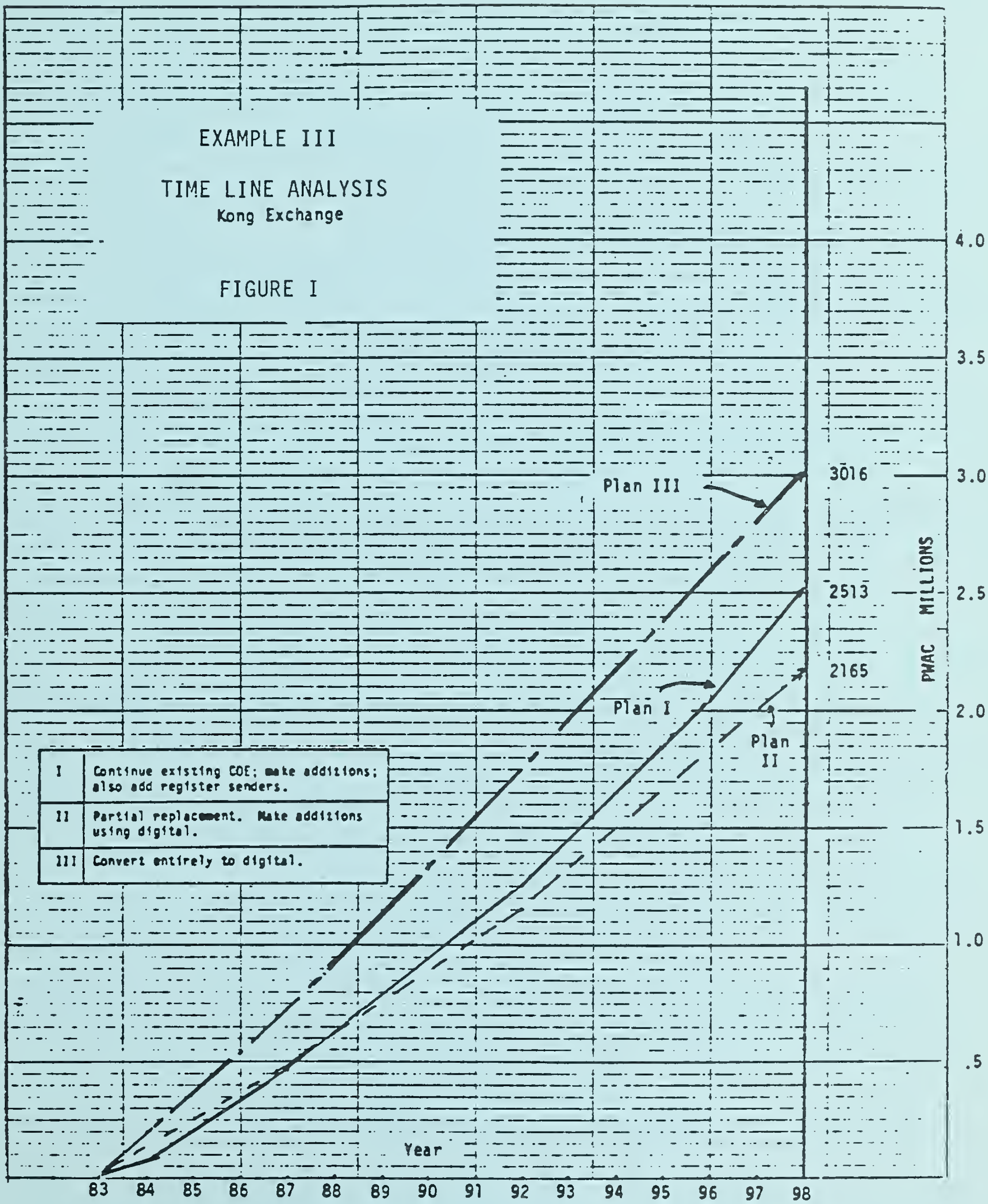
PLANT COST ANALYSIS

EXCHANGE Kong

PLAN 3 OF 3 SHEET 1 OF 1

ITEM Digital (Total Replacement	FIRST COST AMOUNT	FIRST COST YEAR	ANNUAL COSTS: TOTAL PCT. EXCL. MTCE.	ANNUAL COSTS: TOTAL AMOUNT EXCL. MTCE.	ANNUAL COSTS: MAINTENANCE UNIT	ANNUAL COSTS: MAINTENANCE AMOUNT	ANNUAL COSTS: TOTAL ANNUAL COST AMOUNT	PRESENT WORTH OF ANNUAL COSTS OVER 15 YEAR PERIOD: PERIOD OF YEARS	(p/a) FACTOR	AMOUNT
5400 digital line, 600 trunks	$1,491,433	0	17.45	$260,255	15.5	$83,700	$343,955	0-15	7.191	$2,473,380
400 line addition	140,489	3	18.85	26,482	15.5	6,200	32,682	3-15	4.747	155,141
400 line addition	189,830	5	20.36	38,649	15.5	6,200	44,849	5-15	3.495	156,747
200 line addition	110,151	7	22.74	25,048	15.5	3,100	28,148	7-15	2.479	69,779
Building addition	199,650	0	16.40	32,743	1.8	3,594	36,337	0-15	7.191	261,299
Salvage		0								(150,000)
Cutover charges	50,000	0								50,000
TOTALS	$2,181,553						$485,971*			$3,016,346

* After year 7



GRAPHICAL COST COMPARISON

RURAL LIGHTWAVE SYSTEM DESIGN CONSIDERATIONS

Gerald S. Schrage
Systems Engineering Branch
Telecommunications Engineering and Standards Division

A. Background

REA has been involved in lightwave system designs and applications since the first REA field trial in the Commonwealth Telephone Company in 1979. This system was a short wavelength, 45Mb/s bandwidth, interoffice trunking application operating at a DS3 rate capable of carrying 672 voice frequency trunks per fiber optic pair. Since then we have sponsored many additional field trials to test other new lightwave developments. We have in operation, construction, or planning stages 15 different field trials. These trials run the gambit of short or long wavelengths, 1.5, 16, 45, or 90 Mb/s bandwidths, different optical equipments and different cable constructions. All of the field trials at this time involve interoffice trunking. Table 1 lists the current REA lightwave system activities.

B. Limiting Factors

As lightwave system designs have progressed they have been subject to differing limiting factors. Some of the primary factors that have to be considered in any application are attenuation, bandwidth, equipment life, splicing and cost. As developments progressed these factors have changed positions in their limiting effects and some have become insignificant.

1. Attenuation

The attenuation of the fiber per unit length in a lightwave cable was initially the limiting factor in a system application. Attenuation losses have diminished rapidly from the 1000 dB/km level in the mid-1960's to 20 dB/km in the 1970's to approaching 0.2 dB/km in the 1980's. As an example of the effect of this improvement consider our first field trial that used cable with a nominal 6 dB/km fiber loss. This together with other losses required four field repeaters over the 22 km span length. Now, however, our current field trials include span lengths up to 20 km with no field repeaters. This has helped reduce system cost by eliminating the cost of field repeaters, the expense of installation and the periodic expenses of maintaining them. At this point in time I do not see fiber attenuation as being limiting in rural application design. Repeaterless span lengths of up to 30 km are achievable which covers over 90 percent of our potential trunking or loop applications.

2. Bandwidth

Bandwidth in a fiber optic system was not a significant factor in our initial field trial because of the limiting effect attenuation had which caused relatively short span lengths. Now with longer span lengths possible, the end-to-end bandwidth required becomes important. The bandwidth is reduced per unit of length of the fiber. This is caused by two factors i.e. material dispersion and intermodel dispersion. These factors cause pulse distortion such that higher bit rate pulses are not able to be transmitted and meet the bit error rate (BER) performance required. This limitation has been relatively short lived. Material dispersion has been reduced by improvements in the purity of the fiber and improved light sources with a more nearly single wavelength output. A second improvement has been the trend to use single mode cable which propagates a single wavelength and effectively eliminates intermodel dispersion. With these improvements a bandwidth of 500 MHz/km is achievable. We are now able to produce a fiber that will meet any current bandwidth and span length required for rural applications.

3. Equipment Life

The only equipment in a lightwave system design that caused any concern about its life characteristics were the light sources and detectors. All the other associated central office equipment were either standard or slightly modified versions of proven electronic equipment. This included items such as M13 or M12 digital multiplexers, automatic protection switches, alarms, patch panels, and power supplies. Two light sources, lasers and light emitting diodes (LED), are available to inject light power into the fiber. LED's had long life and lower cost, but provided low power. Lasers provided high power at a higher cost and relatively shorter lifetimes. Our initial system required lasers because of the high attenuation. The initial lasers showed premature aging (1000 to 2500 hours) within three months and have been replaced by better quality lasers that indicate a minimum life of 25,000 hours (3 years). Newer lasers promise lifetimes of 100,000 hours (11 years), LED's are semiconductor devices having lifetimes of 1,000,000 hours (110 years). The optical detectors are of two types, i.e. PIN diodes and avalanche photo diodes (APD). Both of these detectors are semiconductor devices with their expected long lifetimes. With these lifetimes the optical power sources and detectors are approaching the situation where they will be expected to last the life of the system design. For the system design application their effect is no longer significant. The selection of which combination to use would be of concern only to the equipment manufacturer.

4. Splicing

All of the initial splicing techniques were forms of fusion welding (flame or arc) of the ends of the fibers. Current splicing advancements are centering on developing a low-loss, repeatable, long lasting and stable mechanical splicing connector for joining fibers. If this type of connector can be developed it will greatly simplify the installation and maintenance of lightwave cables at a reduced cost. For the system designer the primary concern is not the method of splicing, but the loss associated with each splice point. Our first installation averaged 0.75 dB loss per splice and splices were required every kilometer. With 6 dB/km fiber and reel lengths of 1 km, the splice loss amounted to only about 10 percent of the fiber loss budget. Splicing has improved to where the splicing loss averages 1/3 the average of the first trials or about 0.25 dB loss per splice. However, with the low loss fibers approaching 0.2 dB/km and reel lengths now typically 2 kilometers, the splice loss can amount to as much as 35 percent of the fiber loss budget. Percentage-wise the conditions have worsened in splicing loss for the system designer, but in absolute values the average losses are so low that it creates no significant problem in rural lightwave design applications unless there is an unusual number of splices required. A good mechanical splice connector will have more impact on system design and costs at this time than further reduction in average splice loss.

5. Costs

For rural areas it is my opinion that technology has virtually eliminated any practical system design limitations for trunking applications. However, rural subscriber loop applications is a field that requires considerable equipment development but for which little development is known to be in progress. We intend to encourage the development of the necessary equipment and facilities for subscriber loop applications.

With technological developments not being a major consideration, the bottom line consideration is system cost. After an operator has an initial system, for which most are willing to pay some premium, the additional systems must cost less than equivalent alternative systems. If an additional cost is incurred, the design must justify it by virture of increased capacity, longer life, less maintenance, additional services or some other tangible reason. An ititial system can partially justify a cost premium for the operating, installation, maintenance, and training experience it generates for all members of the telephone company staff.

Our first field trial cost about 40 percent more than an equivalent copper cable PCM carrier interoffice trunk design. The first four trials were of the short wavelength design and had a total installed cost of between $300 and $500 per voice frequency interoffice trunk. The combined equipment (multiplexer, optical transmitters and receivers, protection switching, and other devices) cost between $175 to $200 per voice frequency interoffice trunk. These systems had lightwave cable costs of between $2.25 to $2.75 per fiber-meter installed. These spans were all designed for 45 Mb/s bandwidth carrying 672 trunks per span.

All of our current applications are designed for long wavelength operation. With the apparent reduction in cable cost plus the associated low attenuation losses, it appears that long wavelength system design is replacing short wavelength design. The cost associated with these installed long wavelength cables in normal buried or aerial construction ranged from 60¢ to $1.10 per fiber-meter. This is a 50 to 75 percent reduction from the costs incurred just four to five years ago. The cost of the associated electronic and optical equipment has not made quite as dramatic progress. The installed cost of this equipment is between $100 to $225 per voice frequency trunk. The total installed cost per system runs between $200 and $400 per voice frequency trunk for a total system cost reduction of between 25 and 35 percent. These systems are designed for various bandwidths up to 90 MHz serving as many as 1152 trunks.

Tables 2 and 3 list some of these cost parameters for short and long wavelengths system, respectively, assuming 100 percent fill. The costs vary considerably depending on the specific application as would be expected. However, general trends indicate that for a typical current design, the total costs are apportioned in the ratios of approximately 50 percent for cable, 25 percent for multiplexing equipment and 25 percent for optical equipment.

C. Rural Applications

Lightwave rural system designs are potentially applicable as an alternative to any situation where paired cable, PCM carrier or digital radio might be used. The designs are for two basic purposes. They are being used for interoffice trunking and could conceivably be used for subscriber loop applications.

1. Interoffice Trunking

Figure 1 schematically represents the interoffice trunking applications for which lightwave systems have been or will be designed. The rural offices we serve are generally between 5 and 30 km apart and present no unusual difficulty in serving them on a repeaterless basis. The problem in rural areas is in utilizing the full capacity and associated low cost with lightwave trunking. The trunking systems available provide an inherent capacity of 96 to 1344 voice frequency channels. The total cost of the lightwave span is the same whether one voice frequency channel is equipped or if 100 percent of the ultimate voice frequency channels are equipped. Competing cable designs can be built in increments of one channel and PCM carrier systems in increments of 24 channels. If the number of channels required are few then the per channel cost of a lightwave span will be high and unable to compete with cable or PCM carrier designs. No costs are saved by providing a higher ultimate lightwave span capacity than is necessary. The cost might in fact be higher if a higher bit rate digital multiplexer or optical transceiver than is necessary is used. The reverse is also true. Considerable cost can be saved in adding new channels to a lightwave system that has unused capacity. Competing cable or PCM carrier designs will require new construction more often than a lightwave system. In a fast growing route this could result in lower PWAC costs for a lightwave system. If a lightwave system can be filled near its capacity it will provide one of the lowest cost alternatives. To increase the penetration of lightwave trunking systems into rural areas a thin route design with an incremental capacity of four T-1 systems at a total channel cost comparable to today's higher capacity systems is needed.

2. Subscriber Loops

The application of lightwave system design to subscriber loops is so rare that I know of only four systems at this time. There are probably others that I am not aware of. I would like to receive information about them. Of these four applications, I consider only one a pure telephony application.

a. Current Subscriber Loop Applications

The earliest subscriber loop system that I am aware of is a 1978 trial in Toronto, Canada, of an integrated television, telephone and data system. This system served 45 subscribers at a maximum loop length of 1.4 kilometers. Later in 1981 Manitoba Telephone inaugurated a trial of up to 150 subscribers in two linked communities of Elie and St. Eustache. This system was also in integrated television, telephone and data system. The cost of the Manitoba system averaged $30,000 per subscriber. The only reasons for these systems and their astronomical costs was that they were intended to be experimental and not permanent. They were partially financed by the Canadian government. Lastly, Canadian telepone companies could operate integrated systems as opposed to the prohibitions facing United States telephone companies.

A third subscriber loop application was a private point-to-point circuit owned, operated and installed by Niagara Mohawk Power Company in Syracuse, New York. This company also has their own satellite facilities and indicates what private companies can do.

The only true subscriber telephone loop application that I know of is by the Western Reserve Telephone Company from their Perry, Ohio, office to the Perry nuclear power plant. Power plants because of their potential for large voltage rises caused during times of power faults have always required special equipment and designs to neutralize this effect and create safe working conditions. With paired cable serving power plants expensive neutralizing transformers are required. Microwave radio or PCM carrier could also be used for subscriber loops to a power plant without the need for neutralizing transformers. These circuits are relatively expensive also. Western Reserve did an economic study of their case and found that a lightwave system would be less costly than a cable pair system and only about 10 percent more costly than digital carrier.

b. Future Subscriber Loop Applications

In my mind there is no subscriber loop application that could not be filled by a lightwave system design. Technology has removed two primary design barriers, namely, attenuation and bandwidth. The only real barriers left are cost and subscriber lightwave equipment development.

Figure 2 sketches three cases of subscriber loop applications for lightwave systems. The most likely applications will be to serve a PBX. The Western Reserve nuclear plant application is exactly this except the PBX is a special case of serving a power plant. At least one manufacturer makes an optical interface between the lightwave cable and his digital concentrator equipment.

A second application will be development of an optical interface device to adapt grouped digital subscriber carrier to a lightwave cable. This equipment would be located at SAI housing locations where it would cross to the copper distribution pairs to the individual subscriber. The manufacturers of digital carrier and concentrator equipment will develop more optical transceiver interfaces when they determine savings from using lightwave cable to PBX's or SAI housings will justify their usage.

Finally, the ultimate lightwave subscriber loop design would envision a separate fiber pair or pairs to each subscriber. The technological parameters of 64 kb/s with maximum lengths of 30 kilometers for an individual rural voice frequency circuit are easily attainable. Considerable cable cost reduction and inexpensive subscriber lightwave equipment development are required. Estimated copper pair costs of 3 to 6 cents per meter are still considerably less than fiber optic costs of $1.20 to $2.20 per fiber pair-meter. Large cables containing many fiber pairs would reduce the per fiber pair cost but it will be sometime before it approaches the cost of a copper pair. Even if the fiber costs come down to a competitive level each subscriber and associated central office line would require an optical transceiver. This equipment would be analogous to a single line carrier on a copper pair except it would be required even for the main subscriber line. Single line copper pair carrier pays for itself by eliminating the need to add a second copper pair. The optical transceivers on an individual subscriber line would be required for even one line. In that case the only costs that could pay for them would be an even further reduction in the fiber cost below the cost of a copper pair. Because of these cost problems, I do not see any significant near term application of lightwave systems to individual single line subscribers. There may be some applications to multiline or special subscriber line situations.

D. Summary

Lightwave system design applications are technically feasible and in many cases cost effective in many rural interoffice trunking applications. Lightwave system design applications are technically feasible but not cost effective for generalized in rural subscriber loop applications at this time. Specialized applications in the loop plant such as for electric generating or transmission stations could very well be cost effective. Loop applications to single point, high capacity installations such as large manufacturing plants, government or educational complexes, financial centers, etc. could also be candidates for a fiber optic design.

TABLE 1

REA LIGHTWAVE SYSTEM ACTIVITIES

Company	Location	Optical Cable Supplier	Optical Terminal Supplier	Wavelength (nm)	Transmission Bit Rate
Commonwealth Telephone	Dallas PA	ITT	ITT	830	45 Mb/s
Sugarland Telephone	Sugarland TX	Valtec	Farinon	830	45 Mb/s
Palmerton Telephone	Palmerton PA	Valtec	DCC	830/1300	45 Mb/s
Cross Telephone	Warner OK	Valtec	DCC	1300	45 Mb/s
Roanoke & Botetourt Telephone	Daleville VA	ITT	ITT	830	45 Mb/s
Kingdom Telephone	Auxvasse MO	ITT	ITT	830	1.5 Mb/s
Shenandoah Telephone	Edinburg VA	ITT	Telcom	1300	90 Mb/s
No. Pittsburgh Telephone	Gibsonia PA	Gen.	DCC	1300	90 Mb/s
Guam Telephone	Guam		DCC	820/1300	45 Mb/s
Rio Virgin Telephone	Mesquite NV	Valtec	DCC	1300	1.5 Mb/s
N.W. Mutual	Ray ND			1300	1.5 Mb/s
Hargray Telephone	S. Car.	Valtec	Telcom	850	90 Mb/s
Bluffton Telephone	S. Car.	Valtec	Telcom	1300	90 Mb/s
Tri-County Telephone	New Richmond IN	ITT	ITT		16 Mb/s
Nehalem Telephone	Nehalem OR			1300	45 Mb/s

TABLE 2

SHORT WAVELENGTH FIELD TRIAL COSTS

				CABLE			C.O. EQUIPMENT		SYSTEM	
System	# Fibers	Km	VF Ckts	Total Cost	$/F-M	$/Ckt	Total Cost	$/Ckt	Total Cost	$/Ckt
A	4	22.00	672	$230K	$2.60	$342	$110K	$342	$340K	$505
B	4	41.70	864	N.A.	N.A.	N.A.	N.A.	N.A.	$425K	$492
C	6	11.54	672	$193K	$2.79	$287	$112K	$167	$305K	$454
D	12	5.79	1344	$164K	$2.36	$122	$251K	$187	$415K	$309

TABLE 3

LONG WAVELENGTH FIELD TRIAL COSTS

				CABLE			C.O. EQUIPMENT		SYSTEM	
System	# Fibers	Km	VF Ckts	Total Cost	$/F-M	$/Ckt	Total Cost	$/Ckt	Total Cost	$/Ckt
A	4	6.65	N.A.	$17K*	$0.64*	N.A.	N.A.	N.A.	N.A.	N.A.
B	8	5.63	N.A.	$24K*	$0.53*	N.A.	N.A.	N.A.	N.A.	N.A.
C	10	10.60	1344	N.A.	N.A.	N.A.	N.A.	N.A.	$150K	$112
D	4	19.86	768	$79K	$0.99	$103	$82K	$107	$161K	$210
E	4	10.39	768	$33K	$0.79	$43	$82K	$107	$115K	$150
F	6	47.60	1152	$168K	$0.59	$146	$144K	$125	$312K	$271
G	6	63.00	1152	$227K	$0.60	$197	$176K	$153	$403K	$350
H	8	16.58	672	$99K	$0.75	$147	$156K	$232	$255K	$380
I	4	16.46	N.A.	$69K	$1.05	N.A.	N.A.	N.A.	N.A.	N.A.
J	6	8.14	N.A.	$76K**	$1.56**	N.A.	$32K	N.A.	$108K	N.A.
K	12	8.98	N.A.	$103K	$0.96	N.A.	$37K	N.A.	$140K	N.A.
L	8	15.91	N.A.	$188K**	$1.48**	N.A.	$31K	N.A.	$219K	N.A.
M	6	23.81	N.A.	$44K*	$0.31*	N.A.	N.A.	N.A.	N.A.	N.A.
N	12	4.88	N.A.	$62K	$1.06	N.A.	N.A.	N.A.	N.A.	N.A.
O	8	18.55	N.A.	$132K	$0.89	N.A.	N.A.	N.A.	N.A.	N.A.

* Material Cost Only

** Considerable Trenching

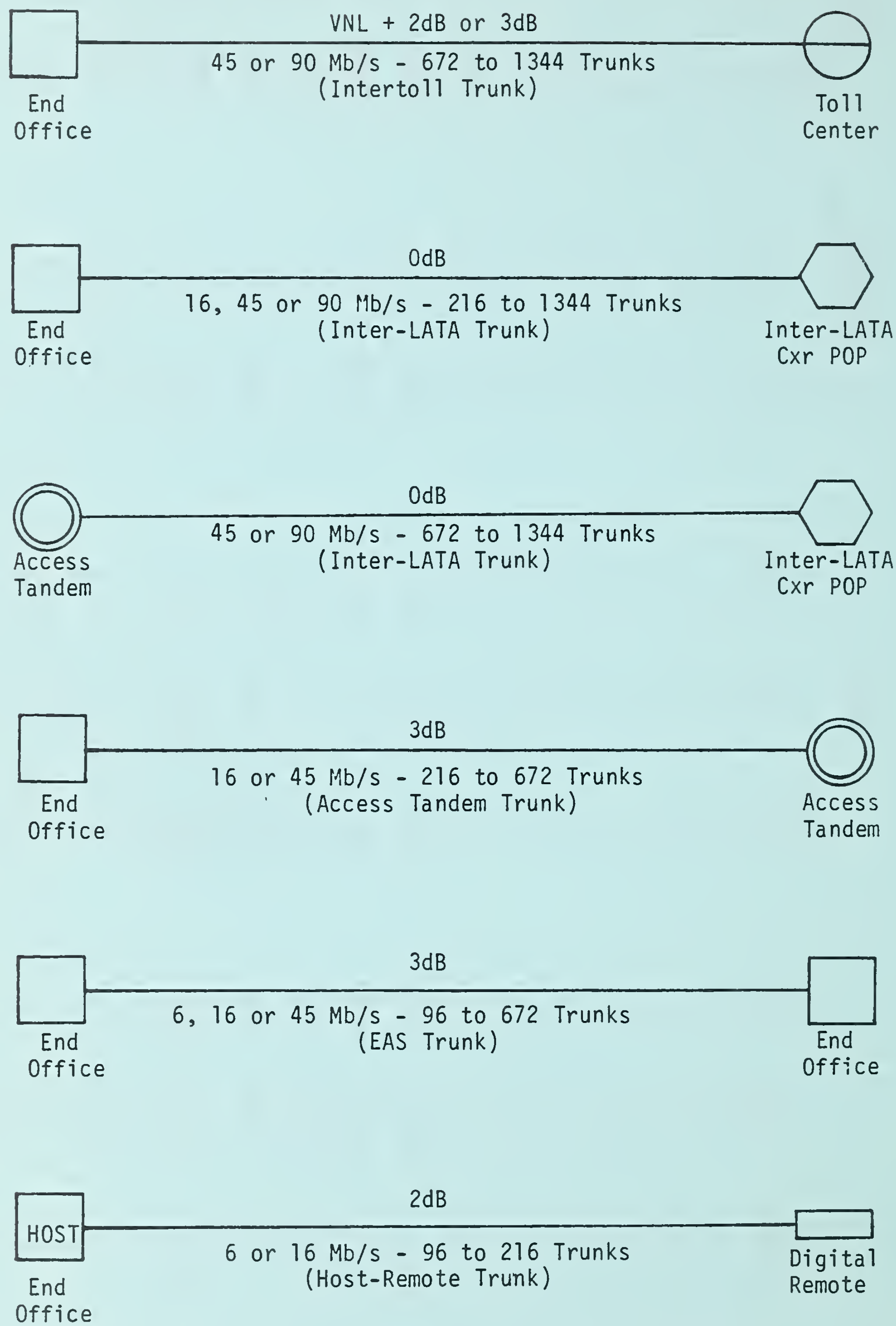


FIGURE 1

PROBABLE RURAL INTEROFFICE TRUNKING LIGHTWAVE APPLICATIONS

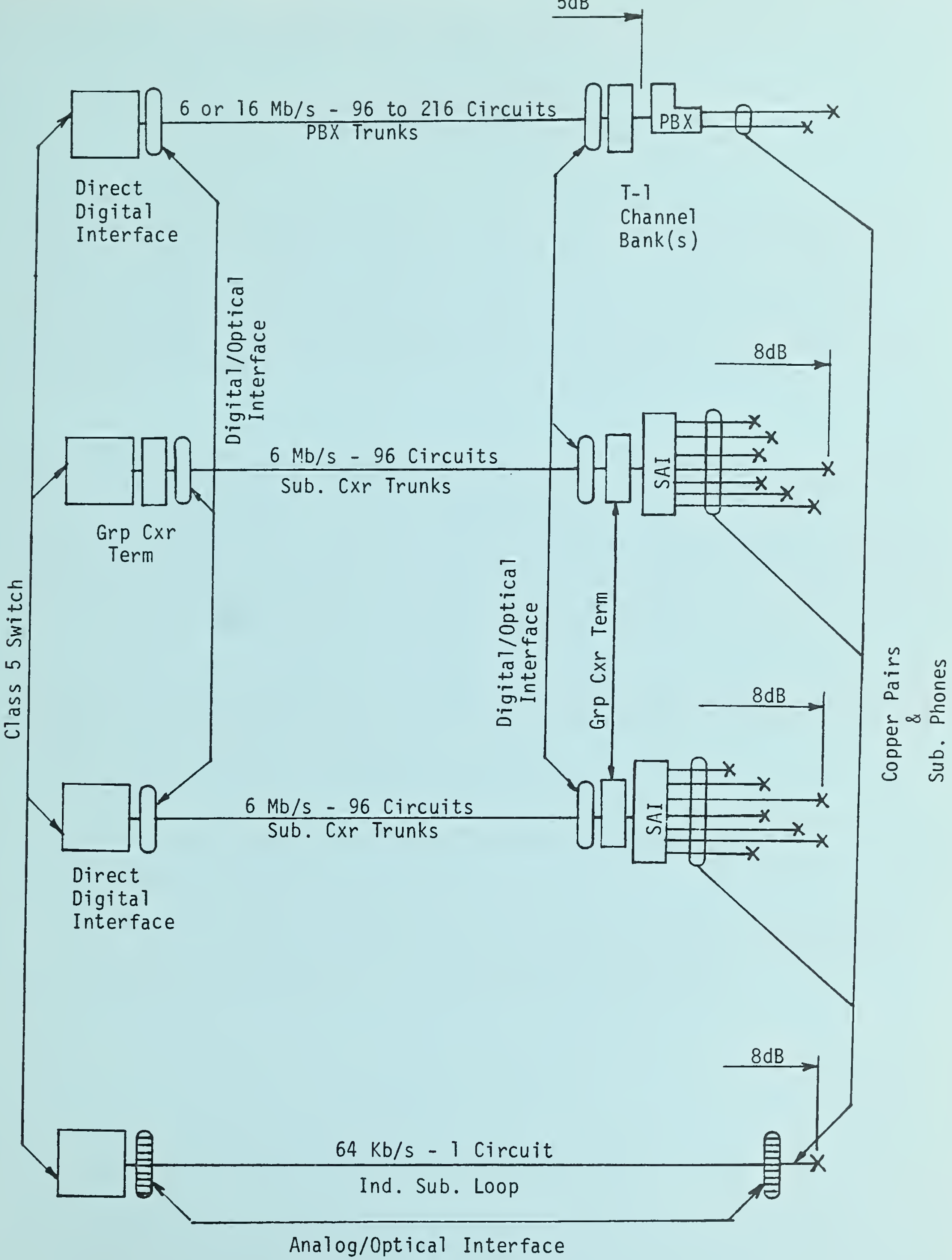


FIGURE 2

CONCEIVABLE SUBSCRIBER LOOP LIGHTWAVE APPLICATIONS

REA/RURAL COALITION NETWORK STUDIES

Gerald S. Schrage
Systems Engineering Branch
Telecommunication Engineering and Standards Division

Since early last year REA has been concerned with deregulation, competition, changes in toll settlement procedures as well as the Bell divestiture and its impact on revenues, tariffs, separations, settlements, and costs to the rural areas of the United States. Our opinion has been that it will mean loss or reduction of some revenue sources with higher charges in most cases to the rural subscriber to make up for these losses. In the long run we see the need to develop new or alternative revenue sources and make use of the lowest cost facilities available so as to keep rural telecommunications affordable and available.

With these goals in mind, last year REA cooperated in an effort with the Rural Coalition to determine what feasible uses satellite technology and other new technologies could have in rural telecommunications. The Rural Coalition consists of three groups, namely, The National Telephone Cooperative Association (NTCA), The Organization for the Protection and Advancement of Small Telephone Companies (OPASTCO), and The National REA Telephone Association (NREATA). From this beginning we have amassed a large volume of information suggesting possible future approaches and options for rural telecommunications companies.

The remainder of this paper will be devoted to reporting on what we have learned and my observations and opinions on what approaches should be seriously considered. The topics to be covered developed in more or less a chronological sequence and I shall discuss them in that manner as follows.

Attachment A - Satellite Informational Meetings

Attachment B - Telephone and Data System (TDS) Facility Survey

Attachment C - Rural Toll Data Questionnaire

Attachment D - Regional Independent Toll Networks (Alabama and Minnesota)

Attachment E - Entrepreneurial Toll Networks (U.S. Switch)

ATTACHMENT A

RURAL COALITION
SATELLITE STUDY GROUP

1. Background

On February 1, 1983, a meeting was held with the REA staff at the request of NASA to inform REA of NASA's concept of an experimental land mobile satellite system and request our support at the FCC in allocating frequency spectrum for this purpose. We were sufficiently impressed with the potential usefulness of this service for rural areas that we sponsored a meeting of the rural telecommunications industry (primarily the Rural Coalition) on March 1 to also hear NASA's views. As a result, REA and members of the Rural Coalition supported NASA's petition to the FCC for frequency space allocations for an experimental land mobile satellite system.

Subsequently, two private entrepreneurial companies solicited meetings in support of their petition to the FCC for authorization for a commercial land mobile satellite system with cellular compatible frequency space in the 800 MHz reserve bands. The Skylink Corporation (a subsidiary of the Synergetics International, Inc.) met with REA on April 8 to discuss the technical and business aspects of their FCC filing. They are currently privately financed for this stage and would require and invite outside capital participation upon award of frequency spectrum. On April 20 the Mobilsat Corporation met with REA and the Rural Coalition for the same purpose. They are inviting capital participation in funding the FCC filing stage.

On May 19 NTCA arranged a meeting of REA and the Rural Coalition with Satellite Business Systems (SBS) to hear their views on uses of satellites for rural applications in general. At this meeting it was decided that a concentrated information gathering process was needed to educate the Rural Coalition on the application of satellites to rural needs.

2. Organization of the Satellite Conference

Three specific services were envisioned as having potential applications in rural communications. These applications were Inter-LATA Trunking, Long Subscriber Loops, and Land Mobile Satellite Systems. A list of potential satellite related organizations was drawn up and each was invited to present a two-hour discussion of any or all of the applications that they would be interested in and the business arrangement they would propose.

A general description of the three applications was given to each organization as follows:

1) Rural Satellite Inter-LATA Trunking. We envision a satellite system capable of supporting four million rural subscribers through 1000 rural telephone companies terminating at the 161 LATA points of

presence. This system would probably operate in a DAMA mode on either a national or regional basis and provide voice frequency trunking to bypass the Class 1, 2, and 3 switching centers in the present terrestrial network.

2) Rural Satellite Subscriber Loops. This application proposes connecting individual customers to their local serving Class 5 office providing standard telephone service and separating subscribers in one company from subscribers in any other company.

3) Rural Satellite Mobile Radio Service. This system would provide mobile radio service to rural subscribers and be capable of operating with the urban area terrestrial cellular mobile radio systems. This system should also be capable of supporting fixed station rural applications.

Applications 1 and 2 are expected to be provided in the C-band or Ku-band frequency allocations and Application 3 would be in the 800 MHz band adjacent to cellular radio. Satellites may be proposed as a single service or hybrid applications.

Letters of invitation were sent to 14 organizations initially and to six more organizations in a second round resulting in 12 presentations being made in two sessions held in June and July per the attached schedule. The major organizations that declined our invitation were AT&T, RCA Americom, and Scientific-Atlanta.

3. Application Evaluation

Of the three suggested applications only two companies, Hughes Communications and Western Union, expressed an interest in all three.

The REA TESD staff is of the opinion after hearing the various presentations that the inter-LATA trunking application should be the first priority for the study group to follow up on. We believe this application is of the most immediate need, has the largest potential traffic volume and is most likely to be economically feasible. We recommend that a traffic model or models be created from data supplied to an engineering committee from a representative sample of REA borrowers. REA would expect to play a major role in the engineering model committee. We would expect the industry associations to assume the role of collecting the necessary traffic data from their members.

The engineering committee would list the data to be collected, but at a minimum it would include for each borrower the following items:

a. Type, size, and location of switch(es)
b. Class 4 functions available
c. Number, size, and destination of toll trunk groups
d. Average busy hour toll traffic by toll group by:

First Session
RURAL COALITION SATELLITE CONFERENCE SCHEDULE
(Room 4306)

	Wed. - June 15	Thurs. - June 16	Fri. - June 17
9:00 a.m.	Satellite System Engineering, Inc. (Pat McDougal)	Ford Aerospace (John Fedak) Vice President- Engineering & System Operations	Skylink Corporation (Laren Kragh) Vice President - Marketing
11:00 a.m.	RCA American Communications (David Martin) Manager, Long Term Planning CANCELED	Satellite Business Systems (R. H. Smith)	Hughes Communications (Ray Lekowski & Norman Weinhouse) Manager, Systems Engineering and Planning
1:00 p.m.	LUNCH	LUNCH	LUNCH
2:00 p.m.	GTE Products Corp. (Jack Golin) Director, Satellite & Video Communications	Mobile Satellite Corp. (John Keisling) President	Unassigned
4:00 p.m.			

RURAL COALITION SATELLITE CONFERENCE SCHEDULE
Second Session
(Room 4306)

	Monday - July 18	Tuesday - July 19
9:00 a.m.	United States Satellites Systems James McKeeff Vice President	Starnet Paul Gaillard Senior Vice President Industry Relations
11:00 a.m.	American Satellite Irwin LeBow Engineering Manager John Johnson Manager, Government Relations	Western Union Mary Kay Williams Director, Satellite Planning Fred Knipp Senior Director, Satellite Services
1:00 p.m.	LUNCH	LUNCH
2:00 p.m.	TeleSat - Canada D. Look Senior Market Analyst RESCHEDULED	Southern Pacific Satellite Corporation Frank Bowen Marketing Manager of Voice Data Services
4:00 p.m.		

(1) Day of week

(2) Time of day

(3) By destination (intra-LATA, adjacent LATA, inter-LATA (home state), inter-LATA (outside home state))

Our first concept of a traffic model envisioned one satellite system serving the entire national base of REA borrowers. This certainly should be one of the models to be constucted and evaluated. However, several companies in Minnesota, Alabama, Wisconsin, and South Carolina are interested in developing regional or state terrestrial networks to capture and control their own and other regional traffic and delivering the remainder to another carrier which could be a satellite system. This would require less ultimate satellite capacity and should also be a model to be studied.

One borrower (Brindlee Mountain Telco) is actively pursuing this approach with one of their customers (SCI) who has now become a partner in the project. SCI built a private microwave system from Huntsville to Arab, Alabama, to link their manufacturing plants together using the Arab NEAX 61 switch and central office facilities. Brindlee Mountain uses the facilities as a reseller in Huntsville. SCI is extending the facilities to Birmingham and reselling in Birmingham will then be available through the Arab switch. Brindlee proposes that this backbone microwave extend through Alabama picking up Montgomery and Mobile with the independent telcos constructing facilities to interconnect with the backbone route. Brindlee would offer to provide switching for intra-Alabama traffic for all companies that want it. Their traffic studies show that most of their toll traffic is to their associated LATA or to the adjacent LATA with 66 percent of all toll traffic staying within Alabama. By keeping all of this Alabama traffic on their own facilities and acting as their own inter-LATA carrier they estimate that instead of getting 25 cents of a one dollar toll call they would keep 75 cents and triple their after divestiture toll revenue. This new revenue source would effectively replace the expected loss in revenue from the changes in the separations and settlements agreements. Because the independent telcos are not bound by the court decreed LATA boundaries, the opportunity for regional terrestrial networks handling the regional toll traffic and handing off the inter-LATA traffic to the carrier that offers the best business deal is very promising.

The other two applications (long subscriber loops and land mobile satellite systems) are borderline in TESD's view and should be downgraded to a lower study priority. Our reasoning for this is that, in the case of long subscriber loops, the cost is prohibitive ($25,000 to $50,000 each) for general subscriber loop applications at this time. If type acceptance is granted by the FCC, we recommend considering terrestial subscriber radio in the 2 GHz band as a more economical solution for clustered subscribers. In the case of land mobile satellite systems, they should be reconsidered at a later time if and when a frequency allocation for this service is made by the FCC. The FCC has requested comments on the applications of both Mobilsat and Skylink for experimental land mobile satellite systems. REA comments to the FCC suggested that neither be approved and that the FCC should first allocate frequency spectrum and then accept applications from all qualified parties. Both of the current applicants offered only minority business positions to the Rural Coalition and if spectrum becomes available the Coalition may wish to apply for it and build their own system.

4. Evaluation of Presentations

We will briefly discuss each of the twelve presentations that were made and highlight our impressions and judgment of their interests and capabilities. The following table summarizes our evaluations.

Organization	1st Study Priority	Separate Study Effort 2nd Priority		
	Inter-LATA Trunking	Long Subscriber Loops	Land Mobile Satellite	No Further Consideration
GTE Spacetel	X	X		
Ford Aerospace	X			
Hughes Communications	X	X	X	
Western Union	X	X	X	
Mobilsat			X	
Skylink			X	
Satellite Sys. Engr.				X
SBS				X
U. S. Satellite				X
American Satellite				X
Starnet				X
GTE Spacenet				X

A. No Further Consideration

Let's first discuss those organizations that we recommend that no further consideration be given at this time.

Satellite System Engineering - This company or one of the same quality and capability will be necessary to provide spacecraft consultant engineering in the design phase. However, we don't believe it is necessary to have this capability for the next stage which should be a traffic modeling exercise.

SBS - By their own admission SBS doesn't comprehend how they could serve or make money serving rural America by their satellite system. We agree with their assessment when, for example, they quote leasing costs of $45,000 to $60,000 per month for their earth stations. They are, however, talking with larger borrowers about large regional traffic volumes.

U. S. Satellite - Our impression of U. S. Satellite is that it is primarily interested in becoming a space segment broker and not providing a system approach. Perhaps if the Coalition develops a satellite system they might provide some space segment capacity.

American Satellite - They did not appear to us to be interested in rural applications at this time. However, they certainly have capacity and capability and may wish to consider rural applications at some future time.

Starnet - Starnet offered to be a carriers' carrier to the Rural Coalition. This does not address the question the Coalition wanted to know, i. e., should the rural industry develop their own satellite system. If the industry does not develop their own system then Starnet will be another competing inter-LATA carrier to be considered.

GTE Spacenet - Since the acquisition of SPCC by GTE the coordinated GTE approach to rural satellite needs will be handled by GTE Spacetel.

B. Inter-LATA Trunking Appliclation

TESD recommends that the following organizations be considered for the traffic modeling phase of the inter-LATA application.

GTE Spacetel - GTE Spacetel has declared that they will be the developer of a total GTE approach for rural GTE companies and REA borrowers space systems needs. They have satellites, transponder capacity, operating experience, the lowest cost proposed earth stations with translation and routing, and a demand assignment, multiple access (DAMA) system design. GTE has extensive experience from its operating and manufacturing companies in interfacing with the national telephone network.

Ford Aerospace - Ford is a builder of satellites and has constructed many of the Intelsat satellites for international communications. It has DAMA experience as the first system of this type (SPADE) was used on an Intelsat satellite. The primary advantage of Ford is that they are reducing transponder costs and offering long term fixed price contracts. Their primary drawback is that their earth stations have no translation and routing capabilities which would impair their usefulness with SxS switches. If a borrower could not access a digital switch this could increase the cost.

Hughes Communications - Hughes was very impressive in its eagerness and agressiveness to respond to rural satellite applications. They did a considerable amount of preliminary system design and analysis work. Hughes has the capability to offer a total system solution. They build satellites and have transponder capacity. They have experience from Indonesia in building a complete rural type DAMA system in a short time frame. They have experience in selecting earth stations and ground equipment that they don't manufacture themselves.

Western Union - Western Union has been first in many satellite aspects starting with the first domestic satellite. They have been in telecommunications for many years and understand and can handle the interfacing problems They probably have more satellites and transponder capacity than any other organization. In addition they have an extensive transcontinental terrestrial microwave system that can be integrated into any solution.

C. Long Subscriber Loop Application

As stated previously, TESD recommends that a separate study effort of second priority be directed toward the problem of long subscriber loops and land mobile satellites. When the timing and resources are right for this effort, we recommend the following companies be considered.

GTE Spacetel - Has developed and is testing a semimobile earth station with translation and routing capability for an estimated cost of $25,000 each in production runs of at least 5,000 units. The central office end of this system would cost $500,000. This would not be useful for an average subscriber, but could find uses on a specialized basis.

Hughes Communications, Western Union - Both companies did not have any concrete proposals but are both interested. With their capabilities each could be expected to develop competitive systems.

D. Land Mobile Satellite Application

Land mobile satellite systems are a very useful service that could be provided to rural America. With the high cost of current equipment we expect the market to be very small in a typical rural exchange. Also with the opposition from the urban cellular system providers to the proposed frequency allocation, we expect a considerable amount of time will pass before the FCC makes a decision. Therefore, we believe that rural land mobile satellite programs should consist of keeping informed of technical and economic changes and advocating frequency spectrum from the FCC.

Mobilsat - Has filed with FCC for frequency space. Invites funding participation for filing stage. Has two former G.E. employees who have designed a system based on ATS-6 experimental equipment they produced at G.E. G.E. is a funding entity to their venture and rural members would have a minority position. Entire venture depends on FCC action.

Skylink - Has filed with FCC for frequency space. Has developed a proprietary transponder amplifier for land mobile service that claims to greatly improve the technical system design. Claims to have agreement on transborder problems with Telesat Canada. Offers only limited partnerships to rural industry. Currently is privately financed for filing stage. Appears to be most interested in national services that bypass telcos. Entire venture depends on FCC action.

Hughes Communications, Western Union - Neither company has plans for a land mobile satellite system of their own but both are interested in developing one for the Rural Coalition. If the FCC opens up frequency space and the Coalition applies and receives authorization then both companies should be approached to present their designs. Western Union has proposed an especially technical novel approach of spread spectrum modulation which might be used on existing or new satellites.

5. Where do we go from here? - Summary

TESD recommends that the majority of the efforts and resources of the group be directed at this time to the inter-LATA trunking application. Long subscriber loops and land mobile satellite applications should be deferred until a technical cost effective breakthrough or FCC action respectively causes a need to revisit the problem.

TESD recommends an engineering study group be organized to create rural traffic models, present such models to potential system suppliers, evaluate the results and report back to the Coalition. In addition the engineering committee would be charged with considering and evaluating any future potential suppliers and presenting the same traffic models to them if appropriate in the judgment of the committee.

TESD recommends that the engineering committee concentrate on developing a DAMA system but allow each supplier to recommend the type of modulation (time-division, frequency modulation, or amplitude modulation) that they prefer for their design. The engineering committee is to request that each supplier provide a proposed system design and cost solution to identical traffic models.

TESD recommends the industry members of the Coalition assume responsibility for collecting from a representative national sample ($\approx$200 companies) traffic modeling data as requested by the engineering committee.

REA recommends that the industry members of the Coalition develop a proposed business and legal structure for national or regional satellite organization(s) with proposed permanent long term funding sources.

REA recommends that the industry members of the Coalition create a short term voluntary contributary financing source for the activities of the study group. In addition to this proposed one time funding they should poll their members on their views on a permanent voluntary contribution effort to fund future R&D projects as the Coalition sees fit.

REA for its part will study applicable laws and regulations with the view toward developing an appropriate loan financing policy. This policy would address all needs for financing competitive and economical toll facilities whether terrestrial or satellite in nature or local, regional, or national in scope.

6. Current Update

Since I made this report progress has been made even if at times it seems ever so slow. We have generated the proposed rural toll traffic questionnaire suggested and it will be discussed in Attachment C. More accurate and precise revenue data on regional networks is available and is discussed in Attachment D. Entrepreneurial companies have made proposals and will be discussed Attachment E. Since we initially met with them both Mobilsat and Skylink have applied for frequency allocations for land mobile satellite service. The FCC has requested comments on the technical merits of these two applications. REA's response has been that neither should be accepted but that a frequency allocation rulemaking should be undertaken and then applications accepted from any qualified organization.

ATTACHMENT B

At the request of the Rural Coalition, Donald L. Porter, Director of Marketing, Telephone and Data Systems, accepted the task of surveying the rural companies served by TDS to determine who didn't have telephone service and why. At that time TDS consisted of 55 operating companies scattered throughout 22 states and serving 274,356 telephones. The results of this survey were surprising in that it indicates only a very small percentage of households (5.8%) don't have telephones because of lack of facilities. This result reinforced the opinion that the present high cost of individual earth stations ($25 to 50K) combined with the apparent small market makes satellite facilities for local loop POTS service unattractive. What follows below is excerpts from Don Porter's detailed report.

PRIMARY RURAL SATELLITE TELEPHONE SERVICES

To find out if there is a true need for Primary Rural Satellite Telephone Service, I researched the 1980 Census of Population and Housing - Advance Estimates of Social, Economic and Housing Characteristics (reference: PHC80-S2). At the time I prepared this report, I showed 5,676,178 households in the United States without telephone service. In order to find out the reasons for these occupied housing units which do not have telephone service, either for economic, facilities or other reasons, I took the liberty of looking at all Telephone Data Systems serving areas for the same time frame. (See attached copy)

In TDS serving areas, there are 129,851 total housing units. Of these 118,307 housing units were with telephone service. We also found there were 11,544 housing units without telephone service.

Of the housing units without telephone service, we found 6.075 (52.6%) to be for economic reasons, 655 (5.8%) due to facilities, and 4,084 (41.6%) to be for other reasons.

Using TDS serving areas as a universe, we found that of the 5,676,178 housing units in the United States without telephone service; 2,985,670 (52.6%) were because of economic reasons, 329,218 (5.8%) were due to facilities, and 2,361,290 (41.6%) were for other reasons.

In reviewing our own construction plans in the TDS serving areas, I would guess that within the next three years, only 25% of the percentage shown above would remain due to facility problems.

The column which concerns me most is the "Economic" column which showed our largest percentile. Perhaps additional studies should be conducted regarding lifeline telephone services in depressed economic areas.

In the "Other" column (which would include housing units such as summer cottages or second homes), all of these could most likely receive service if desired.

Donald L. Porter
Director of Marketing
Telephone and Data Systems, Inc.

PROFILE OF TELEPHONE AND DATA SYSTEMS SERVING AREAS FOR POTENTIAL CUSTOMERS WITHOUT PHONES

1. Columns 1-7 were taken from the 1980 Census of Population and Housing - Advance Estimates of Social, Economic, and Housing Characteristics (report number PHC80-S2).

   Column 6 is computed by dividing the total number of occupied housing units with phones (Column 4) by the total occupied housing units (Column 3).

   Column 7 is computed by dividing the total number of occupied housing units without phones (Column 5) by the total number of occupied housing units (Column 3).

2. Column 8 is taken from the 1980 TDS Statistical Report on Residential Customers.

3. To get Column 10, we divided Column 8 by Column 4.

4. To get Column 9, we added Column 11 and Column 8.

5. To get Column 11, we multiplied Column 8 by Column 7.

6. To get the percentage of reasons for TDS households without telephone service in TDS areas, Columns 12, 13 and 14 were calculated based on the best judgment of the managers in local serving areas.

7. The figures in Column 11 (occupied housing units in TDS areas without phones) were computed using the county percentage of occupied housing units without phones (Column 7).

COMPANY	(1) POP./COUNTY	(2) TOTAL HOUSING UNITS	(3) OCCUPIED HOUSING UNITS	(4) WITH PHONES	(5) W/OUT PHONES	(6) % OF OCCUPIED HOUSEHOLDS WITH PHONES	(7) % OF OCCUPIED HOUSEHOLDS IN COUNTY W/OUT PHONES	(8) NO. CUSTOMERS IN TDS AREA WITH PHONES 12-31-80 (RESIDENTIAL)	(9) TOTAL OCCUPIED HOUSING UNITS IN TDS AREA	(10) % OF OCCUPIED HOUSING UNITS W/ PHONES IN COUNTY SERVED BY TDS	(11) OCCUPIED HOUSING UNITS IN TDS AREA W/OUT PHONES	(12) PERCENTAGES OF REASONS FOR NO SERVICE (ECONOMIC)	(13) (FACILITIES)	(14) (OTHER)
Arcadia	Hancock 64581	24535	23058	22061	997	95.7	4.3	569	593	2.6	24	88%	0	12%
Augusta	Kalamazoo 212378	79333	75405	72807	2598	96.6	3.4	1207	1248	1.7	41	73%	0	27%
Clayton	Lenawee 89948	33533	30044	28785	1259	95.8	4.2	520	542	1.8	22	55%	0	45%
Elnora	Daviess 27836	10511	9878	8888	990	90.0	10.0	374	411	4.2	37	84%	0	16%
Fayetteville	Brown 31920	11806	10683	9095	1588	85.1	14.9	864	993	9.5	129	87%	0	13%
Home - Waldron	Shelby 39887	14821	13823	12916	907	93.4	6.6	1607	1713	12.4	106	84%	0	16%
Home - Pittsboro	Hendricks 69804	23606	22683	21909	774	96.6	3.4	1120	1158	5.1	38	76%	0	24%
Continental	Putnam 32991	10629	10110	9759	351	96.5	3.5	1146	1186	11.7	40	90%	0	10%
"	Paulding 21302	7530	7007	6413	594	91.5	8.5	372	404	5.8	32	94%	0	6%
"	Van Wert 30498	11603	10939	10347	592	94.6	5.4	184	194	1.8	10	100%	0	0
Hickory	Barry 45781	17743	15433	14790	643	95.8	4.2	630	656	4.3	26	77%	0	23%
"	Kalamazoo 212378	79333	75405	72807	2598	96.6	3.4	344	356	.5	12	83%	0	17%
Shiawassee	Ingham 275520	99453	95179	91801	3378	96.5	3.5	313	324	.3	11	73%	0	27%
"	Shiawassee 71140	24398	23359	22304	1055	95.5	4.5	2871	3000	12.9	129	94%	0	6%
"	Livingston 100289	33261	31344	30324	1020	96.7	3.3	157	162	.5	5	80%	0	20%
C.C.I.	Putnam 29163	10171	9404	8716	688	92.7	7.3	1426	1530	16.4	104	95%	0	5%
"	Hendricks 69804	23606	22683	21909	774	96.6	3.4	2200	2275	10.0	75	97%	0	3%
"	Morgan 51999	18196	17160	16160	1000	94.2	5.8	264	279	1.6	15	100%	0	0
"	Montgomery 35501	13681	12967	12420	547	95.8	4.2	300	313	2.4	13	100%	0	0
"	Crawford 9820	4017	3462	2883	579	83.3	16.7	72	84	2.5	12	17%	0	83%
"	Orange 18677	7388	6717	5778	939	86.0	14.0	15	17	.3	2	0	0	100%
BLACK EARTH	DANE 323545	125611	120601	118051	2550	97.9	2.1	826	843	.7	17	5%	0	95%
BLACK EARTH	IOWA 19802	7328	6767	6417	350	94.8	5.2	6	6	.09	.31	0	0	0
BB&W	RACINE 173132	61626	59418	57997	1421	97.6	2.4	863	884	1.5	21	38%	0	62%
BB&W	WALWORTH 71507	28835	24789	23962	827	96.7	3.3	16	16	.06	.52	0	0	0
BB&W	KENOSHA 123137	45981	43064	41447	1617	96.2	3.8	1305	1355	3.1	50	30%	0	70%
CENTRAL STATE	WOOD 72799	26026	25067	24311	756	97.0	3.0	3515	3620	14.5	105	0	0	100%
" "	MARATHON 111270	39320	37703	36238	1465	96.1	3.9	127	132	.4	5	0	0	100%
" "	JACKSON 16831	6560	6073	5647	426	93.0	7.0	74	79	1.3	5	0	0	100%
" "	JUNEAU 21039	8435	7595	7070	525	93.1	6.9	981	1049	13.9	68	0	0	100%
" "	CLARK 32910	11920	11027	10446	581	94.7	5.3	55	58	.5	3	0	0	100%

COMPANY	(1) POP./ COUNTY	(2) TOTAL HOUSING UNITS	(3) OCCUPIED HOUSING UNITS	(4) WITH PHONES	(5) W/OUT PHONES	(6) % OF OCCUPIED HOUSEHOLDS WITH PHONES	(7) % OF OCCUPIED HOUSEHOLDS IN COUNTY W/OUT PHONES	(8) NO. CUSTOMERS IN TDS AREA WITH PHONES 12-31-80 (RESIDENTIAL)	(9) TOTAL OCCUPIED HOUSING UNITS IN TDS AREA	(10) % OF OCCUPIED HOUSING UNITS W/ PHONES IN COUNTY SERVED BY TDS	(11) OCCUPIED HOUSING UNITS IN TDS AREA W/OUT PHONES	(12) PERCENTAGES OF REASONS FOR NO SERVICE (ECONOMIC)	(13) (FACILITIES)	(14) (OTHER)
Amelia	Amelia 8405	2976	2758	2389	369	86.6	13.4	2163	2453	90.5	290	39%	1%	60%
Barnardsville	Buncombe 160934	64768	60274	55778	4496	92.5	7.5	589	633	1.5	44	82%	0	18%
Service	Columbus 51037	18754	17266	13810	3456	80.0	20.0	694	833	5.0	139	25%	0	75%
Calhoun City	Calhoun 15664	5958	5420	4556	864	84.1	15.9	2356	2731	51.7	375	10%	0	90%
"	Webster 10300	3898	3591	3005	586	83.7	16.3	25	29	.8	4	25%	0	75%
"	Yalobusha 13139	5416	4583	3585	998	78.2	21.8	35	43	1.0	8	12%	0	88%
"	Chickasaw 17853	6341	5871	4725	1146	80.5	19.5	10	12	.2	2	0	0	100%
"	Grenada 21043	7535	7111	6107	1004	85.9	14.1	83	95	1.4	12	10%	0	90%
McClellanville	Charleston 276974	99240	90570	81517	9053	90.0	10.0	793	872	1.0	79	89%	0	11%
Peoples	Cherokee 18760	7377	6505	5147	1358	79.1	20.9	4680	5658	90.9	978	0	39%	61%
"	DeKalb 53658	20605	19247	15845	3402	82.3	17.7	2085	2454	13.2	369	5%	0	95%
"	Etowah 103057	39824	36864	33107	3757	89.8	10.2	136	150	.4	14	100%	0	0
St. Stephen	Berkley 94727	31251	28940	25370	3570	87.7	12.3	2410	2706	9.5	296	80%	0	20%
Williston	Barnwell 19868	7193	6471	5401	1070	83.5	16.5	1150	1340	21.3	190	90%	0	10%
"	Orangeburg 82276	28678	25643	21000	4643	81.9	18.1	1104	1304	5.3	200	89%	1%	10%
"	Aiken 105625	39621	36456	32516	3940	89.2	10.8	316	350	1.0	34	90%	0	10%
"	Marion 765233	309455	285092	268390	16702	94.1	5.9	6	6	.002	.35	0	0	0
"	Hamilton 82027	29018	27263	26320	943	96.5	3.5	15	15	.05	.52	0	0	0
Concord	Knox 319694	125803	117951	109585	8366	92.9	7.1	5282	5657	4.8	375	66%	0	34%
Tennessee	Henderson 21390	8255	7686	6586	1100	85.7	14.3	1539	1759	23.4	220	66%	9%	25%
"	Decatur 10857	4814	4081	3365	716	83.7	17.8	2781	3276	82.6	495	59%	11%	30%
"	Perry 6111	2624	2240	1803	437	80.5	19.5	1666	1991	92.4	325	63%	4%	33%
"	Carroll 28285	11278	10321	9263	1058	89.7	10.3	1465	1616	15.8	151	66%	0	34%
"	Benton 14901	6489	5577	4945	632	88.7	11.3	74	82	1.5	8	63%	0	37%
"	Wayne 13946	5166	4792	3714	1078	77.5	22.5	3644	3664	98.1	20	0	100%	0
"	Wilson 56064	20068	18863	17073	1790	90.5	9.5	5482	6003	32.1	521	66%	0	34%
"	Rutherford 84058	30432	28002	25508	2494	91.1	8.9	1587	1728	6.2	141	63%	4%	33%
"	Davidson 477811	187400	177737	167521	10216	94.3	5.7	158	167	.09	9	67%	0	33%
"	Marshall 19698	7633	7144	6236	908	87.3	12.7	535	603	8.6	68	65%	0	35%
"	Knox 319694	125803	117951	109585	8366	92.9	7.1	3907	4184	3.6	277	66%	0	34%

COMPANY	(1) POP./ COUNTY	(2) TOTAL HOUSING UNITS	(3) OCCUPIED HOUSING UNITS	(4) WITH PHONES	(5) W/OUT PHONES	(6) % OF OCCUPIED HOUSEHOLDS WITH PHONES	(7) % OF OCCUPIED HOUSEHOLDS IN COUNTY W/OUT PHONES	(8) NO. CUSTOMERS IN TDS AREA WITH PHONES 12-31-80 (RESIDENTIAL)	(9) TOTAL OCCUPIED HOUSING UNITS IN TDS AREA	(10) % OF OCCUPIED HOUSING UNITS W/ PHONES IN COUNTY SERVED BY TDS	(11) OCCUPIED HOUSING UNITS IN TDS AREA W/OUT PHONES	(12) PERCENTAGES OF REASONS FOR NO SERVICE (ECONOMIC)	(13) (FACILITIES)	(14) (OTHER)
MERIDEN	SULLIVAN 36063	15211	13306	12126	1180	91.1	8.9	228	248	1.9	20	0	0	100%
NORTHFIELD	WASHINGTON 52393	19736	18613	17419	1194	93.6	6.4	1875	1995	10.8	120	42%	16%	42%
EDWARDS	ST. LAWRENCE 114254	38220	35801	32401	3400	90.5	9.5	1239	1356	3.8	117	40%	0	60%
PERKINSVILLE	WINDSOR 51030	21758	19054	17755	1299	93.2	6.8	526	562	3.0	36	30%	0	70%
SUGAR VALLEY	CLINTON 38971	14491	13534	12752	782	94.2	5.8	661	699	5.2	38	20%	0	80%
WARREN	KNOX 32941	13596	12165	11284	881	92.8	7.2	743	796	6.6	53	65%	0	35%
WARREN	LINCOLN 25691	10612	9494	8892	602	93.7	6.3	7	7	.07	.44	0	0	0
HARTLAND	SOMERSET 45028	17161	15346	13533	1813	88.2	11.8	1766	1974	13.0	208	60%	0	40%
HARTLAND	PISCATAQUIS 17634	7109	6290	5597	693	89.0	11.0	105	117	1.9	12	100%	0	0
LUDLOW	WINDSOR 51030	21758	19054	17755	1299	93.2	6.8	1937	2069	10.9	132	0	0	100%
SOMERSET	KENNEBEC 109889	41114	38579	35860	2719	93.0	7.0	216	231	.6	15	13%	40%	47%
SOMERSET	FRANKLIN 27098	10622	9424	8604	820	91.3	8.7	2555	2777	29.7	222	28%	27%	45%
SOMERSET	SOMERSET 45028	17161	15346	13533	1813	88.2	11.8	2448	2737	18.1	289	48%	17%	35%
KEARSARGE	MERRIMACK 98302	37170	34674	32587	2087	94.0	6.0	2984	3163	9.2	179	20%	0	80%
KEARSARGE	SULLIVAN 36063	15211	13306	12126	1180	91.1	8.9	28	30	.2	2	0	0	100%
WEST PENOBSCOT	PENOBSCOT 137015	49416	45974	42389	3585	92.2	7.8	1151	1241	2.7	90	61%	0	39%
CENTRAL STATE	PORTAGE 57420	19450	18313	17741	572	96.9	3.1	583	601	3.3	18	0	0	100%
MIDWAY	CLARK 32910	11920	11027	10446	581	94.7	5.3	3793	3994	36.3	201	8%	0	92%
"	MARATHON 111270	39320	37703	36238	1465	96.1	3.9	12	12	.03	.46	0	0	0
"	TAYLOR 18817	6641	6167	5780	387	93.7	6.3	605	643	10.5	38	5%	0	95%
MOSEL & CENTERVILLE	MANITOWOC 82918	29594	28525	27751	774	97.3	2.7	833	855	3.0	22	15%	0	85%
"	SHEBOYGAN 100935	36711	35484	34704	780	97.8	2.2	1324	1353	3.8	29	15%	0	85%
MT. VERNON	DANE 323545	125611	120601	118051	2550	97.9	2.1	2378	2428	2.0	50	25%	0	75%
"	GREEN 30012	11260	10759	10431	328	97.0	3.0	952	981	.8	29	25%	0	75%
PEOPLES	GRANT 51736	17625	16686	16195	491	97.1	2.9	1396	1436	8.6	40	10%	0	90%
STOCKBRIDGE & SHERWOOD	BROWN 175280	62008	59908	58365	1543	97.4	2.6	12	12	.02	.31	0	0	0
"	CALUMET 30867	10042	9694	9457	237	97.6	2.4	1237	1267	13.1	30	5%	3%	92%
"	MANITOWOC 82918	29594	28525	27751	774	97.3	2.7	166	170	.6	4	0	0	100%
"	KEWAUNEE 19539	6854	6473	6174	299	95.4	4.6	250	262	4.0	12	5%	0	95%
QUINCY	GADSDEN (FL) 41565	13193	12092	9826	2266	81.2	18.7	5774	6853	58.8	1079	98%	0	2%
QUINCY	DECATUR (GA) 25495	9065	8315	6973	1342	83.9	16.1	478	555	6.9	77	98%	0	2%

COMPANY	(1) POP./ COUNTY	(2) TOTAL HOUSING UNITS	(3) OCCUPIED HOUSING UNITS	(4) WITH PHONES	(5) W/OUT PHONES	(6) % OF OCCUPIED HOUSEHOLDS WITH PHONES	(7) % OF OCCUPIED HOUSEHOLDS IN COUNTY W/OUT PHONES	(8) NO. CUSTOMERS IN TDS AREA WITH PHONES 12-31-80 (RESIDENTIAL)	(9) TOTAL OCCUPIED HOUSING UNITS IN TDS AREA	(10) % OF OCCUPIED HOUSING UNITS W/ PHONES IN COUNTY SERVED BY TDS	(11) OCCUPIED HOUSING UNITS IN TDS AREA W/OUT PHONES	(12) PERCENTAGES OF REASONS FOR NO SERVICE (ECONOMIC)	(13) (FACILITIES)	(14) (OTHER)
Troy	Latah 28749	10903	10256	9676	580	94.3	5.7	547	578	5.7	31	48%	3%	49%
Home	Gilliam 2057	993	778	730	48	93.8	6.2	459	487	62.9	28	50%	0%	50%
Mid-State	Stearns 108161	33690	32113	31130	983	96.9	3.1	409	422	1.3	13	40%	0%	60%
"	Pope 11657	4637	4241	4030	211	95.0	5.0	440	462	10.9	22	60%	0%	40%
"	Swift 12920	5131	4694	4496	198	95.8	4.2	114	119	2.5	5	50%	0%	50%
"	Kandiyohi 36763	13686	12871	12389	482	96.3	3.7	3104	3219	25.1	115	80%	0%	20%
"	Meeker 20594	7668	7178	6842	336	95.3	4.7	104	109	1.5	5	50%	0%	50%
Asotin	Asotin, WA 16823	6964	6470	6014	456	93.0	7.0	626	670	10.4	44	88%	11%	1%
"	Wallowa OR 7273	3198	2813	2550	263	90.7	9.3	62	68	2.4	6	0%	100%	0%
'	NezPerceID 33220	13462	12490	11774	716	94.3	5.7	2	2	.01	.11	0%	~ 0%	0%
Oklahoma	Oklahoma 568933	241668	220580	208297	12283	94.4	5.6	3094	3267	1.5	173	69%	0%	31%
"	Mayes 32261	13144	11622	10548	1074	90.8	9.2	654	714	6.2	60	84%	3%	13%
"	Rogers 46436	16922	15650	14830	820	94.8	5.2	1103	1160	7.4	57	70%	4%	26%
"	Wagoner 41801	15399	13768	12282	1486	89.2	10.8	17	19	.1	2	100%	0%	0%
"	Creek 59016	22608	20899	19237	1662	92.0	8.0	1109	1198	5.8	89	79%	4%	17%
"	Tulsa 470593	195395	181620	171776	9844	94.6	5.4	126	133	.07	7	100%	0%	0%
"	Okmulgee 39169	15610	14314	12612	1702	88.1	11.9	130	145	1.0	15	80%	7%	13%
"	Caddo 30905	12100	11069	9847	1222	89.0	11.0	1140	1265	11.6	125	80%	2%	18%
"	Comanche 112456	39943	35142	30827	4315	87.7	12.3	1411	1585	4.6	174	58%	2%	40%
"	Canadian 56452	20659	18648	17836	812	95.6	4.4	265	277	1.5	12	66%	17%	17%
"	Grady 39490	15749	14302	13265	1037	92.7	7.3	235	252	1.8	17	59%	12%	29%
FENNIMORE	GRANT 51736	17625	16686	16195	491	97.1	2.9	1221	1256	7.5	35	0	0	100%
GREENWOOD	CLARK 32910	11920	11027	10446	581	94.7	5.3	1110	1169	10.6	59	10%	0	90%
BONDUEL	WAUPACA 42831	16188	14954	14388	566	96.2	3.8	4	4	.02	.15	0	0	0
BONDUEL	SHAWANO 35928	13435	12347	11753	594	95.2	4.8	1156	1211	9.8	55	25%	0	75%
DODGE CTY	DODGE 75064	26054	24851	24118	733	97.1	2.9	734	· 755	3.0	21	97%	0	3%
ROCK RIVER	JEFFERSON 66152	23451	22264	21579	685	96.9	3.1	1087	1121	5.0	34	75%	0	25%
VALDERS	MANITOWOC 82918	29594	28525	27751	774	97.3	2.7	1449	1488	5.2	39	50%	0	50%
SCANDINAVIA	PORTAGE 57420	19450	18313	17741	572	96.9	3.1	7	7	96.9	.21	0	0	0
SCANDINAVIA	WAUPACA 42831	16188	14954	14388	566	96.2	3.8	1343	1394	9.3	51	5%	0	95%
BADGER STATE	CLARK 32910	11920	11027	10446	581	94.7	5.3	3095	3259	29.6	164	15%	0	85%
WAUNAKEE	DANE 323545	125611	120601	118051	2550	97.9	2.1	2267	2315	1.9	48	80%	0	20%

ATTACHMENT C

As a result of the satellite information gathering seminars, I developed a questionnaire designed to collect traffic data useful for model simulation purposes. It could then be turned over to the satellite network providers who have agreed to give us their proposed network designs and budgetary costs. A copy of the questionnaire that was originally sent out by the Rural Coalition in September 1983 is attached.

It was sent to over 200 companies that in our best guess had or were likely to have toll traffic concentrating capabilities in a Class 4 switching machine. We were required to guess because we had no convenient records indicated where independent company Class 4 switching existed. We picked Class 4 switches as the most likely place to have enough toll traffic to warrant installation of an earth station. It was not meant to indicate that other switch points might not also be feasible.

Not enough companies understood what was needed or the importance of data from all companies no matter how small, so we didn't get enough response. We have sent out a second request to those that didn't respond the first time and from the number of phone calls I think we will have enough data this time around. Our first round of data produced respones from 50 companies representing 280,000 subscribers and 478 exchanges (6.1% and 8.4%, respectively) served by 10,000 toll trunks. We didn't consider this sample large enough and our goal is for at least 10% sampling. The second round has been successful in generating a larger volume of data. We are now working on compiling the data and creating a sample rural toll traffic matrix.

For anyone whom we have not contacted and would like to participate in the data survey, we would be pleased to get your data. Simply reproduce the questionnaire, fill it out and send it to me. I am sure we will be able to use the data at anytime it is received.

RURAL TELEPHONE COALITION

National REA Telephone Association
600 New Hampshire Ave., N.W., Suite 952
Washington, D.C. 20037
202/338-2100

National Telephone Cooperative Association
2626 Pennsylvania Ave., N.W.
Washington, D.C. 20037
202/342-8200

Organization for the Protection and Advancement of Small Telephone Company
Washington Address
1200 New Hampshire Ave., N.W.
Suite 320
Washington, D.C. 20036
202/659-5990

Dear Member:

On your behalf, the Rural Coalition and REA has completed a series of 13 information gathering seminars to determine if it is worthwhile to consider the use of a communications satellite for rural toll trunking purposes sometime after 1984. We have judged that this project is worth pursuing in more detail.

In order to obtain a reasonably accurate magnitude of costs it is necessary to provide the satellite network designers and suppliers with a representative sample of actual rural toll traffic so as to create a computer simulation model. For this we need and request your help in making a traffic study and then completing the attached questionnaire. Each of you has been selected because our records indicate that you already have one or more switches with Class 4 functions in service. These switches would be the most likely locations to interface with a satellite earth station.

Our goal in this project is to see if satellite communications might be the means to keep rural toll calls affordable in the future and rural telcos financially solvent. Without your help this project cannot be pursued. Please take the time and commit your resources to help us.

Sincerely yours,

DAVID C. FULLARTON
Executive Vice President
National Telephone Cooperative Association

A. HAROLD PETERSON
Executive Director
National REA Telephone Association

JAMES G. MERCER
Executive Vice President
Organization for the Protection and Advancement of Small Telephone Companies

RURAL TOLL NETWORKING DESIGN DATA

A. TOLL TRAFFIC MODELING DATA
(Fill in blanks or circle item as appropriate)

1. Company Name ____________________

2. REA Borrower Number (If Applicable) ____________________

3. Toll Exchange Name ____________________

4. Toll Exchange Location (City and State) ____________________

5. Toll Switch Type DIG SPC, ANAL SPC, X-BAR, SxS, Other

6. Toll Switch Class 4C, 4P, 4X

7. Switch I.D. DMS10, DCO, NEAX 61, ITT 1210, ITS 5, Other

8. Sub Lines - Capacity ____________________

9. Sub Lines - Equipped __________ Presently __________ In 1978

10. Toll Trks - Capacity ____________________

11. Toll Trks - Equipped __________ Presently __________ In 1978

12. EAS Trks - Capacity ____________________

13. EAS Trks - Equipped __________ Presently __________ In 1978

14. Switch Features ANI, LAMA, TRANSLATION, TRK ROUTING, Other

15. Toll Trunk Groups
    a. Terminating Exchange ____________________
    b. Size ____________________
    c. (1+) ____________________
    d. (0+) ____________________
    e. (0-) ____________________
    f. (T.C.) ____________________

16. EAS Trunk Groups
    a. Terminating Exchange ____________________
    b. Size ____________________

c. (In) ______________________________

d. (Out) ______________________________

e. (2-Way) ______________________________

17. WATS Lines (Outgoing) Quantity_______ Band _______
Quantity_______ Band _______
Quantity_______ Band _______

18. Number of Data Lines - ___ 300bps ___ 1200 bps ___ 2400 bps
_______ 4800 bps _______ Other

B. EXISTING TOLL TRUNK ROUTE PHYSICAL DATA
(Use separate sheet for each route) (Reproduce this sheet)

1. Originating Exchange Name ______________________________

2. Terminating Exchange (TE) Name ______________________________

3. TE Location (City, State)

4. TE Company BOC, GTE, Other

5. TE Switch Type DIG SPC, ANAL SPC, X-BAR, SxS, Other

6. TE Switch Class 3, 4, Other

7. TE Switch I.D. #1ESS, 4A, DMS100, #3EAX, Other

8. Number of Trk Ckts ______________________________

9. Type of Facility VF CABLE, ANAL CXR, DIG CXR, MICROWAVE, LIGHTWAVE, Other

10. Circuit Length _______ miles (Nearest Route Mile to TE)

C. EXISTING TOLL TRUNK ROUTE TRAFFIC DATA

1. Time Period Measure during Oct. 17-23, if possible Other

2. Avg Busy Day M, T, W, Th, F, Sa, Su

3. Avg Busy Hr(ABH) 9-10, 10-11, 11-12, 12-1, 1-2, 2-3, 3-4, 4-5, Other

4. ABH Load ___ CCS Attempts ___ Completions ___ Holding Time
___ sec.

5. Call Destination Load

a. ________ccs Intra-LATA

b. ________ccs Adjacent LATAs

c. ________ccs Remaining (In State)

d. Out of State (City, State)

1) _____ccs Busiest Destination __________ NNX Code

2) _____ccs 2nd Busiest Destination __________ NNX Code

3) _____ccs 3rd Busiest Destination __________ NNX Code

4) _____ccs All Remaining Destination

D. EXISTING EAS TRUNK ROUTE PHYSICAL DATA
(Use separate sheet for each route) (Reproduce this sheet)

1. Terminating Exchange (TE) Name ______________________________

2. TE Location (City, State)

3. TE Switch Type DIG SPC, ANAL SPC, X-BAR, SxS, Other

4. Number of Trk Ckts ______________________________

5. Type of Facility VF CABLE, ANAL CXR, DIG CXR, MICROWAVE, LIGHTWAVE, Other

6. Circuit Length ________ miles (Nearest Route Mile to TE)

E. EXISTING EAS TRUNK ROUTE TRAFFIC DATA

1. Time Period Measure during Oct. 17-23, if possible Other

2. Avg Busy Day M, T, W, Th, F, Sa, Su

3. Avg Busy Hr(ABH) 9-10, 10-11, 11-12, 12-1, 1-2, 2-3, 3-4, 4-5, Other

4. ABH Load ___ CCS Attempts ___ Completions ___ Holding Time ___ sec.

SEND COMPLETED FORMS TO:

Gerald S. Schrage
Chief, Systems Engineering Branch
USDA:REA:TESD Room 2832
Washington, D.C. 20250

EXPLANATORY NOTES

Section A, Item 8, 9 Subscriber Lines - Total of Subscriber Lines on the toll switch and its tributarities. Presently means as of 12/31/82.

Section A, Item 15 Toll Trunk groups - List only groups to a Class 4 or higher office.

Section A, Item 16 EAS Trunk groups - List only those trunk groups from this toll office, designate the size and terminating exchange for each group.

Section B & C - Complete these sections for each trunk group connecting to a Class 3 or another Class 4. Reproduce form as needed to provide separate sheet for each route.

ATTACHMENT D

REGIONAL INDEPENDENT TOLL NETWORKS

An approach to toll traffic networking that is developing rapidly is regional or intrastate networks. Two examples of this type of design are known and others are in the thinking stages. In Alabama, Brindlee Mountain Telephone Company in cooperation with one of their customers (SCI Systems, Inc.) is developing SCI-Net (an intra-Alabama microwave transmission facility). In Minnesota, three separate borrower groups are developing three separate intra-Minnesota microwave transmission facilities.

ALABAMA NETWORK

Brindlee Mountain Telephone Company (BMT) is located in Arab, Alabama, and has an NEAX-61 digital stored program control switch in place. One of their customers (SCI) built a manufacturing plant in Arab and wanted to tie it together with their other three plants in Huntsville, Alabama. SCI built a private microwave system between Huntsville and BMT agreed to use the Arab switch as the SCI toll outlet for all four plants.

With the Bell System divestiture BMT found themselves close to a LATA (Local Access and Transport Area) boundary. They were designated to be in the Birmingham LATA but they found that a significant portion of their traffic was destined for the Huntsville LATA. Recognizing that they were allowed to transport their traffic across the LATA boundary and eliminate the inter-LATA carrier they studied the revenue effect it would have on their company to use the SCI facilities and their switch to complete toll traffic to Huntsville. Their study is attached and it shows that if toll rates remained unchanged BMT not only would replace what have been lost revenues that by 1988 their monthly revenues would have increased from $29,369 to $36,508. Even assuming as much as a 30 percent toll reduction by 1988 their revenues would be virtually unchanged from an initial 10 percent reduction in 1984.

Exhibit A summarizes the revenue changes to BMT as a function of time 1984 to 1988 and inter-LATA carrier (BMT or AT&T). They have separated the revenues into four parts typical in any inter-LATA border crossing. Element A is the section from the originating office to the BOC. Element B is from the BOC to AT&T. Element C is the AT&T segment. Element D is the terminating BOC element. Based on BMT's analysis their share of the total of $42,142 toll charges would increase from 40.6% to 86.6% if they become the inter-LATA carrier. If they do nothing and AT&T becomes the inter-LATA carrier, then they estimate that their share of the toll revenues would decrease from 40.6% to 20.2%).

Exhibit B graphically illustrates these same values with the added question of what if a toll rate reduction is put into effect. Exhibit C is the computerized printout of data that was produced in the summarized results in Exhibit A.

Based in part on these results SCI and BMT are cooperating in building SCI-Net a microwave transmission facility planned to link Huntsville, Birmingham, Montgomery and Mobile with switching provided at Arab. The link between Huntsville and Birmingham is under construction and extensions to Montgomery and Mobile will follow within two years. An attached map (Exhibit D) shows the locations of the independent Alabama telephone companies and their proximity to the SCI-Net trunking backbone system. BMT suggests that the other independent companies may want to construct facilities to connect to and utilize the SCI-Net. In which case they offer "to provide services in a cooperative environment in accordance with the industry's cost recovery and return on investment practices".

MINNESOTA NETWORKS

In Minnesota three groups of borrowers have proposed building three separate microwave toll networks. These would be in the northern, central, and southern regions of the state. The interest in developing independent company toll networks was precipitated from the borrowers preparing for the effects of Bell System divestiture and Northwestern Bell's intention to abandon certain toll facilities and not replace them.

The attached map (Exhibit E) superimposes the court approved LATA boundaries over the proposed microwave toll facility layout. Looking at this map, three facts are immediately apparent. One, the proposed toll networks connect offices that are in four of the five Minnesota LATA's, i.e. Brainerd, St. Cloud, Rochester, and Minneapolis. Only the Duluth LATA is not included, but one exchange (Wolverton) is even in a North Dakota LATA (Fargo). Second, relatively little additional construction would be required to tie all three networks together. Third, several borrower offices and a toll office are located in the Minneapolis LATA.

Because the primary toll calling community of interest for rural Minnesota subscribers is Minneapolis, REA staff recommended to the borrowers that they consider linking all three networks and transport all the toll traffic over this independent network. At the same time, they could also transport any other intrastate toll traffic that is available. There is also the possibility of transporting traffic to the Fargo LATA through the Wolverton office access point. However, this traffic being interstate toll needs more clarification by the appropriate regulators as to whether or not it would be allowed. Technically, it is certainly possible. The advantages to the independent companies in being associated with the Minneapolis LATA is that a handoff of traffic and sharing of revenues can be accomplished directly with Northwestern Bell without an inter-LATA carrier involvement.

The borrowers propose to establish a stock corporation with equal ownership. Its purpose would be to build an independent toll facilities network to provide a toll outlet for their subscribers. They will study the possibility of tying the networks together and the revenue implications. They intend to submit a loan application to REA to accomplish this project.

REA/Rural Coalition Network Studies

PRO FORMA DISTRIBUTION OF TOLL REVENUES
BMTC TO HUNTSVILLE LATA 1+ TRAFFIC
A.T.& T. AND BMTC AS INTEREXCHANGE CARRIERS
ONE MONTH, SEPTEMBER 16 - OCTOBER 15, 1983, AS BASIS

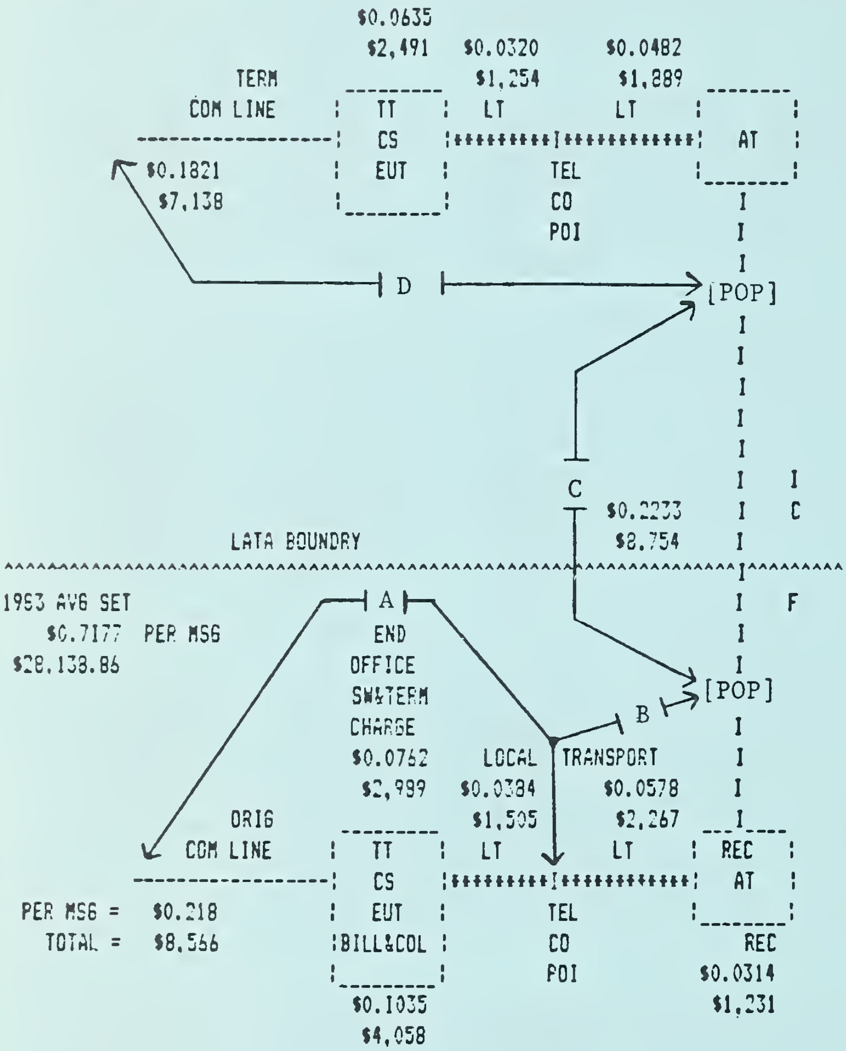
1984 (100% CCL)	AT & T As Carrier	BMTC As Carrier	Net Change
A Originating E.O. (BMTC)	$17,118	$29,369	$12,252
B BOC Functions - BHM LATA	3,500	-0-	(3,500)
C A.T.&T.	8,752	-0-	(8,752)
D Terminating Functions - HSV LATA	12,772	12,772	-0-
Total	$42,142	$42,142	-0-
1985 (75% CCL)			
A Originating E.O. (BMTC)	$14,974	$31,154	$16,178
B BOC Functions - BHM LATA	3,500	-0-	(3,500)
C A.T.&T.	12,680	-0-	(12,680)
D Terminating Functions - HSV LATA	10,998	10,998	-0-
Total	$42,142	$42,142	-0-
1986 (50% CCL)			
A Originating E.O. (BMTC)	$12,835	$32,939	$20,104
B BOC Functions - BHM LATA	3,500	-0-	(3,500)
C A.T.&T.	16,604	-0-	(16,604)
D Terminating Functions - HSV LATA	9,203	9,203	-0-
Total	$42,142	$42,142	-0-
1987 (25% CCL)			
A Originating E.O. (BMTC)	$10,691	$34,724	$24,030
B BOC Functions - BHM LATA	3,500	-0-	(3,500)
C A.T.&T.	20,532	-0-	(20,532)
D Terminating Functions - HSV LATA	7,418	7,418	-0-
Total	$42,142	$42,142	-0-
1988 (0 CCL)			
A Originating E.O. (BMTC)	$ 8,550	$36,508	$27,956
B BOC Functions - BHM LATA	3,500	-0-	(3,500)
C A.T.&T.	24,458	-0-	(24,458)
D Terminating Functions - HSV LATA	5,634	5,634	-0-
Total	$42,142	$42,142	-0-

SEPT 16 TO OCT 15 1983

CCL =	$0.0461
LS =	0.016085
EO LT =	$0.0081
AT LT =	$0.0122
REC =	$0.0314
B&C =	$0.1035

ICO TOTAL TRAFFIC
TO H'VILLE LATA

ORIG MOU =	185,812	4.73
TERM MOU =	154,843	3.94



	PER MSG AT&T AS IC	PER MSG ICO AS IC	PER MOU	TOTAL REV DIS AT&T AS IC	TOTAL REV DIS ICO AS IC
BMTC	$0.437	$0.749	$0.092	$17,118	$29,369
BELL AT	$0.089	0	$0.019	$3,498	0
IC	$0.223	0	$0.047	$8,754	0
DIS. LT	$0.048	$0.048	$0.010	$1,889	$1,889
DIS. EO	$0.278	$0.278	$0.059	$10,883	$10,883
TOTAL	$1.075	$1.075	$0.227	$42,142	$42,142

		%	
ICO	$0.714	66.44%	$28,000.86
BELL	$0.137	12.78%	$5,387.09
RESIDULE	$0.223	20.77%	$8,753.55
TOTAL	$1.075	100.00%	$42,141.51

	ICO TO H'VLE LATA	% OF TOTAL	% OF INTRAST
TOTAL MSGS =	39,207	38.6%	47.7%
ORIG MOU =	185,812	33.3%	49.7%
TERM MOU =	154,843	33.3%	49.7%
TOTAL REV =	$42,142	30.2%	47.6%
REV PER MSG=	$1.075	78.3%	99.8%
REV PER MOU=	$0.227	90.6%	95.8%
MOU PER MSG=	4.74	86.4%	104.2%

	ICO TO TOTAL
TOTAL MSGS =	101,654
ORIG MOU =	557,561
TERM MOU =	464,634
TOTAL REV =	$139,614
REV PER MSG=	$1.373
REV PER MOU=	$0.250
MOU PER MSG=	5.48

	ICO TO INTERST	% OF TOTAL	% OF INTRAST
TOTAL MSGS =	19,489	19.17%	23.72%
ORIG MOU =	183,832	32.97%	49.19%
TERM MOU =	153,193	32.97%	49.19%
TOTAL REV =	$51,147	36.63%	57.81%
REV PER MSG=	$2.624	191.08%	243.74%
REV PER MOU=	$0.278	111.11%	117.54%
MOU PER MSG=	9.43	171.97%	207.38%

	ICO TO INTRAST	% OF TOTAL	% OF INTERST
TOTAL MSGS =	82,165	80.83%	421.6%
ORIG MOU =	373,730	67.03%	203.3%
TERM MOU =	311,441	67.03%	203.3%
TOTAL REV =	$88,467	63.37%	173.0%
REV PER MSG=	$1.077	78.40%	41.0%
REV PER MOU=	$0.237	94.53%	85.1%
MOU PER MSG=	4.55	82.93%	48.2%

	ICO TO B'HAM LATA	% OF TOTAL	% OF INTRAST
TOTAL MSGS =	26,642	26.21%	32.4%
ORIG MOU =	154,555	27.72%	41.4%
TERM MOU =	128,796	27.72%	41.4%
TOTAL REV =	$36,424	26.09%	41.2%
REV PER MSG=	$1.367	99.54%	127.0%
REV PER MOU=	$0.236	94.12%	99.6%
MOU PER MSG=	5.80	105.77%	127.5%

	ICO TO 2 SO ALA LATA'S	% OF TOTAL	% OF INTRAST
TOTAL MSGS =	14,316	14.08%	17.4%
ORIG MOU =	33,363	5.98%	8.9%
TERM MOU =	27,803	5.98%	8.9%
TOTAL REV =	$9,902	7.09%	11.2%
REV PER MSG=	$0.692	50.36%	64.2%
REV PER MOU=	$0.297	118.53%	125.4%
MOU PER MSG=	2.33	42.49%	51.2%

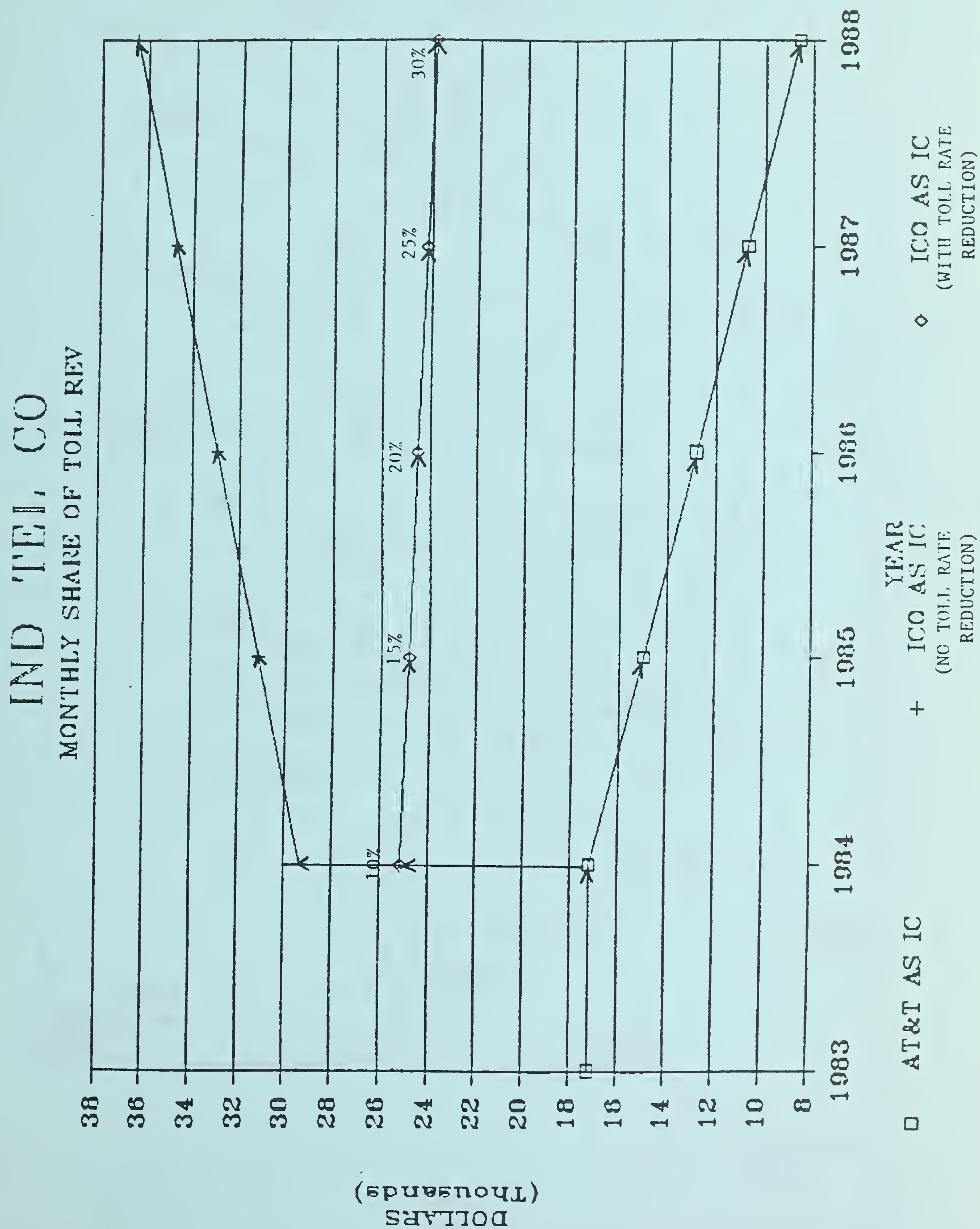
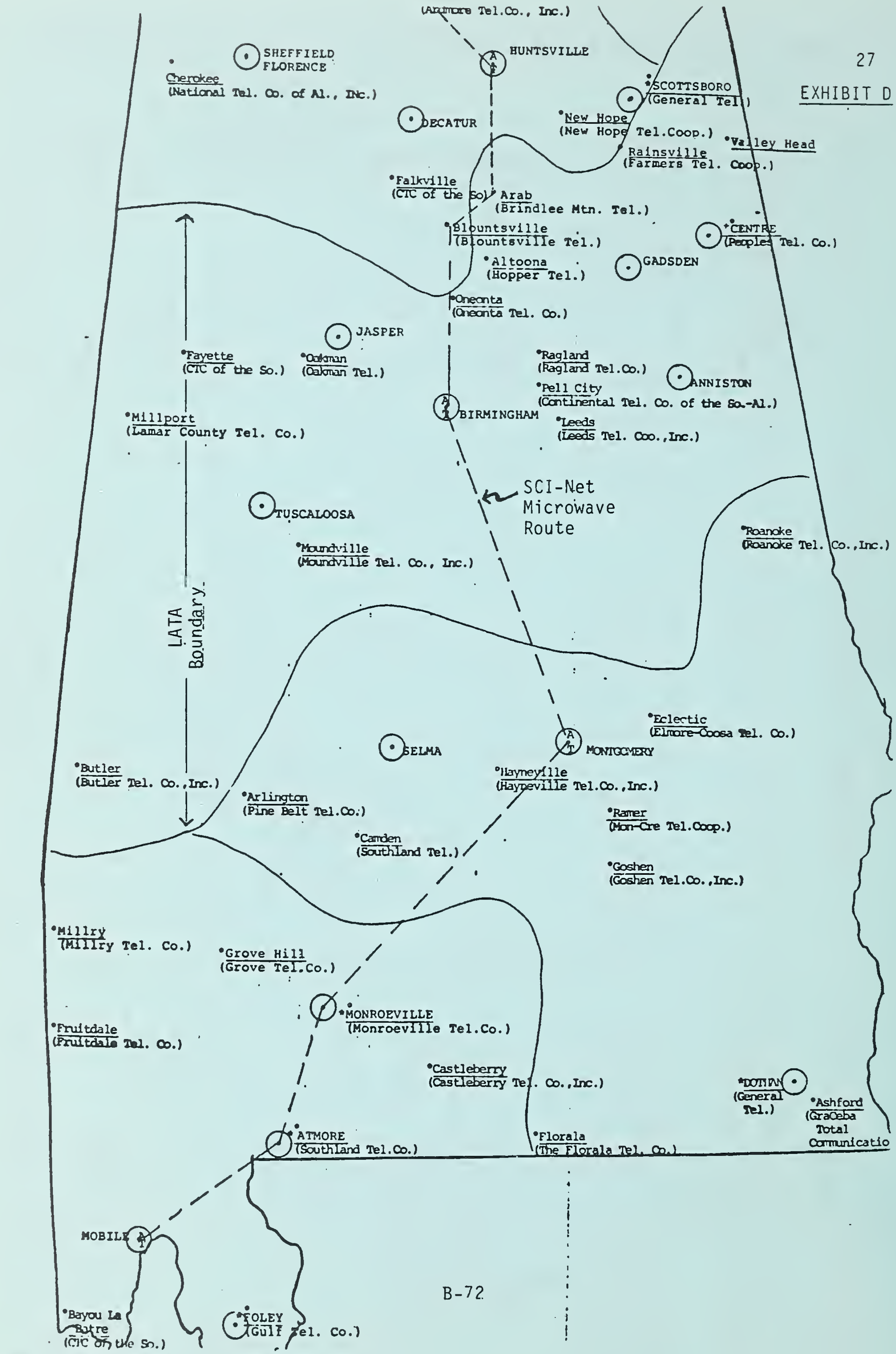
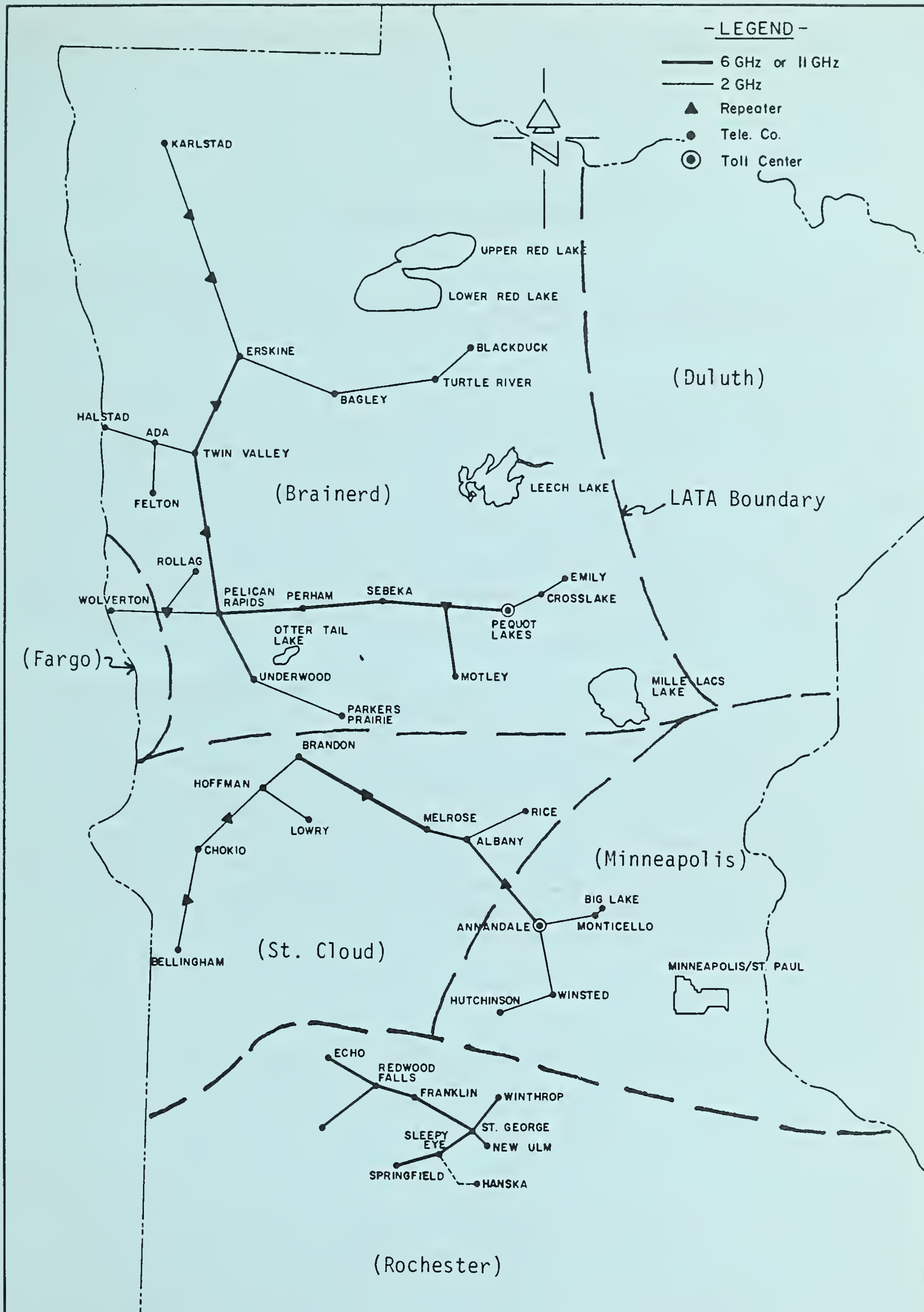

IND TEL CO
MONTHLY SHARE OF TOLL REV
DOLLARS
(Thousands)
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
1983
1984
1985
1986
1987
1988
YEAR
10%
15%
20%
25%
30%
AT&T AS IC
ICO AS IC
(NO TOLL RATE REDUCTION)
ICO AS IC
(WITH TOLL RATE REDUCTION)

EXHIBIT D


(Ardmore Tel.Co., Inc.)
HUNTSVILLE
SHEFFIELD
FLORENCE
Cherokee
(National Tel. Co. of Al., Inc.)
DECATUR
SCOTTSBORO
(General Tel.)
New Hope
(New Hope Tel.Coop.)
Valley Head
Rainsville
(Farmers Tel. Coop.)
Falkville
(CTC of the So)
Arab
(Brindlee Mtn. Tel.)
Blountsville
(Blountsville Tel.)
CENTRE
(Peoples Tel. Co.)
Altoona
(Hopper Tel.)
GADSDEN
Oneonta
(Oneonta Tel. Co.)
JASPER
Fayette
(CTC of the So.)
Oakman
(Oakman Tel.)
Ragland
(Ragland Tel.Co.)
ANNISTON
Pell City
(Continental Tel. Co. of the So.-Al.)
BIRMINGHAM
Millport
(Lamar County Tel. Co.)
Leeds
(Leeds Tel. Coo.,Inc.)
SCI-Net
Microwave
Route
TUSCALOOSA
Moundville
(Moundville Tel. Co., Inc.)
Roanoke
(Roanoke Tel. Co.,Inc.)
LATA
Boundary
Eclectic
(Elmore-Coosa Tel. Co.)
SELMA
MONTGOMERY
Butler
(Butler Tel. Co.,Inc.)
Hayneville
(Hayneville Tel.Co.,Inc.)
Arlington
(Pine Belt Tel.Co.)
Ramer
(Mon-Cre Tel.Coop.)
Camden
(Southland Tel.)
Goshen
(Goshen Tel.Co.,Inc.)
Millry
(Millry Tel. Co.)
Grove Hill
(Grove Tel.Co.)
MONROEVILLE
(Monroeville Tel.Co.)
Fruitdale
(Fruitdale Tel. Co.)
Castleberry
(Castleberry Tel. Co.,Inc.)
DOTHAN
(General Tel.)
Ashford
(GraCeba Total Communicatio
ATMORE
(Southland Tel.Co.)
Florala
(The Florala Tel. Co.)
MOBILE
Bayou La Batre
(CTC of the So.)
FOLEY
(Gulf Tel. Co.)



AMTU

MICROWAVE SYSTEM

EXHIBIT E

CC&I ENGINEERING INCORPORATED
SUN PRAIRIE, WISCONSIN 608-837-7822
FARGO, NORTH DAKOTA 701-280-1550

APP'D	RWR	SCALE	NTS
DRAWN	M. MOE	DATE	10/12/83

ATTACHMENT E

ENTREPRENEURIAL TOLL NETWORKS

In the near future we expect to see more regionalization of independent toll systems such as proposed for Alabama and Minnesota. However, opportunities will develop for new entrepreneurs to promote and organize toll networks.

There are three approaches to this problem. The most readily available method will be to utilize the inter-LATA carriers who have or lease their own network facilities. By some contractual arrangement the independent company would turn over or receive toll calls at some predetermined point and responsibility for the call would cease beyond that point. Another method would be a fully-owned independent toll network such as the terrestrial regional systems or a national satellite system as has been proposed. With these systems the independent company operating group would maintain call control and associated revenues as far as economically feasible. The third method would be for a entrepreneurial group to promote, organize, and build an independent toll network sharing the financing with the independent company partners. This system would extend call control and associated revenues as far as economically feasible.

To date we know of only one organization (U.S. Switch) that is proposing the partnership type of toll system. This company is attempting to organize initially on a state-by-state basis and have reported some success in signing up partners for a $2500 participation fee. For their efforts in organizing these state switches, they generally agree to take a minority ownership position. However, there are situations where the consortium of independent telephone companies taken as a whole have a minority ownership position. The attached material outlines their proposed interim agreements and typical ownership positions. This type of arrangement will have a place whenever the independent companies aren't willing or able to create their own system or where the contractual arrangement with inter-LATA carriers are less than desirable.

INTERIM AGREEMENT

Telco Agrees:

1. To be an incorporator of the State Switch Corporation.

2. To pay Participation Fee.

3. To put their traffic on the network when the State Switch Corporation becomes operational.

4. To supply whatever information required to design the network, and conduct a Feasibility Study.

5. To actively promote U.S. Switch interstate services once the State Switch Corp. is connected to U.S. Switch interstate network.

U.S. Switch Agrees:

1. That the State Switch corp. will provide the same revenue level as the present connecting company at the time the network becomes operqtional.

2. That the long distance rates of the State Switch Corp. will be as low as current Bell rates at the time the State Switch network becomes operational.

3. To cover all costs to organize, design, study feasibility, get regulatory approval over and above the amount collected from the telcos in the Participation Fee.

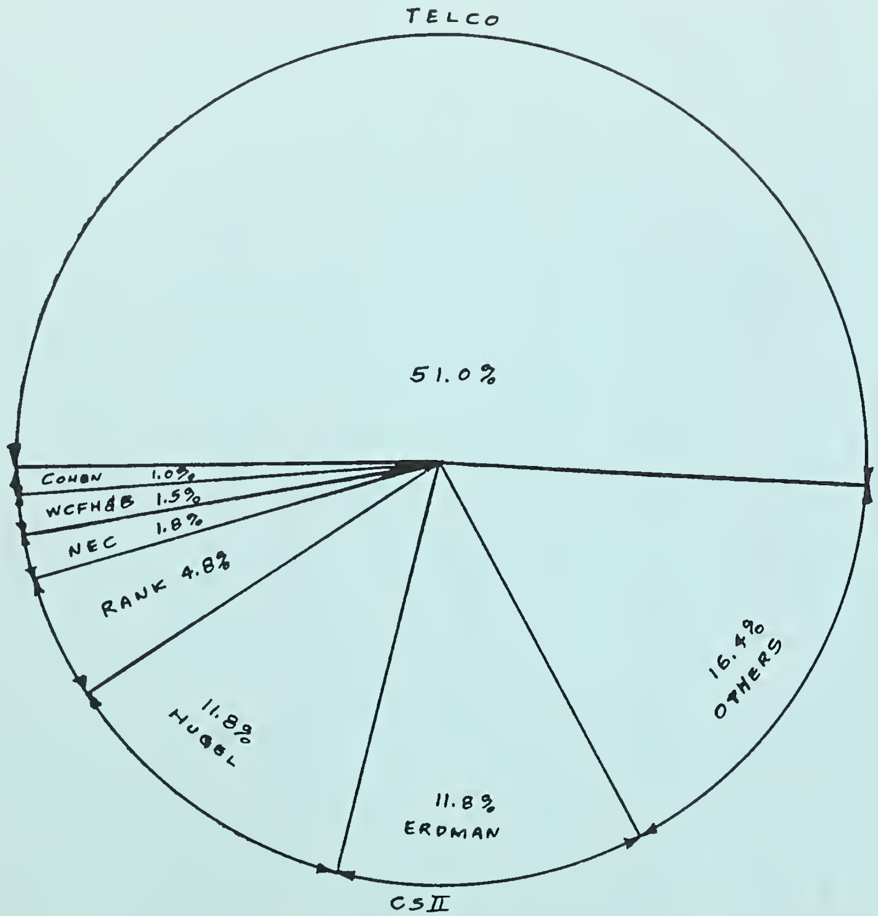
4. To prove feasibility of the project to the telcos.

5. To obtain regulatory approval.

Miscellaneous:

1. Telco is free to connect with whomever they wish until the network becomes operational.

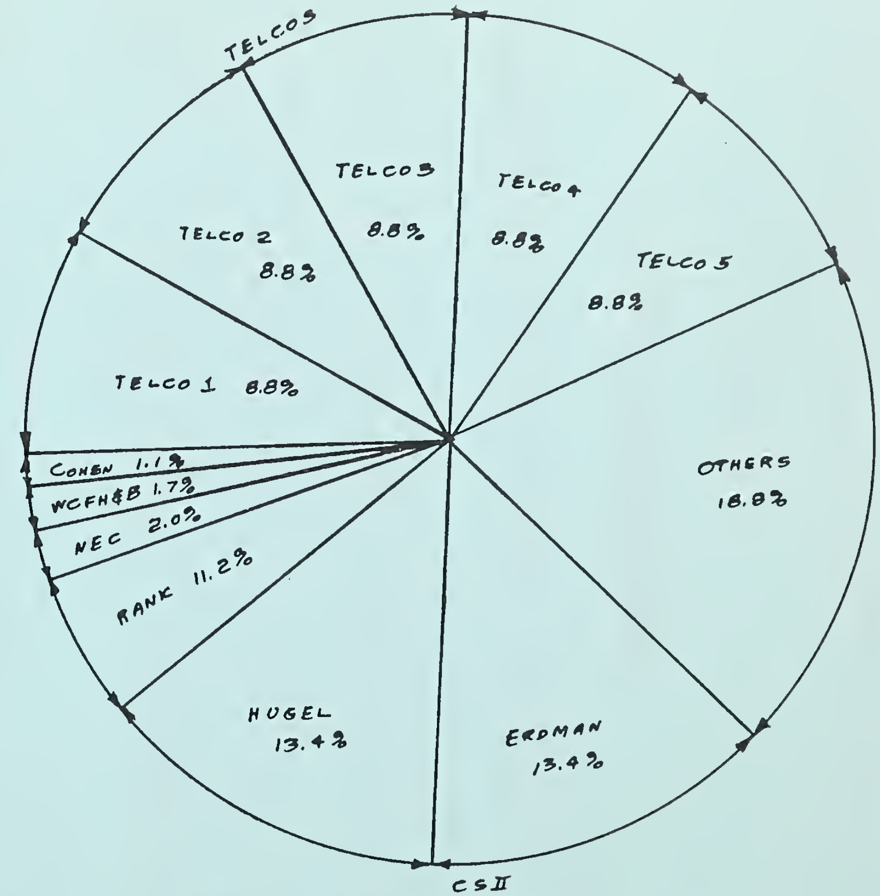
2. The Interim Agreement is good for five years.



TYPICAL STATE SWITCH OWNERSHIP

51% TELCO (MAJORITY)

49% CSII (MINORITY)



ALTERNATE STATE SWITCH OWNERSHIP

56% CS II (MAJORITY)

44% TELCO (MINORITY)

ENGINEERING ASPECTS OF LOCAL EXCHANGE BYPASS

Gerald S. Schrage
Systems Engineering Branch
Telecommunications Engineering and Standards Division

1.- What is Bypass?

In today's environment bypass is a dirty word or a clean word depending on your telecommunications business. If you are the company whose facilities are being bypassed, then bypass can cause a loss of revenue, underutilized facilities, and rising costs and is a threat to your survival. On the other hand if you are a company creating bypass facilities, then it can increase your revenue by adding new subscribers. For our purposes in this paper we are going to consider bypass from the perspective of the local exchange operator. Bypass will then be considered as any alternative facility to the local distribution loop.

Bypass can happen at the local exchange if any of the following facility situations has occurred.

a. The present local facilities are relatively high cost and require high charges.

b. The local facilities are inadequate for the user (i.e. high speed data).

c. The present local facilities are relatively low cost, but regulatory policies require high charges.

From an engineering viewpoint we will primarily address items a and b where a bypasser can provide lower cost or more adequate facilities. We shall concentrate on how bypass is accomplished, who are bypass candidates, and how to prevent or reduce its happening.

2. Technological Bypass Methods

A compilation of the results of 15 studies nationwide done by Dr. Joseph Kraemer of Touche Ross and Company showed that four technologies are presently being used to accomplish local exchange bypass as follows.

Microwave Radio	- 54%
Cable or Wire	- 26%
Satellites	- 19%
Optical Links	- 1%

Other technologies are being developed or proposed such as cellular radio or satellite radio and could conceivably have a considerable impact in the future.

A. Microwave Radio Facilities

Microwave radio systems have provided the majority of the facilities for local exchange bypass because of two reasons. One, it is a mature low cost technology that is widely available. Second, it is ideally suited for high density, point-to-point applications. Dr. Kraemer's studies showed that 1% of business customers generated 33% of the business revenues. From an engineering viewpoint this usually means that one business customer can generate 1/3 of the total business traffic at one location. A microwave radio span can usually be built by a bypass company to serve these traffic clusters at as low a cost as the local exchange company. The local exchange company can many times build a total microwave system less expensively because it can share overhead expenses such as buildings, land, power, and personnel with other facilities it has. The bypass company has to carry all the overhead on the dedicated facility.

Microwave radio has been used for bypass applications over varying distances in both analog and digital transmission modes. It is used for short interbuilding links creating a Local Area Network (LAN) that can transport narrowband and wideband analog or digital signals within a customer's premise. It is probably most used for intracity single hop links tying scattered locations together. It has also been used in multihop installations to connect to a distant backbone transmission route or switching center provided by the bypass company.

B. Satellite Facilities

Satellite facilities for bypass applications are probably the fastest growing method of technology in use. With the cost of earth stations dropping continuously, the potential cost effective uses keep increasing. Some specialized earth stations such as digital audio terminals for radio stations can be provided for about $10,000 each. Satellite bypass facilities are usually most cost effective where there are multiple subsidary locations connected to a central headquarters all of which are hundreds or thousands of miles apart. With the growing availability of transponder space, the cost of uplinks and downlinks is also coming down.

The usual application for satellite facilities to bypass the local exchange consists of a self-contained earth station provided by the bypass company installed on the customer's premise. The satellite facility is in effect a microwave radio link with one repeater and a very tall tower. This type of facility is seldom available to the local exchange company. If the local company is to compete with the bypass company, it must contract with a satellite company for uplinks and downlinks. Unless the local company is in partnership with the lead organization providing the total network, it is unlikely to be able to provide the local earth station.

C. Cable and Wire Facilities

This is presently the second largest bypass technology in use. It has a great potential to grow considerably larger because of the coaxial cable installed by CATV companies. There has been use of paired wire cables for bypass but not extensively. Most of the paired cable bypass has been limited to customer premise cabling between or within buildings. The problem of right of way and land costs prevents much application outside of the customer premise. However, we are seeing agreements for right of way being arranged for bypass companies with other entities such as railroads, electric utilities or gas utilities. The most usual application is the CATV coaxial cable. In large cities there can be two cables running parallel i.e. on institutional cable and an entertainment cable. The institutional cable is placed deliberately to provide video capacity to government and business institutions in the city. It can also provide voice and data facilities. Even where a town or city is small enough so that only one CATV coaxial cable is provided, it still has capacity to integrate voice and data along with the entertainment video. These CATV companies can be low cost bypass facility providers because most of the cost of the coaxial cable is carried by the entertainment video subscribers. They also have the advantage of being almost as widespread as the local exchange company's distribution plant in some locations. A second advantage is that the CATV companies are not restricted from integrating voice, data and video on coaxial cable whereas the local exchange company is subject to regulations prohibiting integration.

D. Future Bypass Facilities

Several other technologies have potential for local exchange bypass. The most prominent candidates are cellular radio satellite radio, optical links, and fiber optic cables. Cellular radio is a service being installed for mobile phone use anywhere in a local market. There is no technological reason why a cellular phone could not be used in a fixed station application and bypass the local exchange even including the switch. The drawbacks at this time are the high cost of equipment development and air time. Satellite radio service has been applied for by two companies. These applications propose voice and data facilities in remote areas where local exchange facilities don't exist. However, bypass can exist at the receiving end of the circuit where the customer's headquarters is located. At that end all the satellite channels would feed a customer premise earth station and bypass the local exchange. Optical links are laser powered lightwave transmission facilities using the air as the transmitting medium. These are restricted to very short links because of attenuation but they have the advantage of being very secure links with wideband capacity. Fiber optic cable is another transmission medium being used for bypass facilities. This facility produces excellent wideband transmission capability at ever decreasing costs. Our experience has shown a typical VF channel cost of $200 to $400. To achieve these costs high density routes of 672 channels or more are typically required. It has been used for as low as 96 VF channel routes but the per channel costs are higher. If right of way is available, fiber optic cable makes an excellent bypass medium in applications spaced 10 - 20 km with high density, point-to-point traffic. Right of way is just not obtaining access to land as being provided by several railroads for burying fiber optic cables. Other installations obtain right of way through joint use of pole lines or buried plant with electric and telephone systems.

3. Who are the Bypassers?

Bypass users are made up of almost all medium and large size corporations, federal, state, county, or city governments, and large educational or research complexes. The Touche-Ross study of all large users in five midwestern states found that 122 of the 405 organizations are already doing some form of bypass. Just as significant they also found that another 129 organizations plan to begin bypass. With bypass this widespread to cite specific organizations would require an exhaustive list. Some of the types of organizations involved are as follows.

Federal Government Agencies	Universities
State Government Agencies	Research Labs
County Government	Hotel and Motels
City Government	Electric Utilities
Banks	Gas Utilities
Brokerage Firms	Teleports
Insurance Firms	Communications Industry
Airlines	Radio Stations
Trucking Firms	Television Stations
Railroads	Retailers
Manufacturers	CATV Companies
National Distributors	Newspapers
Mail Order Houses	Hospitals
Aerospace Firms	

After scanning this list, the question seems to be not which large company is bypassing, but which large company isn't bypassing?

4. Why Does Bypass Occur?

Many reasons are given for bypass to occur, but the primary trigger that appears in every study is cost of service. It has been found that an apparent 10% reduction in cost of service is enough to commit an organization to bypass. The 10% reduction may not be real but if the subscriber thinks it is that is all the motivation he needs. Other than cost of service no other reason is predominant in causing bypass to occur. Some of the other reasons for bypass are listed below.

Poor Maintenance
Insufficient Facilities
Response Time Too Long
Facilities Not Capable of Video or Data
Technically Obsolete
Need Central Control

5. Bypass Counter Strategies

The primary goal in countering bypass is preventing it from ever occurring. Most studies have shown that once bypass has occurred it rarely ever is reversed. This is because of three primary reasons. First, the user who anticipated a 10% saving finds that he can show 30 to 40% reduction in cost to his management. Secondly, the manager who recommended bypass feels his reputation depends on making it successful and will resist any abandonment of bypass. Until this person is gone or can be convinced a change away from bypass is beneficial to him it is probable that bypass will remain. Third, when bypass is implemented sunk costs are incurred. These sunk costs would have to be written off if bypass was abandoned. The most realistic event is that until these sunk costs amortorize from usage, bypass will continue.

From a technology aspect the local exchange company needs to provide the lowest cost and quickest available facility that the user requires. All of the technologies are readily available to the local exchange company except for satellites. Quick reaction to the users needs might be accomplished by establishing a special team of plant and engineering personnel. To achieve the lowest cost of facilities the local company should use cost reduction techniques such as feeder-distribution cable plant, grouped subscriber carrier, host and remote digital switches, and microwave or fiber optic trunking. The local company should install new cost effective technology that can provide increased or improved services as it becomes available wherever an appropriate application can be found. This will provide a technological expertise base to the local exchange company as an alternative to the potential bypasser who might have to develop his own expertise. The most difficult technology for the local exchange company to counteract is satellites. This will require the local exchange company to become affiliated in some way with a satellite facility provider in order to share in the total network that would be provided.

THE IMPACT OF 400 OHM TELEPHONE SETS ON OUTSIDE PLANT DESIGNS

Raymond D. Hayden
Systems Engineering Branch
Telecommunications Engineering and Standards Division

The appearance of 400 ohm telephone sets coupled with unresolved FCC equipment interface regulations has produced questions concerning the design of subscriber loop plant. These telephone sets are of the push-button type and the 400 ohm resistance occurs when a button is depressed. We have recently seen designs using substantially more 22 gauge cable allegedly because of 400 ohm telephones. In another recent design coarser gauge cables were used to avoid using electronic line treatment and carrier equipment (with the exception of digital switches and remotes). We have not been able to study actual REA projects due to not yet receiving requested design data. However, we have studied the possible impact on design guidelines and have made two model design studies.

In the past we assumed a maximum dc resistance of 200 ohms at 20 mA per telephone set. A "voltage maintained" central office (normally by using standby generators) could supply 21 mA into 1900 ohms. Therefore, the maximum cable and load coil resistance was limited to 1700 ohms. Using loop extenders, loops could have up to 4300 ohms maximum outside plant dc loop resistance. The early Dual Tone Multi-Frequency (DTMF), i.e. push button, telephone sets had a dc resistance of about 250 ohms even with a push button depressed. Since most central offices could actually supply an adequate current into loops greater than 1900 ohms, we were able to continue using 200 ohms per telephone set. Around 1979, a new type of DTMF set was introduced, which incorporated a frequency synthesizer on an integrated circuit. The frequency synthesizer generates the DTMF. To provide the minimum supply voltage to the IC, the set needs a minimum current of 20 mA. At 20 mA the set has a terminating resistance of 350 to 400 ohms.

The additional ohms can cause problems on loops between 1500 and 1700 ohms in resistive length, the area just before loop extenders have been traditionally applied. In addition, the additional resistance can also cause problems on some types of existing station carrier. While it would be possible to rebuild existing loops and build new ones to accommodate 400 ohm set resistance, it may not be economically feasible or necessary. The 400 ohm circuits are typically found in the expensive push-button (DTMF) telephones currently being produced. Many of the newer push-button nontone dial pulse (DP) sets that sell for $10 to $20 can operate on less than 20 mA. In addition, telephone companies typically charge higher rates for DTMF lines. Therefore, before we begin changing our practices and redesigning all of our loops to handle 400 ohm sets, we should first consider their penetration into local loop plant. The rate of penetration will vary between projects. Its overall economic effects will vary not only with the penetration rate but also with route length. The first study model addresses economic effects of penetration and route length. It provides some insight into deciding to use loop treatment or more 22 gauge cable on long loops with 400 ohm sets. Penetration and loop length are not the only factors that effect the economics of loop design. The distribution of subscribers can have a much greater effect than either of the other two factors. For example, most of the subscribers will be located within 1500 ohms (28 kft) of the central office (CO).

Our first model studies the question as to whether on an individual subscriber loop basis it may be cheaper to serve the sets beyond 1500 ohms with 22 gauge cable instead of electronics. However, they all normally share the same feeder cable and the additional copper would be wasted on those within 1500 ohms. The higher feeder cable cost more than offsets any savings on the individual loops. The second model studies the effects of subscriber distribution by comparing the use of 22 gauge cable against the use of electronic line treatment and 24 gauge cable.

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IMPACT ON CABLE DESIGN

STUDY I - LE/VFR vs MORE 22 GAUGE CABLE

In this study a comparison is made between using more 22 gauge cable or loop treatment. In the study the incremental cost between 24 and 22 gauge cable is used. The incrementsl costs are based on a project currently under way to develop "Standard Mile" costs and are listed in Table 1.

INCREMENTAL COST
BETWEEN 24 AND 22 GAUGE CABLE

Pair Size	($/kft)	($/Pr. kft)
6	40.24	6.71
12	59.68	4.97
18	79.13	4.40
25	101.81	4.07
50	189.04	3.78
75	263.83	3.52
100	344.85	3.85
150	506.87	3.38
200	668.89	3.34

TABLE 1

The costs are based on the average material costs between 22 and 24 gauge cables used on nongopher projects. For purposes of this study a 50 pair cable was used. It is very close to the average of 46 pairs per cable found on nongopher projects.

PART I - ADDITIONAL COST PER CIRCUIT FOR 400 OHM SETS

In Part I the additional cost incurred to reduce a 1700 ohm loop to 1500 ohms and accommodate a 400 ohm set is determined. Looking at Table 2, at distances less than 28 kft or 1500 ohms of 24 gauge cable there is no additional cost. Between 28 kft and 32 kft the cost rises to $38.77. The cost remains constant at $38.77 beyond 32 kft. Beyond 32 kft the 1700 ohm loop would also require some 22 gauge cable. The alternative to using 22 gauge cable on loops between 28 and 32 kft would be the use of a loop extender. However, a loop extender would cost around $100 or 2.6 times the maximum cost of additional 22 gauge cable ($38.77). The result is that if only one circuit would be involved, it would be less expensive ($38.77 max.) to use additional 22 gauge cable than a loop extender for $100. This example is only hypothetical in that one-pair cables are never provided. It was intended as a building block in the development of cost comparisons for multipair cables.

PART II - BREAKEVEN COST COMPARISON AS A FUNCTION OF DISTANCE AND DTMF PENETRATION

It can be assumed that not all subscribers beyond the 1500 ohm limit (28 kft - 24 gauge cable) would have 400 ohm DTMF sets. In Table 3 the first cost of cable or electronics for various DTMF penetration rates are compared. From the table it can be seen using loop extenders instead of additional 22 gauge cable proves in at 30 kft for DTMF rates below 25%. On 24 gauge loops longer than 32 kft a combination LE/VFR would be required. Whenever the costs shown in Table 3 are positive, it is less expensive to use electronic equipment rather than heavier gauge (22 ga.) cable. The result is that for low 400 ohm set penetration rates (<25%) and short distances (<32 kft) it is less expensive to use LE's on 24 gauge cable instead of 22 gauge cable. In the range of 32 to 45 kft and with any 400 ohm set penetration it is less expensive to use 22 gauge cable rather than LE/VFR's and 24 gauge cable. Beyond 45 kft and higher (>25%) 400 ohm set penetration rates, it is less expensive to use LE/VFR's and 24 gauge cable rather than 22 gauge cable.

PART III - BREAKEVEN COST COMPARISON AS A FUNCTION OF DISTANCE, DTMF PENETRATION AND TIME

The cost of cable plant generally can not be deferred and is incurred when the plant is built. The cost of electronic equipment such as loop extenders and voice frequency repeaters can be deferred until they are needed. In this example, it is assumed that there is an existing base of 50 subscribers on 50 cable pairs. For a medium growth rate (6% annually) 10% cost of money and 8% inflation rate, a 50 pair addition would be selected for future growth. The 50 pair cable would be filled in 12 years, its economic life. (See the Appendix of REA TE&CM 231.) To consider the differences in installation times and costs, a PWAC study must be made. In Table 4 the PWAC costs for LE's and LE/VFR's are developed for a 50% DTMF penetration. We did not include detailed tables for other penetration rates and instead these are summarized in Table 5. Note that the PWAC values for the LE/VFR's do not change due to the DTMF penetration. The loops longer than 32 kft would require LE/VFR's regardless of the presence of 400 ohm sets. The PWAC for the LE's does change depending on the DTMF penetration.

A PWAC comparison for various distances from the central office with a 50% DTMF penetration is shown in Table 6. Using a loop extender instead of 22 gauge cable for loops between 28 and 32 kft is not economic. In fact LE/VFR's do not prove in until at 50% DTMF penetration until the cable is at least 45 kft from the office.

1/23/84

TOTAL KFT	MAXIMUM LOOP RESISTANCE	MAXIMUM LOOP RESISTANCE	LOAD COIL RESISTANCE	1500 ohm MAXIMUM ALLOWED RESISTANCE	1700 ohm MAXIMUM ALLOWED RESISTANCE	KFt. OF 22 ga. FOR 1500 ohms	KFt. OF 22 ga. FOR 1700 ohms	ACTUAL LOOP RESISTANCE	ACTUAL LOOP RESISTANCE	50 PAIR CIRCUIT $ INCREASE FOR 1500
a	b	c	d	e=b-d	f=c-d	g	h	i	j	l
28	1500	1700	30	1470	1670	-0.86	-11.12	1483	1483	
29	1500	1700	30	1470	1670	1.80	-8.46	1500	1535	$6.80
30	1500	1700	35	1465	1665	4.72	-5.54	1500	1592	$17.83
31	1500	1700	35	1465	1665	7.38	-2.88	1500	1644	$27.89
32	1500	1700	35	1465	1665	10.04	-0.22	1500	1696	$37.96
33	1500	1700	35	1465	1665	12.70	2.45	1500	1700	$38.77
34	1500	1700	40	1460	1660	15.62	5.36	1500	1700	$38.77
35	1500	1700	40	1460	1660	18.28	8.03	1500	1700	$38.77
36	1500	1700	40	1460	1660	20.94	10.69	1500	1700	$38.77
37	1500	1700	40	1460	1660	23.61	13.35	1500	1700	$38.77
38	1500	1700	40	1460	1660	26.27	16.01	1500	1700	$38.77
39	1500	1700	45	1455	1655	29.18	18.93	1500	1700	$38.77
40	1500	1700	45	1455	1655	31.85	21.59	1500	1700	$38.77
41	1500	1700	45	1455	1655	34.51	24.25	1500	1700	$38.77
42	1500	1700	45	1455	1655	37.17	26.91	1500	1700	$38.77
43	1500	1700	50	1450	1650	40.09	29.83	1500	1700	$38.77
44	1500	1700	50	1450	1650	42.75	32.49	1500	1700	$38.77
45	1500	1700	50	1450	1650	45.41	35.15	1521	1700	$38.77
46	1500	1700	50	1450	1650	48.07	37.82	1608	1700	$38.77
47	1500	1700	50	1450	1650	50.73	40.48	1694	1700	
48	1500	1700	55	1445	1645	53.65	43.39	1793	1700	
49	1500	1700	55	1445	1645	56.31	46.06	1880	1700	
50	1500	1700	55	1445	1645	58.97	48.72	1966	1700	
51		1700	55		1645		51.38		1720	

g=((a*51.9)-e)/(51.9-32.4)
h=((a*51.9)-f)/(51.9-32.4)
If h<0, l=g*3.78
IF h>0, l=(g-h)*3.78

Table 2
Part 1 of Study 1
Cost per Individual Circuit

TOTAL KFT FROM CENTRAL OFFICE	INCREMENTAL COST PER PR KFT OF 22 ga. FOR 1500 ohms	CABLE PAIR SIZE	INCREMENTAL COST PER KFT OF 22 ga. FOR 1500 ohms		COST PER LE OR LE / VFR	LE OR LE/VFR COST SAVINGS FOR 1500 OHMS 100 % DTMF	75 % DTMF	50 % DTMF	25 % DTMF	0 % DTMF
m=a	n=g* $3.78	o	p=o*n		q	r	s	t	u	v
28										
29	$6.80	50	$340.20		$100.00	($4659.80)	($3409.80)	($2159.80)	($909.80)	$340.20
30	$17.83	50	$891.69		$100.00	($4108.31)	($2858.31)	($1608.31)	($358.31)	$891.69
31	$27.89	50	$1394.72		$100.00	($3605.28)	($2355.28)	($1105.28)	$144.72	$1394.72
32	$37.96	50	$1897.75		$100.00	($3102.25)	($1852.25)	($602.25)	$647.75	$1897.75
33	$48.02	50	$2400.78		$200.00	($7599.22)	($7599.22)	($7599.22)	($7599.22)	($7599.22)
34	$59.05	50	$2952.28		$200.00	($7047.72)	($7047.72)	($7047.72)	($7047.72)	($7047.72)
35	$69.11	50	$3455.31		$200.00	($6544.69)	($6544.69)	($6544.69)	($6544.69)	($6544.69)
36	$79.17	50	$3958.34		$200.00	($6041.66)	($6041.66)	($6041.66)	($6041.66)	($6041.66)
37	$89.23	50	$4461.37		$200.00	($5538.63)	($5538.63)	($5538.63)	($5538.63)	($5538.63)
38	$99.29	50	$4964.40		$200.00	($5035.60)	($5035.60)	($5035.60)	($5035.60)	($5035.60)
39	$110.32	50	$5515.89		$200.00	($4484.11)	($4484.11)	($4484.11)	($4484.11)	($4484.11)
40	$120.38	50	$6018.92		$200.00	($3981.08)	($3981.08)	($3981.08)	($3981.08)	($3981.08)
41	$130.44	50	$6521.95		$200.00	($3478.05)	($3478.05)	($3478.05)	($3478.05)	($3478.05)
42	$140.50	50	$7024.98		$200.00	($2975.02)	($2975.02)	($2975.02)	($2975.02)	($2975.02)
43	$151.53	50	$7576.48		$200.00	($2423.52)	($2423.52)	($2423.52)	($2423.52)	($2423.52)
44	$161.59	50	$8079.51	BEYOND	$200.00	($1920.49)	($1920.49)	($1920.49)	($1920.49)	($1920.49)
45	$170.10	50	$8505.00	1500 ohms:	$100.00	$3505.00	$2255.00	$1005.00	($245.00)	($1495.00)
46	$173.88	50	$8694.00	1500 ohms:	$100.00	$3694.00	$2444.00	$1194.00	($56.00)	($1306.00)
47	$177.66	50	$8883.00	1500 ohms:	$100.00	$3883.00	$2633.00	$1383.00	$133.00	($1117.00)
48	$181.44	50	$9072.00	1500 ohms:	$100.00	$4072.00	$2822.00	$1572.00	$322.00	($928.00)
49	$185.22	50	$9261.00	1500 ohms:	$100.00	$4261.00	$3011.00	$1761.00	$511.00	($739.00)
50	$189.00	50	$9450.00	1500 ohms:	$100.00	$4450.00	$3200.00	$1950.00	$700.00	($550.00)
51	$192.78	50	$9639.00	> 1700 ohm (22 gauge)	$0.00	$9639.00	$9639.00	$9639.00	$9639.00	$9639.00

r,s,t,u or v
= p-(o*q* Percent DTMF), If m < 32 KFt
= p-(o*q) , If 32 KFt < m < 44 KFt
= p-(o*(200-(100* Percent DTMF))),
If 44 Kt < m < 50.5 KFt
= p , If m > 50.5

Table 3
Part 2 of Study 1
First Cost Comparison

50% DTMF YEAR	FOR LOOPS: LESS THAN 32 KFt. NEW LE's (END OF YEAR TOTALS)	GREATER THAN 32 KFt LE/VFR's (END OF YEAR TOTALS)	TOTAL LE PER YEAR	LE INFLATED COSTS	TOTAL LE / VFR PER YEAR	LE/VFR INFLATED COSTS	LE & LE/VFR ANNUAL CHARGE PERCENT	PWAC FACTOR	LE PWAC	LE/VFR PWAC
a'	b'	c'	f'	g'	h'	i'	k'	l'	m'= g'*k'*l'	n'= h'*k'l'
0	0	0						9.077	$0.00	$0.00
1	2	3	$150.00	$162.00	$600.00	$648.00	21%	8.168	$277.88	$1111.50
2	3	6	$159.00	$185.46	$636.00	$741.83	21%	7.341	$285.90	$1143.61
3	5	10	$168.54	$212.31	$674.16	$849.25	21%	6.590	$293.82	$1175.27
4	7	13	$178.65	$243.05	$714.61	$972.22	21%	5.907	$301.50	$1206.01
5	8	17	$189.37	$278.25	$757.49	$1113.00	21%	5.286	$308.87	$1235.49
6	10	21	$200.73	$318.54	$802.94	$1274.16	21%	4.722	$315.87	$1263.48
7	13	25	$212.78	$364.66	$851.11	$1458.66	21%	4.209	$322.32	$1289.29
8	15	30	$225.54	$417.47	$902.18	$1669.87	21%	3.742	$328.05	$1312.22
9	17	34	$239.08	$477.92	$956.31	$1911.67	21%	3.318	$333.00	$1332.01
10	20	40	$253.42	$547.12	$1013.69	$2188.48	21%	2.932	$336.87	$1347.49
11	22	45	$268.63	$626.34	$1074.51	$2505.37	21%	2.582	$339.61	$1358.46
12	25	51	$284.74	$717.04	$1138.98	$2868.14	21%	2.263	$340.76	$1363.03
13	28	57						TOTALS:	$3784.47	$15137.86
14	32									
15	35									
16	39									
17	42									
18	46									
19	51									
20	55									
21										

Table 4
Part 3 of Study 1
Development of PWAC Costs
AT 50% DTMF

Percent DTMF	LE PWAC	LE/VFR PWAC
0	$ 0.00	$15,137.86
5	$ 378.45	$15,137.86
10	$ 756.89	$15,137.86
15	$1,135.34	$15,137.86
20	$1,513.79	$15,137.86
25	$1,892.23	$15,137.86
50	$3,784.47	$15,137.86
75	$5,676.70	$15,137.86
100	$7,568.93	$15,137.86

TABLE 5

Twelve year PWAC costs for LE and LE/VFR on 50 pair cable.

- -

STUDY FOR: 50% DTMF

TOTAL KFT FROM CENTRAL OFFICE	IF 24 ga. LESS THAN OR EQUALS 32 KFt. PWAC: LE	IF 24 ga. GREATER THAN 32 KFt. LE/VFR	IF 22 ga. GREATER THAN 44 KFt. LEorLE/VFR	CABLE PWAC	NEGATIVE PWAC IMPLIES BREAKEVEN
o'	p'	q'	r'	s'	t'
29	$3784.47			$518.78	$3265.68
30	$3784.47			$1359.77	$2424.69
31	$3784.47			$2126.86	$1657.60
32	$3784.47			$2893.95	$890.51
33		$15137.86		$3661.04	$11476.82
34		$15137.86		$4502.03	$10635.83
35		$15137.86		$5269.12	$9868.74
36		$15137.86		$6036.21	$9101.65
37		$15137.86		$6803.30	$8334.56
38		$15137.86		$7570.39	$7567.47
39		$15137.86		$8411.38	$6726.48
40		$15137.86		$9178.47	$5959.39
41		$15137.86		$9945.56	$5192.30
42		$15137.86		$10712.65	$4425.21
43		$15137.86		$11553.64	$3584.22
44		$15137.86		$12320.73	$2817.13
45		$15137.86	$3784.47	$12969.58	($1616.18)
46		$15137.86	$3784.47	$13257.79	($1904.40)
47		$15137.86	$3784.47	$13546.01	($2192.61)
48		$15137.86	$3784.47	$13834.22	($2480.82)
49		$15137.86	$3784.47	$14122.43	($2769.04)
50		$15137.86	$3784.47	$14410.65	($3057.25)
51		$15137.86	$15137.86	$14698.86	($14698.86)

t'=p'+q'-r'-s'
s'=p(Table3) * 16.8% * 9.077

TABLE 6
Part 3 of Study 1
PWAC Comparison
AT 50% DTMF

The results of the PWAC comparisons for other DTMF penetration rates are summarized in Table 7. Using 24 gauge cable and loop extenders instead of 22 gauge cable because of 400 ohm sets do not prove-in unless the DTMF rates are below 25% At the point that 22 gauge loops require electronic loop treatment (45 kft) 24 gauge cable and LE/VFR prove-in. The PWAC comparisons reflect the low net interest rate (10% cost of money minus 8% inflation). The electronics would have proven in much closer to the central office if a greater net interest rate had been used; for example, 15% interest and 5% inflation.

Percent DTMF	24 Ga. and LE "Proves-In" (kft from CO)	24 Ga. and LE/VFR "Proves-In" (kft from CO)
0	29	51
5	29	51
10	29	50
15	30	49
20	31	48
25	31	46
50	NEVER	45
75	NEVER	45
100	NEVER	45

TABLE 7

PWAC COMPARISON

STUDY II - EFFECT OF SUBSCRIBER DISTRIBUTION

In the second study long term economics are analyzed in relation to the distribution of subscribers. Data from the 1969 REA Exchange Plant Survey was used to create a model of a normal subscriber route. In one portion of the study 997 subscriber loops were surveyed. Of the 997 45% were less than 10 kft, 62% - 20 kft, 72% - 30 kft and 80% were less than 40 kft. Noting that the limit for 24 gauge loaded loops with 200 ohm sets and without LE and VFR's is 32 kft, then at least 72% of the loops would not require either active electronic treatment or 22 gauge cable. However, if 400 ohm sets were used the loops between 28 and 32 kft might require loop extenders.

To create the model the subscriber totals are divided by four. This creates a model of a typical exchange having a 1000 line central office and four major cable routes.

Four sequential five-year plans were created (Tables 8 through 14). The existing cables were assumed to have been installed five years ago and sized in accordance with TE&CM Section 210. TE&CM Section 210 calls for sizing the cables for a maximum 80% five-year fill. The cable additions were derived using the cable selection table (Table 8) from the current draft TE&CM Section 231. The TE&CM draft table is an improvement over the older fill factor table in that it takes into account the existing subscriber base when there are substantial cable pairs in existence. The current fill factor table works well when there are no existing pairs. It is equivalent to the zero (0) existing pair column in the selection table. However, it undersizes additions when there are many existing and usable cable pairs.

A 16.8% annual charge is used for cable. A 21.0% annual charge is used for the loop extenders and voice repeaters. An 8% inflation rate and 10% cost of money are used. The subscribers were grouped in 10 kft sections for convenience and the cable pair size transition points are therefore 10 kft apart. In effect we have 10 kft design areas, which is not too different from the 9 kft of the early SAVE guidelines. Tables 9 - 14 develop the PWAC values for four five-year design comparisons. The first cost (with inflation) of the 22 gauge plan was 394% of the LE/VFR plan. The PWAC for the 22 gauge plan was 313% of the LE/VFR plan.

Impact on Pair Gain Equipment

The impact of 400 ohm telephone sets on pair-gain systems varies and depends on the type of carrier.

Station Carrier

On newer station carrier models the manufacturers have increased the drop ohm limits to compensate for the 400 ohm telephone sets. With older models the 400 ohm telephone sets could be a problem. However, the older station carrier need not be junked just because of the 400 ohm sets. In most cases the 400 ohm set penetration rate will be low. In addition, some of the newer station carrier are interchangeable with existing models of the same manufacturer. Also the older station carrier models could be reterminated with subscribers having only 200 ohm sets.

PCM Subscriber Carrier and Concentrators

When REA was developing the SAVE concept, application guidelines were issued for PCM carrier. The guidelines specified that the dc loop resistance for 22 and 24 gauge loops not exceed 1300 ohms. The 1300 ohm figure was chosen more for attenuation purposes than loop resistance. Thirteen hundred ohms of cable plant is very close to 6 dB of loss. In designing PCM systems 2 dB is allowed for equipment loss leaving 6 dB for the cable plant (of the 8 dB maximum loop loss). A typical PCM carrier system can be represented by a 44 volt battery with a 400 ohm internal resistance. At 20 mA the resistance could be up to 2200 ohms (44 volts ÷ 20 mA). Since the system has a 400 ohm internal resistance, 1800 ohms are available for the cable plant and the telephone set. In the case of a 400 ohm set, 1400 ohms would be left for the cable plant.

Remote Switching Terminals (RST)

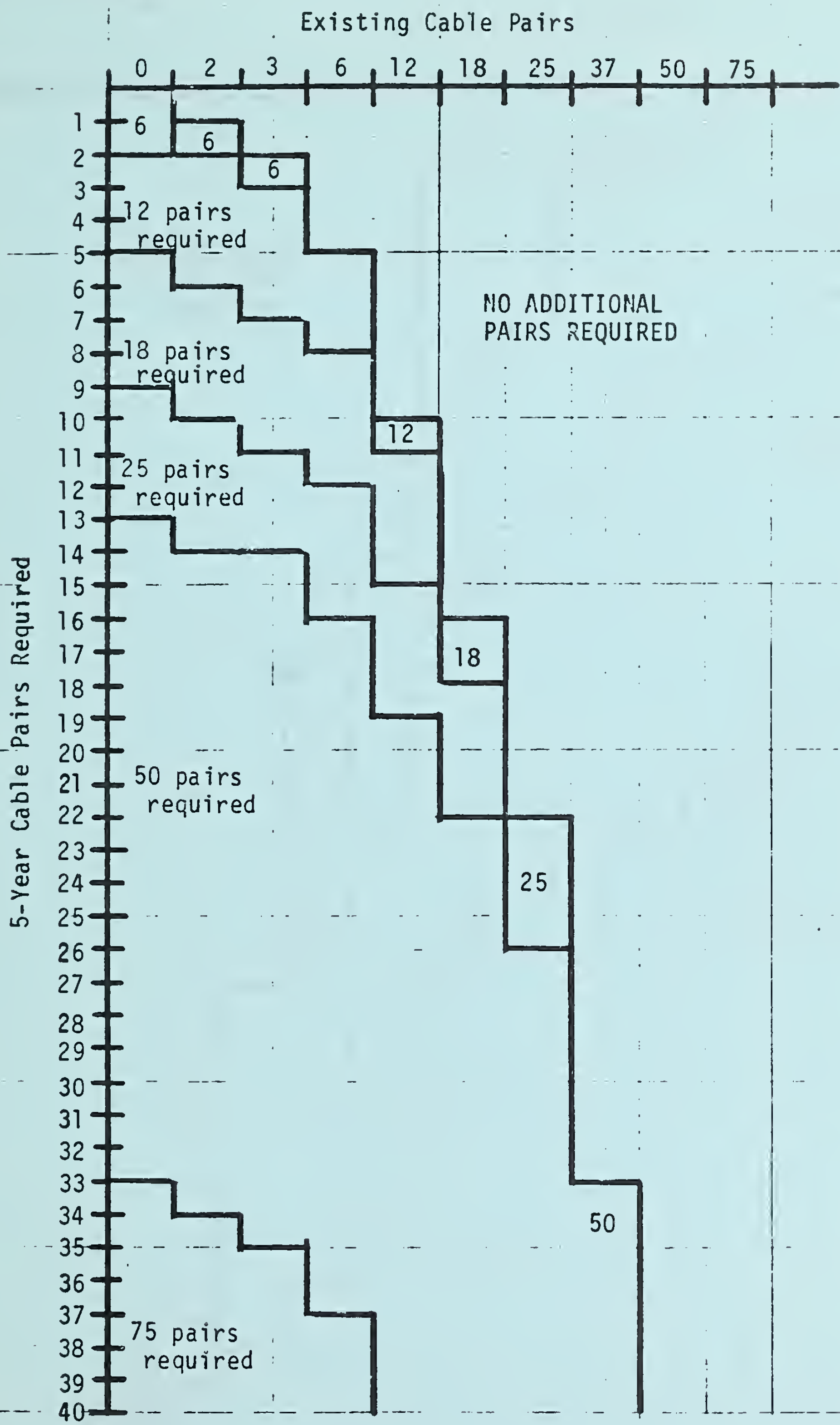
If these units are equipped with standby generators, then the same constraints and economics that applied to physical loops from a 1900 ohm central office would also apply to loops from a RST. If a RST does not have a standby generator, then like a PCM carrier terminal loops from it should be limited to 1800 ohms. The maximum cable plant resistance would be 1400 ohms for a 400 ohm set and 1600 ohms for a 200 ohm set. Unlike PCM carrier, the RST is assumed to be part of a central office. Loops from the RST may have a loss of up to 8 dB. Rather than wasting capital or more copper, loop extenders should be used on long loops from the RST.

Conclusion and Recommendations

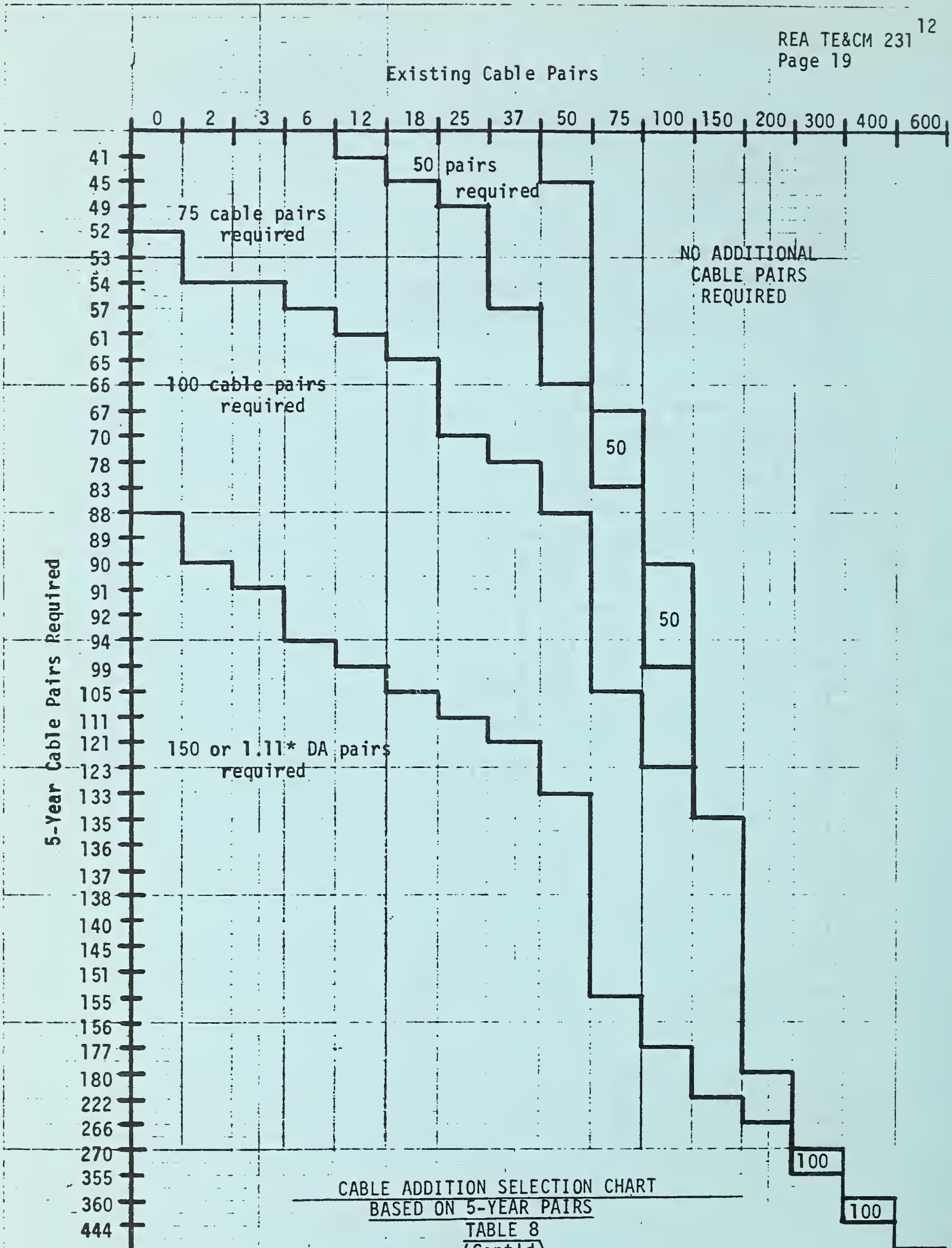
Based on our initial studies, in some cases using 22 gauge cable plant can be more economic than using electronic line treatment. This is especially true in areas of high 400 ohm set penetration with clusters of subscribers just beyond the 1500 ohm point of 24 gauge cable (28 kft to office). However, owing to the distribution of subscribers, in most cases electronic line treatment will be much more economical than using coarser gauge cable. Even with clusters of subscribers it would be more economical to use pair gain equipment rather than placing 22 gauge cable, especially when there are 50 or more subscribers and suitable cable already exists. In addition, it may not be too long before feeder circuits will be provided by fiber optic circuits. Some day even paired distribution cables may be replaced by an optical communication port into the home or in some cases by cellular or other types of radio. Therefore, our guidelines are as follows:

1. Physical plant should not be designed for 400 ohm sets, only for 200 ohm sets. If a 400 ohm set is installed beyond the office limits and will not work, put a loop extender on the line. Of course, if it is on a station carrier derived line, a loop extender will not be of much use. The carrier should be replaced with a newer model or be moved closer to the subscriber.

2. Use line treatment or pair gain equipment to serve long loops. Carrier based pair gain devices should be considered for use on all loops over 60.8 kft in length (3000 ohms of 24 gauge cable). Use of 22 and 19 gauge cables must be supported by engineering economic studies on a cable route basis and not on an exchange basis. Note: 22 gauge cable may be easily justified when most of the pairs are used for carrier span lines. The reduction in carrier repeaters (from a 24 to 22 gauge span line) will not only reduce initial electronic equipment costs, but more importantly reduce long term maintenance costs and improve system reliability.



CABLE ADDITION SELECTION CHART
BASED ON 5-YEAR PAIRS
TABLE 8



CABLE ADDITION SELECTION CHART
BASED ON 5-YEAR PAIRS
TABLE 8
(Cont'd)

DATE 1/11/84
FILE IMPACT505

BASE SYSTEM INFORMATION

PERCENT DISTRI- BUTION (10 KFt. DA)	DESIGN AREA LOCATION (KFt. FROM CO)	CUMULATIVE SUBCRIBERS	SUBCRIBERS PER DESIGN AREA	SUBCRIBERS PER DESIGN AREA PER ROUTE	DESIGN AREA SUBS	DESIGN AREA CUM. CKTS.	PAIRS 80 % FILL	DESIGN AREA LOCATION (KFt. FROM CO)	EXISTING PAIRS
						997			
45%	0	997	452	113	113	249	312	0	400
17%	10	545	170	43	43	136	170	10	200
10%	20	375	82	21	21	94	117	20	150
	28	LE w 24 ga.	21	5	5	73		28	
8%	30	272	17	4	4	68	85	30	100
	32	VFR w24 ga.	67	17	17	64		32	
7%	40	188	26	7	7	47	59	40	75
	44	LE w 22	40	10	10	40		44	
5%	50	122	2	1	1	31	38	50	50
	50.5	VFR w 22	44	11	11	30		50.5	
3%	60	76	28	7	7	19	24	60	25
2%	70	48	19	5	5	12	15	70	18
1%	80	29	7	2	2	7	9	80	12
1%	90	22	8	2	2	6	7	90	12
1%	100	14	14	4	4	4	4	100	6
100%			997	249					

TABLE 9

BASE SYSTEM INFORMATION

FIRST FIVE YEAR DESIGN									FIRST FIVE YEAR DESIGN		
DESIGN AREA LOCATION (KFt. FROM CO)	EXISTING PAIRS	YEAR 5 DESIGN AREA CUM. CKTS.	PAIRS 90 %	PAIR SHORTAGE	ADDITION PER DRAFT SECTION 231	INCREMENT. COST PER KFt.	LENGTH KFt	EXTENDED COST	LE OR VFR REQUIRED FOR GROWTH	LE & VFR COSTS	EXTENDED COST
0	400	334	371	-29					84		
10	200	182	203	3	100	$344.85	10	$3448.50			
20	150	125	139	-25							
28		98							25	$100.00	$2474.12
30	100	91	101	1	50	$189.04	10	$1890.40			
32		85							22	$100.00	$2157.88
40	75	63	70	-5							
44		54							14	($100.00)	($1366.43)
50	50	41	45	-5							
50.5		40							10	($100.00)	($1012.14)
60	25	25	28	3	25	$101.81	10	$1018.10			
70	18	16	18	-0							
80	12	10	11	-1							
90	12	7	8	-4							
100	6	5	5	-1							
						$635.70					

		CABLE		LE / VFR
FIRST FIVE YEAR:				
INSTALLED COST		$6357.00		$2253.43
INFLATION / FACTOR	8%	100.00%	8%	100.00%
INFLATED COST		$6357.00		$2253.43
ANNUAL CHARGE FACTOR		16.8%		21.0%
ANNUAL COST		$1067.98		$473.22
YR 0 PWAC FACTOR		9.077		9.077
DEFERRED PWAC		0		0
NET PWAC FACTOR		9.077		9.077
PWAC		$9694.02		$4295.42
MONTHLY COST		$89.00		$39.43
MO. $ PER NEW SUB.		$1.06		$0.47
MO. $ PER ALL SUB.		$0.27		$0.12

TABLE 10

FIRST FIVE-YEAR PWAC

	SECOND FIVE YEAR DESIGN							SECOND FIVE YEAR DESIGN			
	24	25	26	27	28	29					
DESIGN AREA LOCATION (KFt. FROM CO)	YEAR 10 EXISTING PAIRS	YEAR 10 DESIGN AREA CUM. CKTS.	PAIRS 90 %	PAIR SHORTAGE	ADDITION PER DRAFT SECTION 231	INCREMENT. COST	LENGTH KFt	EXTENDED COST	LE OR VFR REQUIRED FOR GROWTH	LE & VFR COSTS	EXTENDED COST
0	400	446	496	96	150	$506.87	10	$5068.70	113		
10	300	244	271	-29	0	$0.00	10	$0.00			
20	150	168	187	37	100	$344.85	10	$3448.50			
28		131							33	$100.00	$3310.93
30	150	122	135	-15	0	$0.00	10	$0.00			
32		114							29	$100.00	$2887.73
40	75	84	94	19	75	$263.83	10	$2638.30			
44		72							18	($100.00)	($1828.59)
50	50	55	61	11	50	$189.04	10	$1890.40			
50.5		54							14	($100.00)	($1354.47)
60	50	34	38	-12		$0.00	10	$0.00			
70	18	21	24	6	25	$101.81	10	$1018.10			
80	12	13	14	2	18	$79.13	10	$791.30			
90	12	10	11	-1		$0.00	10	$0.00			
100	6	6	7	1	12	$59.68	10	$596.80			
						$1545.21					

	CABLE	LE / VFR
SECOND FIVE YEAR:		
INSTALLED COST	$15452.10	$3015.59
INFLATION FACTOR	146.93%	146.93%
INFLATED COST	$22704.20	$4430.90
ANNUAL CHARGE FACTOR	16.8%	21.0%
ANNUAL COST	$3814.31	$930.49
YR 0 PWAC FACTOR	9.077	9.077
DEFERRED PWAC	3.791	3.791
NET PWAC FACTOR	5.286	5.286
PWAC	$20162.42	$4918.56
MONTHLY COST	$317.86	$77.54
MO. $ PER NEW SUB.	$2.82	$0.69
MO. $ PER ALL SUB.	$0.71	$0.17

TABLE 11

SECOND FIVE-YEAR PWAC

THIRD FIVE YEAR DESIGN								THIRD FIVE YEAR DESIGN			
DESIGN AREA LOCATION (KFt. FROM CO)	YEAR 15 EXISTING PAIRS	YEAR 15 DESIGN AREA CUM. CKTS.	PAIRS 90 %	PAIR SHORTAGE	ADDITION PER DRAFT SECTION 231	INCREMENT. COST	LENGTH KFt	EXTENDED COST	LE OR VFR REQUIRED FOR GROWTH	LE & VFR COSTS	EXTENDED COST
0	550	597	664	114	150	$506.87	10	$5068.70	151		
10	300	327	363	63	100	$344.85	10	$3448.50			
20	250	225	250	-0	0	$0.00	10	$0.00			
28		175							44	$100.00	$4430.77
30	150	163	181	31	100	$344.85	10	$3448.50			
32		153							39	$100.00	$3864.43
40	150	113	125	-25	0	$0.00	10	$0.00			
44		97							24	($100.00)	($2447.07)
50	100	73	81	-19	0	$0.00	10	$0.00			
50.5		72							18	($100.00)	($1812.59)
60	50	46	51	1	50	$189.04	10	$1890.40			
70	43	29	32	-11	0	$0.00	10	$0.00			
80	30	17	19	-11	0	$0.00	10	$0.00			
90	12	13	15	3	18	$79.13	10	$791.30			
100	18	8	9	-9	0	$0.00	10	$0.00			
						$1464.74					

	CABLE	LE / VFR
THIRD FIVE YEAR:		
INSTALLED COST	$14647.40	$4035.55
INFLATION FACTOR	215.89%	215.89%
INFLATED COST	$31622.64	$8712.44
ANNUAL CHARGE FACTOR	16.8%	21.0%
ANNUAL COST	$5312.60	$1829.61
YR 0 PWAC FACTOR	9.077	9.077
DEFERRED PWAC	6.145	6.145
NET PWAC FACTOR	2.932	2.932
PWAC	$15576.55	$5364.42
MONTHLY COST	$442.72	$152.47
MO. $ PER NEW SUB.	$2.93	$1.01
MO. $ PER ALL SUB.	$0.74	$0.26

TABLE 12

THIRD FIVE-YEAR PWAC

FORTH FIVE YEAR DESIGN								FORTH FIVE YEAR DESIGN			
DESIGN AREA LOCATION (KFt. FROM CO)	YEAR 20 EXISTING PAIRS	YEAR 20 DESIGN AREA CUM. CKTS.	PAIRS 90 %	PAIR SHORTAGE	ADDITION PER DRAFT SECTION 231	INCREMENT. COST	LENGTH KFt	EXTENDED COST	LE OR VFR REQUIRED FOR GROWTH	LE & VFR COSTS	EXTENDED COST
0	700	799	888	188	200	$668.89	10	$6688.90	202		
10	400	437	486	86	150	$506.87	10	$5068.70			
20	250	301	334	84	100	$344.85	10	$3448.50			
28		235									
30	250	218	242	-8	0	$0.00	10	$0.00	59	$100.00	$5929.37
32		205									
40	150	151	167	17	100	$344.85	10	$3448.50	52	$100.00	$5171.48
44		130									
50	100	98	109	9	75	$263.83	10	$2638.30	33	($100.00)	($3274.73)
50.5		96									
60	100	61	68	-32		$0.00	10	$0.00	24	($100.00)	($2425.65)
70	43	38	43	-0	0	$0.00	10	$0.00			
80	30	23	26	-4	0	$0.00	10	$0.00			
90	30	18	20	-10	0	$0.00	10	$0.00			
100	18	11	12	-6	0	$0.00	10	$0.00			
						$2129.29					

	CABLE	LE / VFR
FORTH FIVE YEAR:		
INSTALLED COST	$21292.90	$5400.47
INFLATION FACTOR	317.22%	317.22%
INFLATED COST	$67544.68	$17131.21
ANNUAL CHARGE FACTOR	16.8%	21.0%
ANNUAL COST	$11347.51	$3597.55
YR 0 PWAC FACTOR	9.077	9.077
DEFERRED PWAC	7.606	7.606
NET PWAC FACTOR	1.471	1.471
PWAC	$16692.18	$5292.00
MONTHLY COST	$945.63	$299.80
MO. $ PER NEW SUB.	$4.68	$1.48
MO. $ PER ALL SUB.	$1.18	$0.38

TABLE 13

FOURTH FIVE-YEAR PWAC

TOTALS AT YEAR 25

DESIGN AREA LOCATION (KFt. FROM CO)	YEAR 25 EXISTING PAIRS	YEAR 25 DESIGN AREA CUM. CKTS.	PAIRS 90 %	PAIRS TO BE RETIRED	PAIR SHORTAGE	PERCENT SHORTAGE
0	900	1070	1189	400	689	58%
10	550	585	650	200	300	46%
20	350	402	447	150	247	55%
28		314				
30	250	292	324	100	174	54%
32		274				
40	250	202	224	75	49	22%
44		173				
50	175	131	145	50	20	14%
50.5		128				
60	100	82	91	25	16	17%
70	43	52	57	18	32	56%
80	30	31	35	12	17	48%
90	30	24	26	12	8	31%
100	18	15	17	6	5	28%

TOTAL:	CABLE	LE / VFR	PERCENT INCREASE
INSTALLED COST	$57749.40	$14705.04	393%
INFLATION FACTOR			
INFLATED COST	$128228.52	$32527.98	394%
ANNUAL CHARGE FACTOR			
ANNUAL COST	$21542.39	$6830.87	315%
PWAC	$62125.18	$19870.41	313%
MONTHLY COST	$1795.20	$569.24	
MO. $ PER NEW SUB.	$3.26	$1.03	(AVERAGE)
MO. $ PER ALL SUB.	$2.25	$0.71	315%

TABLE 14

TOTAL PWAC VALUES AT YEAR 25

CONTENTS

Outside Plant (pink sheets)

LIGHTWAVE CABLE, SPLICING AND HOUSINGS

INTRODUCTION

The Rural Electrification Administration is actively participating with both manufacturers and telephone companies to evaluate new cable designs, splicing techniques and housing methods on fiber optic systems. Within REA financed projects there are approximately 15 active, or soon to be active, fiber optic systems. The information and experiences obtained from these systems will be incorporated into material specifications (PE's), splicing standards (PC's) and telecommunications engineering and construction manuals (TE&CM's) for general dissemination to the telephone industry.

HISTORY

The REA fiber optic field trials have already provided valuable information concerning the operation and design of these systems. For example, an early cable design did not require armor on buried cable. The first field trial involved a project that was located in an area not normally affected by gophers and the cable was not armored. However, due to our limited experience with fiber cable, an aluminum shield was placed in the cable. The system was installed and operational when a failure occurred. The failure was traced to a break in the cable caused by ground hogs. Fortunately, the break in the cable placed a ground on the shield and the damaged area was located and the fibers were repaired using the flame fusion technique. The repaired cable was placed in a Brand-Rex splice case, encapsulated and buried. As a result of this problem, it was determined that the flame fusion method of splicing was totally unacceptable due to the splicing time required to repair the damage and that a method had to be devised to control the ground hog population in the area. The Wild Life Service recommended the use of cyanide gas as a proven method of controlling ground hogs. The telephone company applies the chemical every spring and fall. In order to monitor the success or failure of the gas, the telephone company tests for grounds on the cable shield, on a monthly basis, for an indication as to whether or not the rodents have returned. Both procedures have proven successful. A second incident involved an aerial system where the fiber optic cable was attacked by a family of mice. The aerial cable had been brought down the pole, buried in a flexible duct, looped through a handhole and spliced in a splice case mounted in a pedestal. The cable was not armored. The mice chewed through the plastic handhole and built their nest. They were able to attack the optical cable in numerous places and were successful in cutting all four fibers. An emergency repair was accomplished using GTE Elastomeric connectors that were installed without the use of a Fiber Optic Time Domain Reflectometer (FOTDR). Subsequently, the splice was tested with an FOTDR and the loss through the connectors ranged from .2 to .5 db. After this incident, all splice cases were removed from the pedestals and were mounted on poles. A third incident involving rodents occurred when a home owner attempted to shoot a squirrel and hit the cable damaging several fibers. As a result of these cable problems, REA requires that all buried fiber optic cable contain armor. In addition, armor is available as an option for aerial cable.

We have experienced attenuation problems, the first occurred during extreme temperature variations. The cable was suspect and replaced by the manufacturer. However, the problem has reoccurred and is being investigated. Another project had a significant amount of cable damage during plowing. The construction period allowed sufficient time for the cable to be repaired. While our experience with splice cases and housings has been satisfactory, we have experienced one field trial problem that involved retractable pedestals. The mid point pedestal had to be locked in the extended position when it was found that the bell jar design of the pedestal did not keep water out. After extending the center section of the pedestal, a metal housing was installed as a permanent cover. This project will be monitored for water problems in the other retractable pedestals.

CABLE SPECIFICATION

A cable specification is currently being written that covers the minimum requirements that REA believes are necessary to withstand routine installation practices and perform as the cable was intended. The major points in the specification will be:

- Multimode graded and single mode stepped index glass fibers.
- 125 micrometer cladding diameter.
- Factory splices of fibers.
- Color coding standard similar to the copper conductor scheme.
- Standard fiber counts of 4, 6, 8 and 10 fibers.
- Total waterproofing with both filling and flooding.
- Polymer coated armor for buried application.

- o Standard polyethylene cable jacket materials.
- o OPTICAL CABLE markings.
- o METER length markings.
- o Maximum attenuation.
- o Minimum bandwidth.
- o Wide range wavelength capability.
- o Close tolerance Numerical Aperture (NA).

REA presently has one cable company listed to supply multimode graded index fiber cable, for aerial and underground applications, to REA borrowers. The cable is totally dielectric including the strength member and armor is not available. Other cable manufacturers are expected to be listed by early spring. Several single mode field trials are being considered for installation this summer. The cable specification should be completed and ready for distribution by mid 1985.

CABLE SPLICING

A splicing standard (PC-7) is being developed for fiber optics. This standard will provide guidance for both fusion splicing and mechanical connectors. Only multimode graded index fibers have been used on REA projects. However, the field trials involving single mode step index fibers should provide additional information for the standard. The standard should be completed by 1985.

The splicing methods used to date are:

- o Flame fusion splicing - used in the first REA fiber optic field trial in Commonwealth Telephone of Dallas, PA - 1979.
  - No longer in use.
- o Arc fusion splicing - used in the remaining REA fiber optic field trials, except where connectors were used.
  - Most commonly used technique.
- o Mechanical splicing - used at Cross Telephone of Warner, Ok-1982 and North Pittsburgh Telephone of Gibsonia, PA - 1983.
  - Other mechanical connectors will be evaluated as they become available.

HOUSINGS

The key words in the evaluation of housings for fiber optic splice points are accessibility and protection. For the purposes of this paper, splice cases shall be considered as housings.

Splice Cases

- Conventional cable splice cases have seen wide use for both filled and unfilled fiber splices.
- The unfilled fiber optic splice for aerial or above ground does not need special consideration beyond a neat, well arranged fiber organizer.
- The filled, or flooded fiber optic splice has utilized the reenterable urethane, rubber like, materials and the "heavier-than-water" liquid encapsulants as fillers.

Housings

- REA standard BD3, BD4 and BD7 pedestals have been used.
- Buried retractable pedestal units.
- Ground level housing designed for fiber optics.

The practice of field trialing splice cases, organizers and housings shall continue. We are concerned about numerous problems, such as, (1) possible fiber damage during reentry into splice cases, and (2) protection offered to splices and connectors in organizers and housings. It is quite apparent that additonal study on the part of REA is required.

There has been a variety of approaches to below-ground, aerial and ground level housing methods.

- Buried encapsulated splice case.
- Buried retractable pedestal housings.
- Buried handhole with pedestal mounted on top.
- Ground level pedestal with splice case installed inside.
- Aerial splice case, nonencapsulated.

REA feels that the telephone company should choose the housing method best suited to their needs. With more experience REA will develop specifications for fiber optic splice cases and housings.

REA FORM 515 CONTRACT

The following is an example of the REA Form 515 entries for fiber optic cable. These same units will apply to aerial (c) and underground (u) cable:

*	BFC	-	Buried Filled Cable.
*	X	-	Insert the number of fibers in the cable.
*	F	-	Constant to indicate Fiber Cable.
*	Y	-	If desired fiber loss is the standard 1 db per kilometer leave out, if a loss greater than 1 is acceptable, insert loss value that would be acceptable.
**	___	-	If other than loose tube buffer insert "T" for tight tube buffer.
**	___	-	If other than dual windows insert "W" for single window or "M" for single mode.
**	___	-	If other than 50 micron fiber core, insert actual fiber core diameter.

NOTE: * Must be provided.

NOTE: ** Optional, do not provide if standard.

Examples:

BFC4F	Buried Filled Cable with 4 Fibers.
BFC4F2T	Buried Filled Cable with 4 Fibers 2 db loss per kilometer and tight tube construction.

The above REA Form 515 entries were accepted by the 515 Committee prior to recent changes in the fiber optic cable specification. They were provided as an example and changes are anticipated. For example - armored and non-armored cable will have to be added. New fiber construction types, such as slotted and ribbon, will have to be provided for.

Demarcation Device Development

As of January 1, 1983, all new Customer Premises Equipment (CPE) was deregulated. Customers purchase CPE from any available source. Part 68 of the Federal Communications Commission (FCC) rules and regulations outlines conditions on use, registration, complaint procedures and other issues on this subject.

The FCC proposed that a Demarcation Device be provided for the purpose of separating the customer owned wiring from the telephone company wiring. This device will be designated as the Demarcation Point. Unfortunately, the FCC did not resolve numerous questions relating to this issue, such as, where the device would be physically located, inside, outside or either.

The Demarcation Device will be installed on all new construction or where a customer modifies existing wiring. Customers that do not modify existing wiring are not required to have the device.

Currently two types of devices are being marketed. There is the Network Interface Device (NID) and a Remote Interface Device (RID). For the purposes of this paper only the NID shall be discussed.

The basic requirement for the NID is that it contain a modular jack for customer access in the event that the telephone is out of service, thus providing customer access to the telephone line isolated from the residence. The NID would contain terminating hardware for either single or dual line connections. Above all the NID would have to provide adequate protection for the modular jack.

Numerous devices currently being marketed have taken the device one step further and provided facilities for the installation of a protector within the housing.

REA does not accept Network Interface Devices at this time. We are studying the requirements for such a device and will develop a specification. One major requirement shall be that the NID when designed to contain a protector be U/L listed and the actual device is marked as U/L listed. Additional requirements have not been identified as of this date.

REA financed projects desiring to install NID's at this time should contact their Area Director with their request. We recommend that only U/L listed devices be used when the NID is designed to contain a protector and that the manufacturer provide detailed test data verifying environmental and electrical testing accomplished on the unit. These products should be considered for field trials.

It is our understanding that the FCC will issue a position paper on the Demarcation Device in the near future.

Revision of REA Splicing Standard PC-2

The Rural Electrification Administration (REA) is collecting data for the purpose of revising REA Bulletin 345-6, "Standard for Splicing Plastic-Insulated Cables."

Many technical and material innovations have rapidly arisen in the telecommunications industry over the past few years substantially improving the techniques and the products affiliated with the splicing of plastic insulated cables.

Some of the major changes have come about through the introduction of modular splicing and the dramatic increase in the use of the Service Area Interface Cabinets (SAIC) on REA financed systems.

This document will designate all the applications of modules and update REA requirements covering splicing arrangements within the SAIC.

We are investigating the possibilities of new techniques for grounding the cable shield to the housing and the number of bonding harnesses required to achieve shield continuity with the related cable sizes.

REA also sees a necessity to increase the maximum number of cable pairs to be spliced within the associated housing.

Other areas are being considered and will be addressed in the final document. The revised document is expected to be finalized in the first quarter of 1985.

Revision of REA Specification PE-33 for Cable Shield Bonding Connectors

The present shield bonding connectors used within REA were designed to be installed on medium to large outside plant cables. These same connectors were also installed on small diameter sevice wire, which results in difficult and time consuming installations because the current specification does not allow for connectors specifically designed for service wire. To alleviate the above problem REA is currently revising the specification. Major points of revision are as follows:

(a) Classification of connectors into three types - cable, service wire, and universal.

(b) Updating of electrical requirements.

(c) Addition of a salt fog test for corrosive environments.

The final draft of the revised specification is being distributed to the industry for comments.

Revision of REA Specification PE-57 for Spring Action Type Bonding Connectors Within Buried Plant Housings

The present specification only covers the performance of the spring action terminal. Because of some reported problems with these terminals, REA has decided to revise the specification to improve the performance of the spring action terminal and the harness wire. Major points of the specification revisions are as follows:

(a) Addition of performance requirements for the harness wire.

(b) Addition of mechanical requirements for all types of end terminations.

(c) Improved performance requirements for the spring action terminal.

(d) Addition of salt fog test for corrosive environments.

A first draft revision has been circulated to the industry for comments and REA is now receiving comments from the industry on the first draft.

Revision of REA Specification PE-26 for Voice Frequency Loading Coils

The Outside Plant Branch is presently revising REA Specification PE-26 for voice frequency loading coils. One major change being investigated is the use of filled cable stubs on all loading coil assemblies intended for direct buried, manhole, strand and pole mounted applications. This action would eliminate the use of loading coil cases equipped with an air core cable stub, except for special applications where REA decides that a filled stub is not practical. Therefore, all loading coil assemblies for direct buried, manhole, strand and pole mounted applications would be classified as universal. REA classifies a universal loading coil assembly as an assembly with a plastic case equipped with a filled, gopher protected cable stub that is capable of being buried in the ground.

The REA's main concern is the fact that some universal assemblies being used in the field are equipped with air core cable stubs. The assemblies with the air core stubs are identical in physical appearance as the assemblies with filled stubs and inadvertently could be installed in the ground. This could create unnecessary expenses and major maintenance problems.

REA does not foresee any significant problems arising from this change and feels that a universal loading coil assembly would insure a higher quality product for the borrowers.

The addition of mini-loading coils is also being carefully considered for incorporation into the PE-26 specification. The mini-loading coil would have certain restrictions limiting its application. Mini-loading coils would not be installed along rural leads exceeding five miles or in areas of high lightning activity. They would never be used in areas where lightning damage to cable and/or loading coils has been experienced. This would not preclude the use of large assemblies containing mini- coils at the first load point in those locations where there is limited space for the loading coil assembly.

Revision of REA Specification PE-39 for Filled Buried Cable

The current specification is being revised to provide borrowers with improved existing designs and the use of new designs. The revised specification will have the following items incorporated into the specification:

(a) Increasing the compound flow test requirement from 65° C to 71° C.

(b) Allowing service pairs in screened cable.

(c) Allowing the integral shield/screen separator tape design.

(d) Improving the near-end crosstalk loss performance requirements of screened cable.

(e) Addition of near-end crosstalk loss and attenuation requirements at 1576 kHz for T1C carrier systems.

The first draft of the revised specification is now being circulated within the industry for comments. REA expects the revised specification to become effective in the first quarter of 1985.

Revision of REA Specification PE-89 for Filled Telephone Cable With Expanded Insulation

The current specification, which became effective in 1982, limits the use of expanded insulated filled cables to pair counts of 200 pairs and greater and conductor sizes to 22, 24 or 26 gauge. These limitations were placed on the specification to control its use by REA borrowers until the Outside Plant Branch reviewed data received from field trials of small pair count cables. This data has been reviewed and based upon our evaluation the current REA Specification PE-89 is undergoing the following revisions:

(a) The allowance of pair counts below 200 pairs.

(b) The allowance of 19 gauge size conductors.

(c) Increasing the compound flow test requirement to 80^{0} C for aerial applications.

(d) Allowance of service pairs in screened cable to be used for fault locate, interrogation and pressure check operations.

(e) Allowance of the integral shield/screen separator tape design.

(f) Improvement in the near-end crosstalk loss performance requirements for screen cable.

(g) The addition of near-end crosstalk loss and attenuation performance requirements at 1576 kHz for T1C carrier systems.

Items a, b and c were a result of field trial evaluations; whereas, the remaining items are a result in advancements in technology. The revised specification containing the above mentioned items has been accepted by Technical Standards Committee "A" (Telephone). The revision has been forwarded to the Federal Register as a proposed rule with expectations that the revised specification will become effective in the fourth quarter of 1984.

New REA Specification PE-87 for Terminating (TIP) Cable

REA recommends that all entrance cable be manufactured with fire resistant materials. To that end, REA TE&CM 810 has recommended that cables commonly referred to in the industry as "TIP" cables be used for this express purpose. Although REA has listed "TIP" cables within the REA List of Materials for years, such listing has been without a formal performance standard. Since it is our responsibility to provide borrowers with quality "TIP" cables, REA has recently developed a new specification for "TIP" cables. This specification is referred to as REA Specification PE-87, "Terminating (TIP) Cable." The new specification became effective on December 30, 1983. Some of the major points of the specification are:

(a) 22 and 24 Awg tinned conductors.

(b) Dual extruded insulation - primary layer of natural or white polyethylene and colored outer skin of polyvinyl chloride.

(c) Single-sided coated aluminum shield which is bonded to a polyvinyl chloride outer jacket.

(d) Electrical performance requirements.

Manufacturers presently listed for "TIP" cables have been given a June 30, 1984, deadline for qualification to the new specification.

Revision of REA Specification PE-20 for Plastic-Insulated, Plastic-Jacketed Station Wire

Because of the advancements made in station wire designs from the initial date of the current specification which is August 29, 1974, REA has revised the specification to incorporate these new designs. The revised specification has been accepted by Technical Standards Committee "A" (Telephone) and the revised specification was published in the Federal Register as a proposed rule on December 30, 1983, for public comment. The revised specification incorporates the following items:

(a) Residual Antioxidant Test for conductor insulation.

(b) Allowance of a 3 pair design.

(c) Allowance of beige and ivory colored jackets.

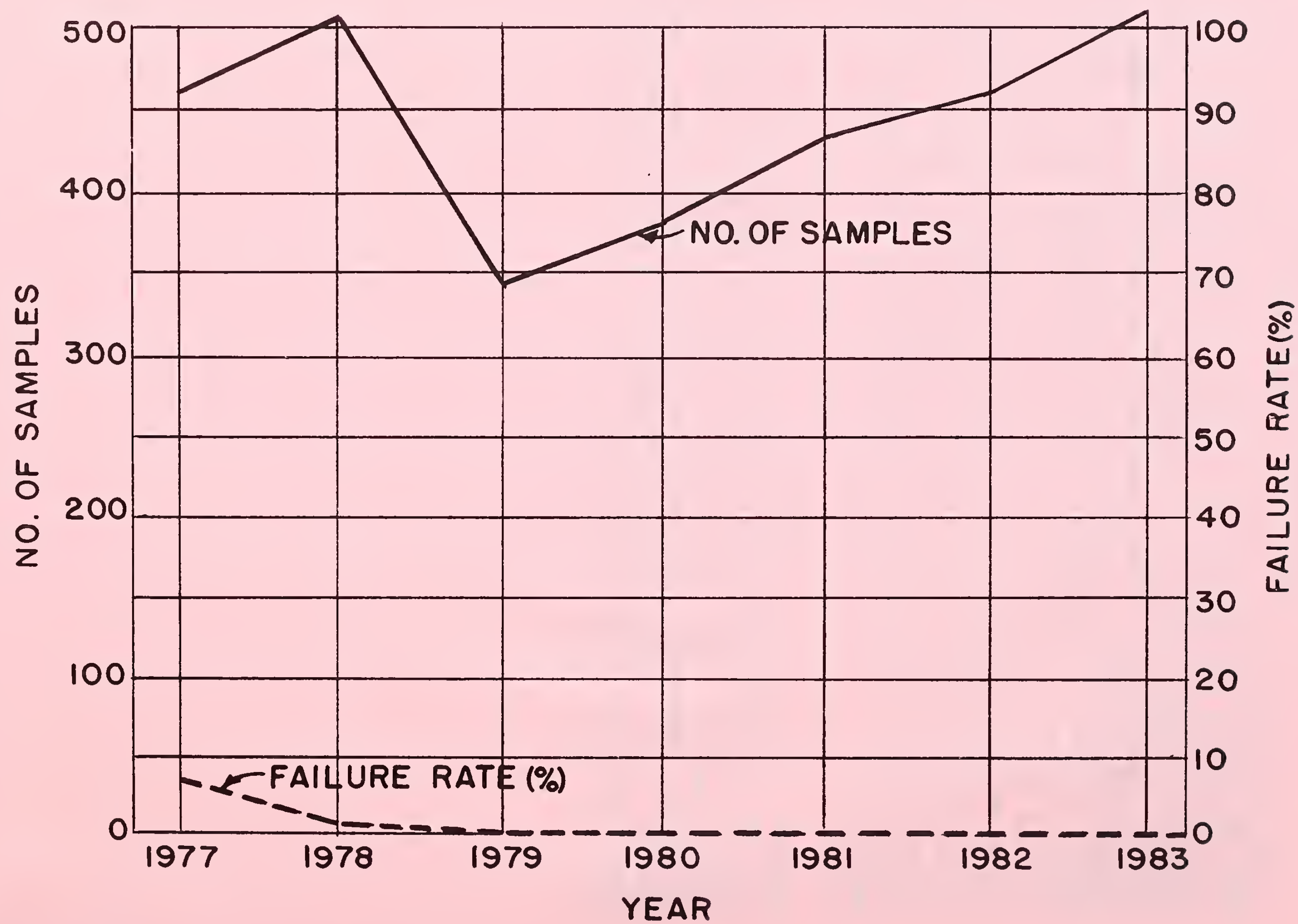
(d) Improved electrical performance requirements.

WIRE AND CABLE QUALITY ASSURANCE PROGRAM

In 1976 the Outside Plant Branch initiated a Quality Assurance Program as a means of determining the quality of cables and wires that were being received and installed at REA borrowers' projects. This program required REA field personnel to submit cable and wire samples taken randomly from borrowers' projects throughout the year to the Outside Plant Branch for electrical and mechanical evaluation. As can be shown by the accompanying Graph, REA field personnel have been very responsive to the program because of quantity of samples received for evaluation. Another fact pointed out by the Graph is that the number of cable problems detected in the evaluation samples has declined to practically zero since the inception of the program. It should also be pointed out that if cable problems were detected, the Outside Plant Branch notified both the manufacturer of the product and the borrower. In notifying the product manufacturer of the problem, we requested that immediate action be taken by the manufacturer to resolve the problem at the borrower's location, take corrective action in their manufacturing process to prevent a reoccurence of the problem and inform REA as to what corrective action was taken.

Although the Graph shows essentially zero cable problems, REA borrowers continue to have problems with cables and wires which are not detected by this program. The reason that these problems are not being detected is because this program only evaluates a relatively small percentage of cables and wires installed at borrower's locations. The way to eliminate these undetected problems is to increase the responsiveness of the program along with increased plant inspections of manufacturing facilities. Steps have been initiated to achieve progress in both of these areas.

CABLE SAMPLES EVALUATED AND FAILURE RATES BY YEAR



OUTSIDE PLANT LABORATORY

In 1980, REA received permission from the U.S. Marine Corps located at Quantico, Virginia to develop a parcel of land located in a remote section of the base into a functional working outside plant laboratory. The size of this parcel of land is approximately 5.5 acres. The site is completely enclosed by a security fence and the site contains a renovated block house. Some of the evaluations to be performed at this laboratory are as follows:

(a) Evaluation of new methods of installation.

(b) Evaluation of long term aging tests on new product designs.

(c) Evaluation of new cable test methods such as fault locating and shield to ground resistance test.

(d) Simulate field faults and use the evaluation data to develop practices for locating such faults and to develop repair practices.

(e) Simulate a working subscriber loop and evaluate the effects on the loop through induced faults to develop improved REA practices.

REA FORM 515 CONTRACT REVISIONS

Introduction

At the 1982 Symposium, REA published draft changes to the REA Form 515 Contract and Supplements 515a, 515c, 515d, 515f and 515g. The following is intended to provide the current status on these revisions.

Discussion

We have not published the aforementioned changes primarily due to a change in government regulations. These changes require that the supplements be identified as REA Bulletins. As of December 30, 1983, the supplements were assigned bulletin numbers as follows:

515a	Bulletin 345-150
515c	Bulletin 345-151
515d	Bulletin 345-152
515e	Bulletin 345-153
515f	Bulletin 345-154

As a result of this action, the supplements may now be revised and submitted for final approval and printing.

Status

The REA Form 515 requires additional review and internal approval before revision. The documentation necessary for this review and approval is being prepared.

The REA Form 515 supplements are being reviewed and updated. Due to the quantity of changes, the supplements will be completely reprinted. Estimated completion date is the first quarter of 1985.

Revisions

The following are the major revisions to the contract:

- The addition of expanded insulated cable for buried and underground applications.
- The addition of fiber optic cable for aerial, buried and underground applications.

- o New options and sizes for buried plant housing units-BD's.
- o New sizes for the serving area interface cabinet-BD's.
- o Designation of two types of ground wire, a #10 Awg, insulated, tinned copper and a #6 Awg, insulated copper wire.
- o Numerous editorial changes throughout the contract.

Conclusion

Until such time as the revised REA Form 515 and supplements are issued, only the official REA Form 515 contract and supplements should be used. The drafts published in the 1982 Symposium package should not be used.

AVERAGE BID COST REPORT

Prior to 1975, REA published Report No. 35, "United States Average Bid Costs For Outside Plant Assembly Units." This report calculated the average cost of labor and materials for the REA Form 511 units. When the REA Form 515 contract replaced the REA Form 511 contract the program for producing these reports was dropped. REA has now written a new program for the REA Form 515 units and the report should be available by the third quarter of 1984.

The new program has been updated and when available shall include units for fiber optic cable as they appear in the REA Form 515 contract.

Contents

Transmission (green sheets)

CENTRAL OFFICE GROUNDING AND BONDING PRACTICES

Myron L. Brewer
Transmission Branch
Telecommunications Engineering and Standards Division

The following REA TE&CM, Section 810, Issue No. 6, dated September 1983 entitled, "Electrical Protection of Electronic Analog and Digital Central Office Equipment" has been published and distributed. This practice presents the concepts of single point grounding systems for application to electronic central office equipment. The design is essentially for small offices housed in single story buildings.

ELECTRICAL PROTECTION OF ELECTRONIC ANALOG AND DIGITAL CENTRAL OFFICE EQUIPMENT

CONTENTS

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers and other interested parties with information in the design, installation and operation of REA borrowers' telephone systems. In particular, this section covers electrical protection practices recommended for electronic analog and digital central offices. The practices are also applicable to digital remote switching terminals housed in central office type buildings.

1.2 This section, replacing Issue 5, dated August 1980, has been revised to present the concepts of single-point ground systems. The single-point ground system isolates the electronic switching equipment from all elements of the total central office grounding system except at a single point. This isolation minimizes the flow of potentially damaging currents.

1.3 Electronic switching systems are susceptible to excessive induced transient voltages which may be introduced through incoming circuits, the central office grounding system, or by electrostatic action. The inherent voltage sensitive characteristics of electronic switching systems are due primarily to the fragile nature of semiconductor components and their fast transient response characteristics. Semiconductors typically have low breakdown voltage ratings and can be permanently damaged by excessive voltage spikes.

1.4 The basic grounding system discussed in this section is designed for application in the single floor office buildings typical in the sytems of REA borrowers. This section may be utilized as described in paragraph 14 to improve protection of electromechanical switching systems that have power and lightning surge related problems.

1.5 The single point grounding system described in this section is designed to meet the protection requirements of most central office equipment manufacturers. No deviation should be made from the described method unless there are compelling reasons for change. (See Paragraph 1.6).

1.6 Some central office equipment manufacturers may request grounding systems exceeding those recommended herein. These might include a rigid, low maximum resistance requirement for the central office ground field or various forms of extraordinary lightning protection. The costs of providing and maintaining these features can be quite high.

1.7 This discussion of central office grounding systems is essentially based on resistance since this is a primary parameter that is readily understood. However, the essential factor in building and switching system protection is the grounding system impedance, especially the reactance component, of the grounding conductors. The general guidelines presented in this practice are based on providing a system having a relatively low overall impedance to the flow of lightning and power fault currents.

2. DEFINITIONS

2.1 The following terms are defined as an aid to understanding their usage in this section. They are terms commonly used for describing telephone central office grounding systems. Different terms have been used by individual manufacturers and operating companies other than those commonly used. Such terms are included in parentheses at the end of each definition, where applicable.

2.2 BUILDING STRUCTURAL GROUND: a ground bond connected to structural steel and/or reinforcing steel rods contained within the building walls, roofs, floors, footings, or foundations.

2.3 CABLE ENTRANCE GROUND BAR (CEGB): a copper ground bar provided for the purpose of terminating incoming telephone cable shields on a common connection point. The bar is normally located close to the entrance location. (CABLE VAULT GROUND BAR).

2.4 CENTRAL OFFICE GROUND FIELD (COGF): a series of interconnected ground rods, buried perimeter cable or a metallic well casing for provision of a low resistance path to earth ground. (CENTRAL OFFICE GROUND GRID).

-.5 COLLOCATED SWITCHING SYSTEM: two or more separate switching systems, at a single location.

2.6 ELECTROSTATIC DISCHARGE (ESD) PROTECTION: protection required to minimize electronic component damage related to static voltage discharges. Static charges are typically generated by moving personnel or moving air in a work area where relative humidity is low.

2.7 FUSE LINK: a length of fine gauge wire in series with a larger gauge wire, for the purpose of "fusing" open during a current-surge condition. This element normally provides protection from currents which could otherwise heat conductors and start fires.

2.8 GREEN WIRE GROUND (GWG): a normally noncurrent carrying conductor provided for the protection of personnel and equipment. The green color code distinguishes the lead from the current carrying grounded conductors (neutrals) which are natural, gray or white. (EQUIPMENT GROUNDING CONDUCTOR)

2.9 GROUND LOOP: ground loops exist when there is more than one electrical path from a point in a circuit to a reference ground connection. Such parallel paths to ground are normally not a problem if associated with the nonsensitive circuitry located outside the IGZ. Ground loops are undesirable for equipment located inside the IGZ.

2.10 GROUND WINDOW BAR (GWB): a copper ground bar provided for the common connection of all equipment located inside the Isolated Ground Zone (IGZ), see paragraph 2.8. (GROUND WINDOW GROUND BAR, MAIN GROUND BAR, GROUND WINDOW SPLICE PLATE).

2.11 INSULATING JOINTS: nonconducting inserts provided at specified points in metal framework of equipment located inside the IGZ. These are provided for the purpose of insulating the IGZ equipment from outside ground connections.

2.12 INTERMEDIATE GROUND BAR (IGB): a copper ground bar, insulated from its support used as a distributing point for a ground wire from the Master Ground Bar (MGB) (see paragraph 2.10) to be connected to several racks or frames of equipment, usually in the non-IGZ area, but <u>not</u> to include battery (+) from the main power board.

2.13 ISOLATED GROUND ZONE (IGZ): a dedicated area within an office building wherein all equipment is electrically insulated from all external grounds except through a single ground connection between the GWB and the MGB. The isolated area should preferably extend a minimum of six feet (1.8 meters) on all sides from the equipment frames and framework and where practical be separated from other equipment by permanent walls. The IGZ will normally house sensitive electronic components. (ISOLATED AREA).

2.14 MAIN DISTRIBUTING FRAME (MDF): a distributing frame where outside plant cables are terminated on vertical protection assemblies. Cable pairs are also cross-connected on this frame to CO line equipment terminated on horizontal blocks.

2.15 MASTER GROUND BAR (MGB): a copper ground bar used as single point connection for surge producers, surge absorbers, non-IGZ equipment grounds, and IGZ equipment grounds. The MGB is normally non-current carrying and isolated from the building/structural ground.

2.16 MDF GROUND BAR (MDFB): a copper ground bar typically provided at the bottom of the MDF used as the connection point for tip cable shields and MDF protector assemblies. The MDFB may be used as an MGB in small offices. (ENTRANCE CABLE PROTECTOR BAR).

2.17 MDF PROTECTOR ASSEMBLY: an assembly consisting of a protector module and a connector module.

2.18 METALLIC WATER SYSTEM: a public or private water system that includes an outdoor section or buried metallic water pipe at least 10 feet in length and owned by the telephone company.

2.19 MULTIGROUNDED NEUTRAL (MGN): a power distribution system which provides a grounded conductor having multiple direct connections to earth ground. In this system, at least 4 grounds must be provided in each mile of line, not including grounds at individual services. This multiple grounding arrangement provides a very low impedance path to earth ground for the purpose of absorbing lightning and switching surges. It also provides a return path for residual (unbalanced) currents resulting from less than perfect balance on associated three-phase power distribution systems.

2.20 PERSONNEL DISCHARGE PLATES: plates provided in equipment areas containing voltage-sensitive electronic equipment. These plates are connected to ground and are used to discharge body voltages to ground rather than through accidental contact with sensitive electronic components.

2.21 SINGLE POINT GROUNDING: a grounding system utilizing a single point, usually the MGB, to provide a zero reference potential to ground for an entire office switching system. While the voltage at this connection point may rise above zero volts-to-earth-ground under fault conditions, the entire switching system will also rise at the same rate to the same voltage. This helps minimize any circulating currents between switching components during a condition of lightning or power surge.

2.22 SURGE ABSORBERS (A): surge absorbing paths with a low resistance connection to remote earth ground. A grounding element which has a low resistance path to earth ground is considered a primary surge absorber. There are only three primary surge absorbers: (1) the central office ground field, (2) the power system multiground neutral (MGN), and (3) a metallic water system.

2.23 SURGE PRODUCERS (P): connections to metallic sources of lightning and/or power surges. For example, radio/microwave towers, telephone cable shields, telephone cable pairs and power system conductors.

3. SINGLE POINT GROUNDING

3.1 Single-point grounding is based on several related principles. There is a need to control the high voltage differences which are produced between the ends of single conductors such as copper wires and busbars by fast rising electrical surges. Reference Appendix A for a discussion of the voltage effects from rising surge currents.

3.2 Surge potentials need to be equalized through controlled bonding of central office ground elements. Among these ground elements (see Figure 1) are:

a - Surge Producers (P)
b - Surge Absorbers (A)
c - Non-IGZ equipment grounds (N)
d - IGZ equipment grounds (I)

3.3 Single-point grounding is used to reduce voltage differences and control surge currents. The basic elements of a single point grounding system include the following:

3.3.1 A Master Ground Bar (MGB) with connections grouped to confine lightning and power surge activity. This is also the point for establishing a common reference plane, with respect to earth ground, for the entire central office.

3.3.2 A Ground Window Bar (GWB) for establishment of a single local reference point for grounding sensitive electronic equipment within the IGZ. Section I (see paragraph 4) of the MGB provides a single-point termination and ground reference to which the GWB and associated electronic equipment are bonded.

3.3.3 An Isolated Ground Zone (IGZ) surrounding the electronic switch and other sensitive electronic equipment. The IGZ will consistently have the reference to ground as the GWB.

3.4 A high voltage rise can occur between the point of strike and point(s) of dissipation under momentary large surge conditions, such as those resulting from direct or indirect lightning strikes to cable or other outside plant connected to the MGB. The MGB bonding configurations illustrated in Figure 1 and 6 enable high current surges to be concentrated and dissipated through the P and A sections of the bar. This maintains the lowest possible potential at the point of MGB-GWB connection. The connection sequence of P-A-N-I as shown in Figure 1 is very important to the overall protection effectiveness.

3.5 All equipment located within the IGZ electrically floats at essentially the same potential as the GWB when the single-point grounding concept is used. When all switch modules are operating at the same potential, no damaging voltages appear across sensitive components and surge currents are eliminated.

4. MASTER GROUND BAR (MGB)

4.1 The MGB is the hub of the basic central office grounding system used as a common point of connection for the P-surge producers and A-surge absorbers, as well as the equipment grounds for both the N-nonisolated and I-isolated equipment areas. Sizing of ground conductors is discussed in Paragraph 8. The MGB is a copper bar insulated from its support. The MGB may be located either on a wall near the MDF, or on the cable vault wall. In small offices it may be located on the MDF as described in Paragraph 4.2.2. The various connections to the MGB should be tagged or stencilled to identify each as described in Paragraph 8.3.

4.2 Surge Producers (P Section of MGB): The MGB is the preferred connection point for surge producers.

4.2.1 Cable Entrance Ground Bar (CEGB): Cable shields should be bonded directly to a CEGB in offices where a cable vault has been provided. The CEGB is connected by the most direct route to the MGB. The CEGB is a copper bar insulated from its support.

4.2.2 MDF Ground Bar (MDFB): The main frame protector blocks should be bonded directly to the MDFB. A detailed discussion of MDF protection is provided in Paragraph 7. This ground bar is also the bonding point for terminating the MDF end of tip cable shields to ground. The MDFB may be used as the MGB in very small offices where installation of a wall-mounted MGB is impractical. With this application, the bar should be insulated from its support and have sufficient length to provide the connection sequence shown in Figure 1. It is important, that the integrity of all sections of the bar are preserved for the life of the ground bar arrangement. The MDFB may be insulated from its support as required by the manufacturer.

4.2.3 Radio and Microwave Equipment Grounds: Connect all <u>indoor</u> cabinets which are a part of these system(s) directly to the MGB. <u>No</u> connections should be made to the GWB or other central office ironwork. Where the MDFB is used as the MGB, these equipment grounds should be connected to the P section of the bar. Radio/microwave towers are provided with outdoor, dedicated grounding systems. Surge voltages should be equalized by bonding the dedicated grounding system to the central office ground field at a point outside the building for personnel safety and equipment protection. This connection is discussed in Paragraph 4.3.2 - 4.3.2.2.

4.2.4 Standby Power Plant Framework Ground: A connection should be provided between the standby power plant framework and the MGB to equalize framework voltages for safety reasons. When the standby power plant is located in a separate building from the electronic equipment an earth electrode should be installed and connected to the standby power plant framework.

4.3 Surge Absorbers (The A section of MGB): The MGB is also the preferred connection point for the three primary surge absorbers. They are the power system multigrounded neutral, the central office ground field and the metallic water system. Bonding of the power neutral and water pipe, on the MGB does not replace the requirements of the National Electrical Code for separately bonding the commercial power service.

4.3.1 Multigrounded Neutral (MGN): The MGN with its multiple connections to earth throughout the power system normally has a low resistance to earth ground. Because of this low resistance it may be the most important ground connected to the MGB. The low resistance to earth ground makes it an excellent surge absorber. The MGN may occasionally become a momentary surge producer due to nearby lightning strikes or power system transients. Refer to Paragraph 8 for a discussion of ground system conductor sizes. In any case the ground conductor between the MGN and the MGB should be the same size or larger than the commercial MGN service entrance conductor to the building.

4.3.1.1 Occasionally a non-MGN power system (e.g., delta or unigrounded wye system) will be encountered. A bond is still required between the local power ground electrode and the MGB. Non-MGN systems do not qualify as primary surge absorbers. They must therefore be excluded from the calculations of ground resistance discussed in Paragraph 4.6.1.

4.3.2 Central Office Ground Field: The outdoor portion of the ground conductors connecting the central office ground field to the MGB should be buried a minimum 2.5 ft. (0.76m) below finished soil grade and enter the building through a nonmetallic conduit. The conductor should be placed in a straight line with no splices to reduce the impedance to fast rising surges. See Paragraph 8 for a discussion of ground conductors. When lightning rods and/or radio/microwave towers are provided these should be connected to the central office ground field outside the building as described below.

4.3.2.1 Lightning Rod Ground: Lightning rod systems are grounded via a separate dedicated ground field. A bond should be provided between the central office and lightning rod ground fields, to minimize inductive noise coupling, reduce the chance of flashover, and provide protection for personnel and equipment. The connection point between the two ground fields should be accessible to permit temporary disconnection for earth resistance measurements. The preferred location for this connection is where the conductor between the central office ground field and the MGB is connected to the ground field. An easily accessible, permanent handhole closure is recommended for this connection. The conductors should follow the most direct route with a minimum of bends. See Figures 2 and 6.

4.3.2.2 Radio/Microwave Tower Ground: A bond should be provided between the central office ground field and the radio/microwave tower ground for the same reasons discussed above. All provisions for this grounding should be identical to those described in Paragraph 4.3.2.1. Where both lightning rod and tower ground systems exist, both systems may be connected to the central office ground field in the same handhole closure.

4.3.3 Central Office Metallic Water System: It is important to bond to the central office metallic water system, where one exists, to comply with National Electrical Code (NEC) requirements. This also provides an additional low resistance connection to earth ground. When no water system is present in the building, this ground connection may be omitted. If the central office water system entrance piping includes at least 10 ft. (3m) of buried metallic pipe in direct contact with earth (1981 NEC Articles 250-80 and 250-81) from either a drilled well or public water system it will qualify as a metallic water system. The water system metallic entrance pipe must also be owned and controlled by the Telephone Company if used as a primary surge absorber. Ground wire connections should be made to the main entrance pipe of the water system. When there is a water meter or insulating joint in the pipe a bypass bonding wire should be installed to insure electrical continuity. Permission from the owner of the water system is required when the pipe on the street side of the meter is not owned by the telephone company or where there is an insulated coupling at the meter. The electrical service will be bonded to the water piping as shown in Figure 6 to comply with Article 250-80 of the National Electrical Code.

4.3.4 Building Structural Ground: A connection should be provided to the building structural ground for earth grounding and potential equalizing safety reasons. This ground is not considered to be a primary surge absorber. A low resistance path to ground is provided by reinforced concrete that is in direct contact with bare earth, such as building footings. Structural steel used in some buildings can have voltage differences from equipment frames installed in the building. This occurs when equipment frames rise in voltage due to current surges through the MGB or when lightning strikes the structure. During building construction, rebars should be lashed to steel column anchor bolts at each floor/roof level. Connection to the steel columns should be made between the nearest accessible point and the MGB. Ground wire connections should be made directly to the rebar during construction of new reinforced concrete buildings containing no steel columns.

4.4 Non-IGZ Grounds (N section of MGB): The N section is primarily a common voltage reference point to which all non-IGZ equipment frames are connected. The single-point grounding system is designed to confine all lightning and surge currents to the P and A sections of the MGB. The connections to the N section prevent voltage differences between equipment racks, etc. in the non-IGZ area. Surge currents and shock hazards for personnel in the building are thereby effectively minimized. All equipment frames, ironwork, and other exposed metallic surfaces that could become energized are bonded to the MGB at this point. The N section is also the connection for equalizing voltages on the positive (+) central office power bus. This connection between the positive (+) battery terminal and the MGB is not normally a d-c power current carrying conductor and is provided only for equalizing voltage differences.

4.5 IGZ Grounds (I Section of MGB): The I section of the MGB normally should have the least voltage variation of any section along this ground bar. All ground connections to the GWBs are made in this section.

4.6 Ground Resistance Objective: Reasonable effort to meet the objective ground resistance is an important factor in implementing a single-point grounding system. Installation of a perimeter ground around and outside the building foundation perimeter is recommended. Other types of ground fields are acceptable where the ground resistance objective can be met (reference Paragraph 4.6.2).

4.6.1 The combined central office ground resistance from the three primary surge absorbers, as defined in Paragraph 4.3, should be five-ohms or less when measured at the MGB subject to the limitations of Paragraph 4.6.2. Where all three primary surge absorbers are provided at a central office, the five-ohm objective should be met <u>when any two</u> of the grounds are connected. For central office buildings where only two surge absorbers are available, the objective for the central office ground field is five-ohms or less. (See TE&CM Section 802 for a discussion of grounding techniques.)

4.6.2 Establishment of a low resistance ground field can be difficult at the location of some rural central office buildings. The actual measured resistance to remote earth of the ground field provides a guide for determining if it is practical to attempt achieving the five-ohm objective resistance. Where the measured value of the ground field alone is between five-and 25- ohms, further efforts to reduce the resistance is not recommended. The work required to reduce the resistance an additional one- or two-ohms could be very expensive. When the actual measured resistance exceeds 25-ohms additional effort should be made to reduce the resistance. Earth resistivity measurements should be completed at various depths and locations around the building before initiating any reduction effort. Calculation of the approximate anticipated resistance to earth based on the recorded results of the measurements should be completed for various ground configuration and electrode lengths. The results of these calculations will indicate the probability of attaining the objective ground resistance. (Reference TE&CM Section 802).

4.6.2.1 Following are some techniques which may reduce the central office ground field resistance:

a. Attach to building rebar ground.
b. Drive extended or sectional ground rods to a depth of up to 32 ft. (9.75m).
c. Establish a second ground field.
d. Install one or more 6 to 10-inch (15.2 to 25.4 cm) well casings. These should extend below the water table level.

4.6.2.2 Application of chemical soil treatment, as described in TE&CM Section 802, is not recommended. Chemical treatment is not permanent and must periodically be renewed. Where chemically enhanced grounds are used a program should be initiated to measure the ground resistance at six month intervals to insure they are all still effective.

4.6.3 The resistance of the central office ground field should be determined prior to selecting the specific equipment for installation. The manufacturers of equipment should be advised when the five-ohm central office ground field objective cannot be achieved by established methods. Where extraordinary measures must be taken to protect the equipment warranty the added costs should be considered as described in Paragraph 1.6.

5. CENTRAL OFFICE GROUND WINDOW BUSBAR (GWB)

5.1 All equipment grounds that originate inside the IGZ are terminated on the GWB which should preferably be physically located inside the IGZ and insulated from its support. The use of a GWB which is provided by the equipment manufacturer as an integral part of the switching equipment is acceptable. Normally those ground conductors originating inside the IGZ that are terminated on the GWB will be placed by the personnel installing the switching equipment.

5.2 A separate IGZ should be established with its own GWB where additional electronic or digital switching equipment is located in a remote area of the same floor or on another floor of the building.

5.3 Connect each GWB to the MGB with a conductor following the most direct route. This grounding conductor should be 2/0-gauge or coarser copper with a resistance of less than 0.005 ohms. (Reference Paragraph 8) The use of parallel conductors for redundancy is acceptable as required by the manufacturer.

5.4 The conductors terminating on the GWB should be suitably identified as described in Paragraph 8.3.

5.5 The frame grounds of ONLY that switching equipment and associated electrical equipment located INSIDE the IGZ should be connected to the GWB as may be required by the equipment manufacturer. This includes but is not limited to those items described in the following paragraphs.

5.5.1 All metal framework of the switching systems (e.g., frames, cabinets, bays, etc.) should be connected to the GWB. The manufacturer's recommendations for establishing these connections should be followed.

5.5.2 The cable racks, static control ground mats, discharge plates, transmission equipment, and protective grounds of any other IGZ equipment that obtains power from the main power plant should also be connected to the GWB. Any special recommendations from the equipment manufacturer should be complied with.

5.5.3 The manufacturer's instructions on isolation of the battery charger framework ground from the internal positive (+) chassis connection should be followed.

5.5.4 The a-c conductors including the protective ground conductors serving all 120 volt a-c electrical convenience receptacles and all direct wire peripheral equipment, located in the IGZ, should be sized in accordance with normal "green wire" criteria. Each termination point should be tagged to indicate the green wire is a GWB isolated ground wire. The manufacturer's recommendation for the metallic racks within the IGZ will determine how the green wire is handled in the IGZ. The metallic racks may be insulated from the concrete floors and reinforcing steel or connected to it. Routing of the a-c conduit and protective green wire ground in the manner described below insures compliance with National Electrical Code requirements.

5.5.4.1 Racks insulated from building: The conduit carrying 120 volt a-c conductors into the IGZ should be routed to a junction box located adjacent to the GWB. The green wire should be solidly connected to the junction box and a wire connection established between the junction box and the GWB. Use of metallic or non-metallic conduit for extending and bonding the a-c conductors into the IGZ is at the option of the manufacturer. Where metallic conduit is used care should be taken during installation to assure it is insulated from foreign grounds (building structural steel and reinforced concrete members) beyond the GWB. There is no need to install isolated <u>orange</u> convenience receptacles with this configuration since everything beyond the GWB in the IGZ is at GWB ground potential. Isolated a-c ground convenience receptacles may be installed as required by the manufacturer.

5.5.4.2 Racks not insulated from building: The conduit carrying 120 volt a-c conductors into the IGZ should be routed directly to the metallic racks. Since these racks are at the same ground potential as the conduit and green wire by being connected to the reinforced concrete floor there should be no connection to the GWB. Isolated a-c ground convenience receptacles may be installed as required by the manufacturer. Equipment in the IGZ should be isolated from the metallic racks which are not isolated from building grounds.

5.5.5 Where overhead lighting fixtures located in the IGB are an integral part of or are in electrical contact with the equipment frame(s), the associated green protective ground wires should be connected to the GWB isolated ground wire system. For convenience, they may also be connected to the GWB where the connections above do not exist. All fixtures connected to the GWB system need to be isolated from building structural steel and reinforced concrete members. Green wires associated with lighting fixtures having no electrical contact with the equipment frames may be connected in the conventional way to the a-c distribution panel ground.

5.5.6 The protective grounds for teletypewriters, cathode ray tube consoles, test equipment and other a-c powered devices located or used within the IGZ area are normally provided by the green wire leads in the attached power cords. The green wire pins should not be removed from the 3-wire power cords of such equipment and 2-wire adapters should not be used.

5.5.7 Every precaution should be taken to insure the integrity of the IGZ. No foreign grounds should be permitted to come into contact with any equipment within the IGZ except through the GWB, except as indicated by the equipment manufacturer.

6. ISOLATED GROUND ZONE (IGZ)

6.1 An isolated ground zone is defined in Paragraph 2.8.

6.1.1 If practical, permanent markers should be placed on the floor to identify the IGZ boundaries. Paint or tape of distinctive color such as orange should be used.

6.1.2 Precautions should be taken to insure that no permanent or temporary ground connections are permitted to cross the IGZ boundary except as defined in Paragraph 5.5.4.2.

6.2 The metal framework associated with digital electronic central office equipment and associated peripheral equipment should be installed and bonded in accordance with the manufacturer's requirements. Some manufacturers require the frames be isolated from the floor while others permit anchoring directly to the floor.

7. MAIN DISTRIBUTING FRAME (MDF)

7.1 Special grounding considerations are required at the MDF to control incoming surges and provide protection for personnel. The design should provide for this with any of the existing or new MDF protectors that are available. The MDF is treated as being outside of the IGZ in all cases.

7.1.1 MDF protector assemblies should be mounted directly on the vertical frame ironwork. The assemblies mounted on each vertical should be interconnected with a #6 copper conductor to provide a low resistance path for surge currents. Each vertical group of protector assemblies should be connected to the MDFB with a #6 copper conductor. Alternate means of connection to the MDFB are acceptable which do not rely on the frame ironwork for conducting surge currents to ground.

7.1.2 The MDFB should be insulated from the ironwork in all cases where it is used as a MGB (paragraph 4.2.2). The MDFB may be insulated from its support as required by the CO manufacturer.

7.1.3 Protective "ground connections" should be provided between the MDFB and frame ironwork for personnel protection regardless of the type protector assemblies used. The protective ground leads should be 14-gauge and less than 12 in. (30 cm) in length. Paint must be thoroughly removed at points of connections to the ironwork. One connection should be provided for every 35 ft. (10 m) of frame length.

7.1.4 Where the MDFB is used as the MGB in very small offices (Paragraph 4.2.2) the protective "ground connections" (paragraph 7.1.3) should be connected in the N section of the bar. The MDF protector ground should be connected to the P section of the bar.

7.2 Transmission equipment termination and protection: Digital carrier equipment and sensitive electronic pair gain systems should normally be located inside the IGZ. Some carrier equipment has internal gas tubes for bypassing voltage surges to ground. Equipment of this type should be located outside the IGZ. Analog subscriber and station carrier equipment, voice frequency repeaters and loop extenders are normally located outside the IGZ. All equipment frames located outside the IGZ should be grounded through connections at the N section of the MGB. The equipment located inside the IGZ should be grounded to the GWB.

7.2.1 Protectors for all carrier equipment are normally located on the MDF. An exception may be made to this rule. The protectors for some toll carrier entrance cables are mounted in the carrier bays located in a non-IGZ area.

7.2.1.1 The termination of analog and digital type toll carrier systems on the same protector assembly is not advisable. This practice minimizes coupling that can produce analog carrier circuit noise.

7.2.1.2 Shields of intra-office cable connecting the MDF to carrier equipment bays should be open at the MDF end and grounded at one point to the MGB or GWB. This grounding arrangement provides electrostatic shielding and maintains GWB integrity.

7.2.1.3 Separation of the transmit and receive sides of the cable for T-carrier systems should be maintained. This may be accomplished by using compartmental separation or separate transmit and receive cables all the way to the MDF protector assembly. Between that point and the carrier equipment the separation is usually maintained through use of shielded jumpers, separate shielded transmit and receive cables, or multipair cables with individually shielded pairs.

7.3 Entrance and Tip Cables: The most important characteristics of tip cables, from a protection standpoint, are resistance to flammability and ease of termination. They should also be chemically compatible (i.e., should not chemically react) with the outside plant cables. They should be gauged as described in Paragraph 7.3.2.

7.3.1 Most REA accepted polyvinyl chloride (PVC) insulations and jacket formulations used in telephone cables have adequate flame resistance. They can, however, be destructively damaged chemically by cable filling compounds that are in common use. Polypropylene and polyethylene insulation, polyethylene jackets, and some filling compound types will promote combustion.

Use of filled cables in switchboard rooms should be avoided due to fire hazard. Because of these considerations, nonfilled PVC insulated and jacketed cables (or other insulation with equivalent flame resistance) are preferred for use inside central office buildings and for terminations on the MDF. For compatibility reasons, polyethylene grease (low molecular weight polyethylene) and petroleum jelly (petrolatums) filled cables should not be spliced to conductors insulated with PVC. PVC jacketed tip cables currently available are not usually suitable for outdoor use because of their low resistance to ultraviolet attack and their tendency to become brittle at low temperatures.

7.3.2 The recommended precedure, for use with either filled or nonfilled 24-gauge or smaller gauge polypropylene and polyethylene insulated outside plant cables, is to use a special 22-gauge polyethylene insulated PVC covered conductor tip cable with a PVC outer jacket (ALVYN[R]), or equivalent, in place of PVC insulated. Only those cables accepted by REA that are included in the REA List of Materials should be used. With this arrangement, if the outside cables are filled, the outer PVC covering of the tip cable conductors can be attacked by the filling compound. It may crack in the immediate vicinity of the splice after having been in place for sometime. Tests have shown that the polethylene insulation on the wire beneath the PVC covering will remain intact and retain adequate dielectric strength. This provides an electrically satisfactory splice in spite of the loss of the thin PVC outer layer. The portion of the tip cables run in the office and terminated on the MDF retain their PVC covering and remain flame resistant.

7.3.3 If the first sections of the outside plant cables are coarser than 24-gauge an additional splice would be needed to install a fuse link between the tip cables and each outside plant cable coarser than 24-gauge. Fuse links are typically 24-gauge and have a minimum length of 4 ft. (1.2m) as shown in Figure 3. The additional splices are expensive and undesirable. Therefore, they should be avoided when possible. One means of avoiding the extra splice is to use a 24-gauge entrance cable between the office and riser pole, manhole or pedestal outside the office.

7.3.4 In the event that neither a cable vault nor a splicing trough exists, the outside plant cables should be brought into the central office and spliced to the ALVYN[R] or equivalent, tip cables as close a practicable to the cable entrance. When this design is used, the entrance of the outside plant cable into the building and the splice itself should be enclosed in a fireproof box mounted on the inner side of the building wall as shown in Figure 4.

7.4 Protection: Incoming cable pairs terminated on MDF protector assemblies should be protected with protector modules. These modules, which connect an arrestor between each cable conductor and ground, effectively limit foreign potentials that will reach the equipment in the office. The modules should contain white coded carbon blocks or orange coded gas tube arrestors that are included in the REA List of Materials. These arrestors breakdown at less than 1000V under surge conditions.

7.4.1 Cable pairs associated with carrier, loop extenders, voice frequency repeaters, special circuits or "stand alone" tone-to-pulse converters should be protected with orange coded gas tube protector modules. This equipment is tested to withstand only the maximum voltage passed by these modules. Past experience with most electronic equipment has shown there is very little margin above the test level. Other types of special high voltage gap protection as recommended by the equipment manufacturer are acceptable.

7.4.2 Electromechanical central office equipment has generally had an adequate dielectric strength margin to withstand more than the maximum voltage passed by listed arrestors. Because of this there have been instances where blue coded carbon block arrestors were used (contrary to REA recommendations) without causing problems. However, there have been reports of electronic equipment failures in these same offices equipped with blue coded arrestors. The replacement of existing blue coded with white coded carbon block arrestors is essential when an existing mainframe is retained for protection of a new electronic digital switch.

7.5 Current Limitation: Mainframe protectors which are included in the "List of Materials Acceptable for use on Telephone Systems of REA Borrowers (Item nm) are capable of carrying, without hazard, the sustained current which may result from commercial a-c power contacts to outside plant cable having 22-gauge or finer wire. There are a number of MDF protectors available on the market which do not have adequate current carrying capability. It is important that the borrower's engineer ascertain that the MDF protectors delivered by the COE contractor are actually on the List of Materials.

7.6 Heat Coils: Since 1966 REA has strongly recommended that MDF protectors be furnished without heat coils. Historically, heat coils were used as protection against current surges. Laboratory tests have proven that heat coils do not protect line relays under the large majority of fault current conditions that can occur in actual telephone systems. Further, heat coils and fuse links offer little, if any, protection for today's electronic switching components. Since heat coils are "high maintenance" items compared to fuse links, the latter are preferred for meeting National Electrical Code objectives in the C.O. Heat coils should not be used with carrier frequency pairs due to high frequency attenuation. The addition of heat coils increases the cost of the telephone system with virtually no protection benefits.

8. GROUND CONDUCTOR SIZING, ROUTING AND TERMINATING

8.1 The point of reference for sizing all protective ground conductors except green wire conductors and dc power conductors is the MGB. To determine the appropriate conductor size first establish the distance between the two points of connection via the desired route (i.e., between the MGB and CEGB). Next refer to Figure 6 to determine the resistance objective between the two points. Finally from Table A find the wire size with a maximum footage for the desired resistance objective equal to or greater than the wire distance between the two points. Use of Table A or calculated resistance values are permissible in lieu of measurement. The general guidelines in the following paragraphs are also recommended.

8.1.1 The finest recommended conductor size is 6-gauge, except for the 14-gauge protective grounds at the MDF described in paragraph 7.1.3.

8.1.2 The conductor between the MGB and GWB should always be 2/0 gauge or coarser. The suggested size provided in this paragraph pertains to protective ground conductors only - not to d-c power conductors. The maximum resistance of this conductor should be less than 0.005 ohms.

8.1.3 The conductor between the MGB and the neutral ground bar in the a-c service entrance panel board should always be 2/0 or coarser. The maximum resistance of this conductor should not exceed 0.005 ohms.

8.1.4 The maximum conductor resistance from the MGB to the initial point of connection with all surge producers should not exceed 0.01 ohms.

8.1.5 The maximum conductor resistance from the MGB to the point of connection with all surge absorbers should not exceed 0.01 ohms, except as described in Paragraph 8.1.3.

8.1.6 The maximum conductor resistance from the MGB to the point of connection with all equipment grounds should not exceed 0.01 ohms.

8.1.7 Where an intermediate ground bar (IGB) or connection is provided, the 0.01 ohm objective should be divided on either side of the IGB or connection.

8.2 The planning and installation of the wiring is critical to the provision of an effective grounding system. Care should be taken to minimize induction that may appear in grounding system wiring. Recommended guidelines for installation of grounding system conductors include:

8.2.1 Ground conductors should be insulated to permit integrity testing. Conductors should also be free of splices. If splices must be made only compression connectors or exothermic welding should be used.

8.2.2 Ground conductors should be routed in a manner that will avoid sharp or right angle bends. Routes should follow the most direct path with gradual bends to minimize the inductive reactances that tend to impede surge currents and reduce the overall effectiveness of the grounding system.

8.2.3 Ground conductors except the green wires and d.c. power conductors, should not be routed closely parallel to other conductors in the office so as to minimize induction of surges into equipment wiring. These conductors should not be routed through cable racks or troughs, or within confines of any iron work.

8.2.4 The ground conductor should only be placed in nonmetallic conduit. If it must be routed through metallic conduit both ends of the conduit should be bonded to the grounding conductor. Further ground conductors should not be encircled with metal clamps. This is essential to eliminate the high inductive reactance that will impede the flow of surge current along the conductor.

8.2.5 Wire-to-wire and wire-to-ground rod connections should be made only with compression connectors or exothermic weld connections. Solder joints should not be used for any central office system grounding connection.

8.2.6 Wire-to-bonding-bar (busbar) connections should be made with lugs that have a compression connectors or exothermic weld connection. The lugs should have bolt-on provisions for the busbar connections using copper bolts and nuts. Periodically, some of the busbar connections may be removed for test purposes.

8.3 It is desirable that the following stencilling and tagging be provided for simplification of maintenance and testing:

8.3.1 Permanent adhesive cable labels or suitable plastic tags should be provided on ground wire leads at all busbars to identify the origin of each conductor.

8.3.2 The location for each ground conductor should be identified on each ground bar by permanent adhesive label or stencilling.

8.3.3 The designated P, A, N and I segments of the MGB should be clearly identified.

8.3.4 Permanent identification tags should be placed on lightning, CO and radio/microwave ground leads at their accessible points of connection to the central office ground field outside the CO building.

9. <u>POWER SERVICE PROTECTION</u>

9.1 The minimum protection for a.c. power serving central office buildings should consist of a suitable arrestor in the electric power secondary circuit. The borrower is responsible for determining that the characteristics of the secondary power arrestor coordinate with the dielectric strength and surge current carrying ability of all items of ac powered equipment in the central office. These items would include heating, air conditioning equipment, etc. This normally means a secondary power arrestor having a surge breakdown not exceeding 1800 volts peak, and a valve device to prevent power follow current. At least one secondary arrestor is available which will breakdown on 1200 volts or less. Lower breakdown arrestors may be more expensive than the 1800 volt arrestor. However, when the condition described in Paragraph 9.3.1 exists with equipment that can withstand 1200 volts, adequate protection may be provided with only a 1200 volt secondary arrestor at less cost than that of the combination.

9.2 In some instances a secondary power arrestor may be provided by the power company to protect its watt-hour meter at the building service entrance. These devices may not be suitable for protecting central office equipment because they are usually designed to coordinate only with the dielectric strength of watt-hour meters (usually 9 to 10 kV). This is normally too high for telephone power equipment.

9.3 The use of a secondary arrestor to protect the a-c power service entering a central office building is strongly recommended. Some secondary arrestors have a rapid response and coordinate readily with normal a-c powered equipment. They may be mounted either at the weather head or at the load center. Others have poorer characteristics and must be mounted at the weather head, with at least 20 ft. (5m) of steel conduit separating the arrestor from the load center to assure proper operation.

9.3.1 If, after the installation of a secondary arrestor, power failures are still experienced from surges on the a-c bus, a supplementary protector; as shown in Figure 5, should be applied to the affected branch circuit. Recommended supplementary protection consists of a maximum duty gas tube in series with self-restoring circuit breakers or an impedance, to prevent the tube from holding over after the surge has passed.

10. RADIO OR MICROWAVE INSTALLATIONS

10.1 Radio or microwave towers which are located on or in close promixmity to CO buildings require special protective considerations. Their height and conductivity increases the probability of a direct lightning strike.

10.2 Details for the protection of the tower and associated equipment are covered in TE&CM 825, Paragraph 5.

10.3 It is important for protection of the central office equipment that the tower grounding system be bonded to the CO grounding system. This connection should be made outside the building as described in Paragraph 4.3.2. Thus a direct strike to the tower should be diverted to the grounding system rather than enter the office.

11. ELECTROSTATIC & ELECTROMAGNETIC FIELD EFFECTS

11.1 Static electricity is the accumulation of stationary electrical charge on a body or conducting medium created by physical motion such as drawing a comb through hair. Even circulating air currents can cause a charge buildup, especially during periods of low humidity. The electrostatic charge is discharged by grounding the charge storing medium.

11.2 Many circuits packs used in electronic or digital switching equipment contain active devices such as field effect transistors (FET), metal oxide semiconductors (MOS) and complementary metal oxide semiconductors (CMOS). These static-sensitive components can be permanently damaged when voltages higher than their breakdown point are applied to them. The human body can develop and store a charge of up to 40,000 volts by walking across a nonconductive floor during periods of low humidity. Because of this, special provisions should be applied to prevent circuit component damage from this potential hazard when handling printed circuit cards designated by the supplier to be sensitive to static discharge.

11.3 The accumulation of electrostatic discharge by a body may be reduced in a confined area such as a central office by increasing the relative humidity. Body electrostatic accumulation, at 60% relative humidity, is minimal. Even at this excessive humidity level there is no guarantee the electrostatic build up is eliminated. Further, the humidity may also cause equipment contamination, corrosion, or leakage path problems on the printed circuit cards and associated components. Such problems can produce either permanent or intermittent troubles.

11.4 There are two kinds of electrostatic conditions that produce equipment problems; direct arc into the electronic equipment, and radiated energy that reaches circuits through electric and magnetic field coupling. Discharged electrostatic energy can create a localized voltage (electric) field and current (magnetic) field in adjacent circuit cards. Both types of fields can cause permanent equipment damage and/or logic circuit errors.

12. <u>GENERAL ENVIRONMENTAL & HANDLING REQUIREMENTS FOR ELECTROSTATIC - SENSITIVE EQUIPMENT</u>

12.1 Proper environmental and handling considerations for electrostatic sensitive equipment are essential to prevent component damage and switch down time. The general procedures recommended in Paragraphs 12.2 and 12.3 will reduce the probability of equipment damage.

12.2 The following environmental conditions should be provided where possible:

12.2.1 Appropriate relative humidity levels should be maintained since static charges accumulate more readily under very dry climatic conditions. Refer to the equipment manufacturer's relative humidity recommendations.

12.2.2 Adequate air and dust filters should be installed in air ducts.

12.3 The following precautions should be observed when performing building and equipment maintenance procedures:

12.3.1 Grounding straps should be worn when handling printed circuit cards designated by the manufacturer as being susceptible to damage. Refer to the equipment manufacturer's procedures relating to this subject.

12.3.2 Grounded conductive floor tiles or mats should be installed, where required. The conductive floor tile manufacturer's recommendations should be followed for installation connection to ground, and maintenance of the floor to preserve conductivity.

12.3.3 Printed circuit cards should not be touched or handled by their components or connector pins.

12.3.4 The repair or modification of circuit cards should not be attempted in the local office. Units should be returned to the manufacturer for repair if tests have been made which show that particular cards are defective. An adequate stock of spares should be maintained in proper storage containers.

12.3.5 Conductive printed circuit card containers should be used as recommended by the equipment manufacturer.

12.3.6 Where the Enable/Disable feature is provided and the manufacturer recommends no card should be inserted or removed until the Enable/Disable switch is in the disable position and/or the card slot connection is disabled by software command.

12.3.7 Only the grounded conventional or isolated a-c ground convenience outlets located in the IGZ may be used for operating tools, test equipment and custodial equipment inside the IGZ. Refer to the equipment manufacturer's instructions regarding the use of a-c tools or test equipment in the equipment area.

12.3.8 Steel wool, steel wool pads or dry untreated cloths or mops for floor maintenance should not be used.

12.3.9 Defective fluorescent lighting components should be replaced. These include defective starters, flickering fluorescent tubes,or noisy ballast transformers. Failure to replace these items may introduce noise into power supply lines and systems.

12.4 The following precautions should be observed when operating motor driven devices in the central office building:

12.4.1 All cleaning equipment and motor driven tools should be in good working order.

12.4.2 Motor driven devices should all have grounded 3-conductor cords to bleed-off static charges or brush-noise generated radio frequency transients.

12.4.3 Motors that are not an integral part of the manufacturers switching equipment should not be started, operated or stopped inside the IGZ.

12.4.4 Equipment should be removed from service when adding or removing wire-wrap connections. Where this is not possible, manual or pneumatic wire-wrapping tools with insulated bits should be used.

12.4.5 Tools with Silicon Controlled Rectifier (SCR) motor speed controls should not be used. The SCR can cause transients in the power supply line and generate magnetic fields.

12.5 The following precautions should be observed for magnetic tapes, floppy discs, and other memory devices:

12.5.1 Motor driven equipment should not be located adjacent to tape transports or memory devices. An extra long hose should be used when vacuuming with the cleaner itself located several feet outside of the IGZ.

12.5.2 Magnetic apparatus such as recording tapes and tape transports should not be exposed to the magnetic fields produced by such items, for example, as flashlights, magnetic screwdrivers or electric motors.

12.5.3 Magnetic tapes should be stored in radio frequency tight high mu ferrous metal cabinets to avoid information loss.

13. DISCHARGE PLATES

13.1 For protection of static sensitive equipment, all personnel should fully discharge any static charge on their body before touching or handling any part of the switch. This is especially important in common control areas. Central office personnel when working in the switching area should touch the nearest discharge plate before touching any part of the switch when required by the equipment manufacturer.

13.2 Installation of electrostatic discharge plates should be considered where they have not been provided by the equipment manufacturer. They should not be installed until the manufacturer has been consulted for recommendations on locations and ground connections. The shape and method of attaching the plates should be accomplished in a manner that will not create any hazard to personnel or limit access to the equipment. Personnel discharge plates should be located, where practical, at intervals within an arms length of any maintenance location.

13.3 Supplemental discharge plates may also be provided by:

13.3.1 Hinged metallic doors when they are grounded with a 14-gauge conductor to the building structural steel or the MGB. Conductive paint should be applied to the doors and metallic door knobs should be left bare.

13.3.2 Light switches and a-c power outlets with metallic plates/covers which are electrically connected to the grounded green wire inside the electrical box.

13.4 Warning Signs: Appropriate warning signs should be posted on all equipment area entry doors and inside the CO where they can be easily seen without creating a safety hazard. The signs should be worded to warn personnel of the electrostatic sensistive area and the need for discharging body static before handling equipment.

14. APPLICATION TO ELECTROMECHANICAL SYSTEMS

14.1 The principles described in this practice may be selectively applied to electromechanical switching systems. It is especially valuable where it has been historically difficult to protect from power and lightning surges. The only principle that should not be applied is the IGZ arrangement unless there is voltage sensitive equipment in the system.

14.2 It is recommended that some provisions of the protection methods described in this practice be applied to all electromechical switching systems.

14.2.1 A connection between the ac neutral ground bar in the ac service entrance panelboard and the MGB should be established.

14.2.2 An earth ground as low as is practical for the area in which the office is located should be provided. (See Paragraph 4.6.)

14.2.3 Bonding should be provided outside of the building between radio/microwave tower grounds, lightning rod grounds and the central office ground fields.

14.2.4 Common bonding of metallic system components should be provided as recommended by the National Electrical Code.

14.2.5 Grounding conductors should be routed as described in Paragraph 8.2.

14.3 Other portions of the protection method may be provided on an optional basis, depending on the specific needs and limitations of the installation.

14.3.1 In electromechanical systems the MGB and the GWB may be combined in a single bar.

14.3.2 The removal of the charger frame ground strap to the positive (+) terminal is optional.

14.3.3 Establishment of a small IGZ may be desirable where there are types of voltage-sensitive electronic equipment requiring special protection. An electronic line concentrator that has a record of protection-related failures might be treated in this manner.

14.4 Where electromechanical equipment is collocated with electronic switching equipment, the electronic equipment should be protected as described in this practice. The electromechanical equipment should be treated as described in paragraph 14.1-14.3 except the Paragraph 14.3.2 option. Further, the equipment should be grounded to the N section of the MGB.

APPENDIX A

VOLTAGE EFFECTS FROM RISING SURGE CURRENTS

1. GENERAL

1.1 This appendix provides a discussion of the voltage effects on grounding conductors from self inductance in the presence of high surge currents with fast rise times. The discussion is designed to provide a better understanding of the basis for some of the general rules relating to routing of grounding conductors in central office buildings.

1.2 Every conductor has self inductance which provides an impedance to lightning and other surges. A significant voltage difference will occur between the ends of a grounding conductor during the period a surge current is flowing. This potential difference should not appear across sensitive electronic equipment.. Further points in the overall grounding system, between which the potential can appear, should not be located so personnel can touch both simultaneously.

2. SELF-INDUCTANCE

2.1 The self inductance (Lg) of a solid, round, non-magnetic and straight ground wire in air or plastic conduit may be approximated with:

$$Lg = 0.061\ell \left(\log_e \frac{48\ell}{d} - 0.95\right) \qquad (1)$$

Where: Lg = Self inductance in microhenries (μH)
ℓ = Wire length in feet
d = Wire diameter in inches

2.1.1 All grounding connections in a typical small rural central office can probably be made using only #6 (0.162" (0.4cm) diameter) and 2/0 (0.3648" (0.927cm) diameter) conductors. Lengths of 30 ft. (9.1m) might be required for some connections. From equation (1) the self inductance for 30 ft. (9.1m) of #6 wire is 14.9 μH and with 2/0 is 13.4 μH.

2.2 The self inductance (Lg) of a ground wire in steel conduit where ends of conduit are not bonded to wire is given as:

$$Lg = 0.061\ell \left(\log_e \frac{48\ell}{d} - 0.95 + 1200 \log_e \frac{d_1}{d_2}\right) \qquad (2)$$

Where: 1200 = permeability of iron (estimated)
d_1 = outside diameter (OD) of conduit in inches
d_2 = inside diameter (ID) of conduit in inches

2.2.1 The self induction of the 30 ft. (9.1m) lengths of #6 and 2/0 wire encased in unbonded rigid steel conduit with an OD of 1.315in (3.34cm) and ID of 1.049in (2.66cm) may now be determined from equation (2). The self inductance of the #6 wire is 511.2 μH and 2/0 is 509.7 μH.

2.2.2 A grounding conductor 30 ft. (9.1m) long would not likely be placed in steel conduit. A more common use of conduit is for carrying the conductor through a wall via a one foot (0.3m) length. A one foot (0.3m) length of #6 wire through a one foot (0.3m) unbonded rigid steel conduit will have a self inductance of 16.8 μH and 2/0 will have 16.8 μH. The self inductance of one foot (0.3m) of wire in steel conduit is higher than for 30 ft. (9.1m) of bare wire in air.

3. VOLTAGE LEVEL FROM SELF INDUCTANCE

3.1 The calculation of the momentary voltage that will develop across a length of conductor using the conductor self inductance is possible. This voltage is given by the differential relationship:

$$e = L \frac{di}{dt} \qquad (3)$$

Where:
- e = voltage
- L = inductance (Henries)
- di = change in current (Amperes)
- dt = change in time (seconds)

3.1.1 Assuming a moderate surge of 2000 peak amperes with a rise time of 10 microsecond through the 30 ft (9.1m) bare wire described in paragraph 2.1.1, from equation (3), the voltage developed across the wire could be:

#6 = 2980 volts
2/0 = 2680 volts

3.1.2 If this wire is placed in unbonded 30 ft (9.1m) rigid conduit as described in Paragraph 2.2.1 the voltage developed would be:

#6 = 102,240 volts
2/0 = 101.940 volts

3.1.3 Study of the example described in Paragraph 2.2.2 where a one foot (0.3m) length of unbonded rigid steel conduit is used to pass the grounding conductor through a wall is more practical. From equation (3) the voltage developed across the one foot (0.3m) conductor length would be 3360 volts for either #6 or 2/0 wire. The voltage developed across one foot (0.3m) of wire in conduit is 13 percent higher than for 30 ft. (9.1m) of bare #6 wire and 25% higher than for 30 ft. (9.1m) of 2/0 wire.

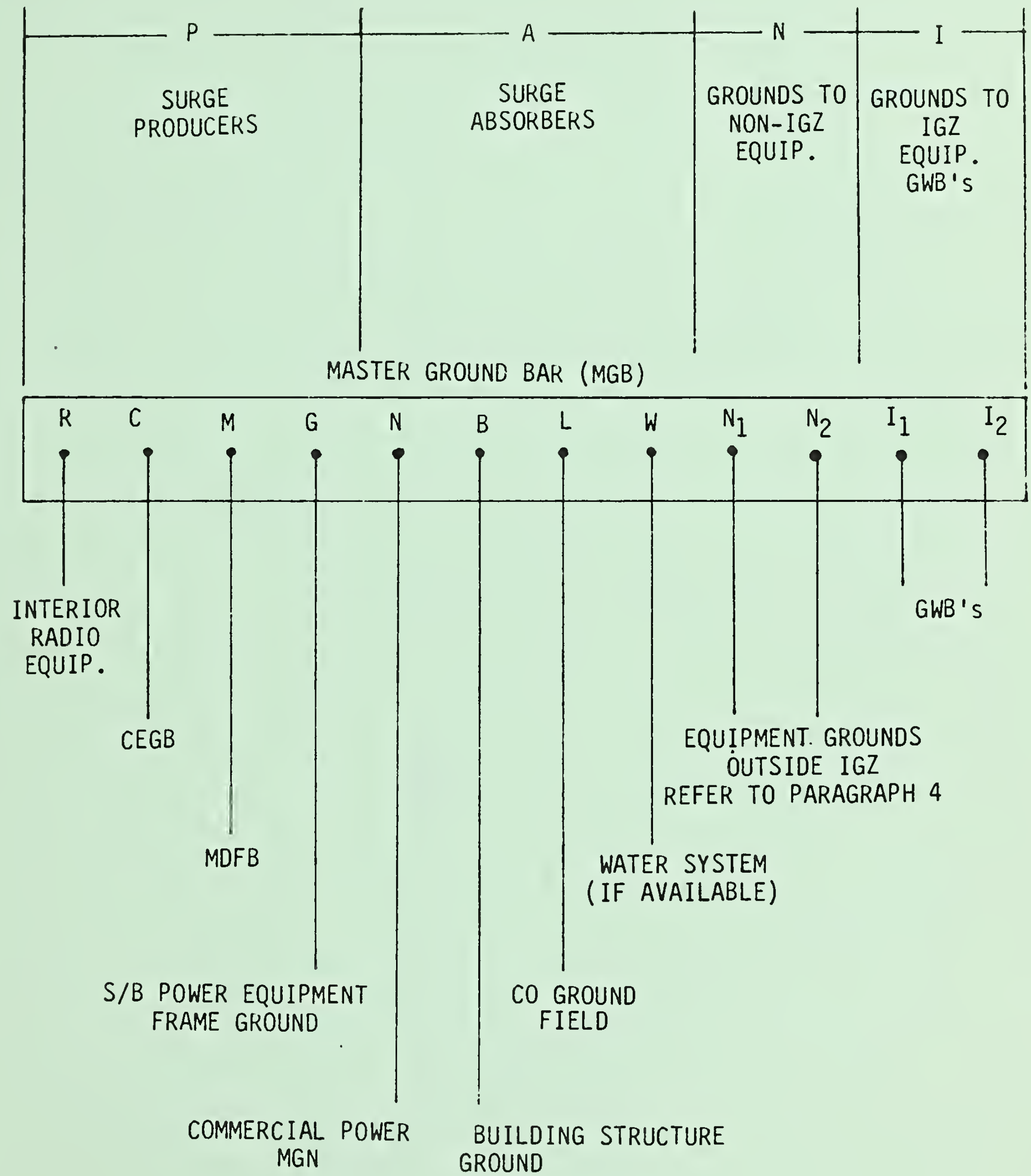


FIGURE 1
MGB - PROTECTION CONFIGURATION

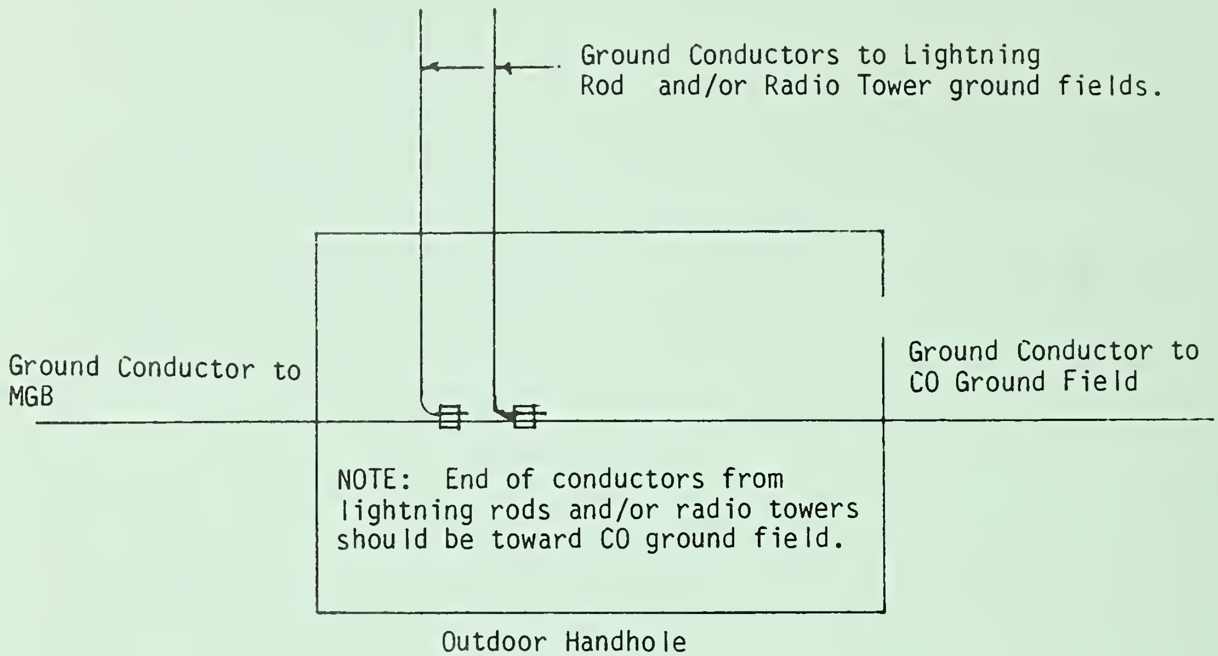


FIGURE 2
Outdoor Ground Conductor Connections

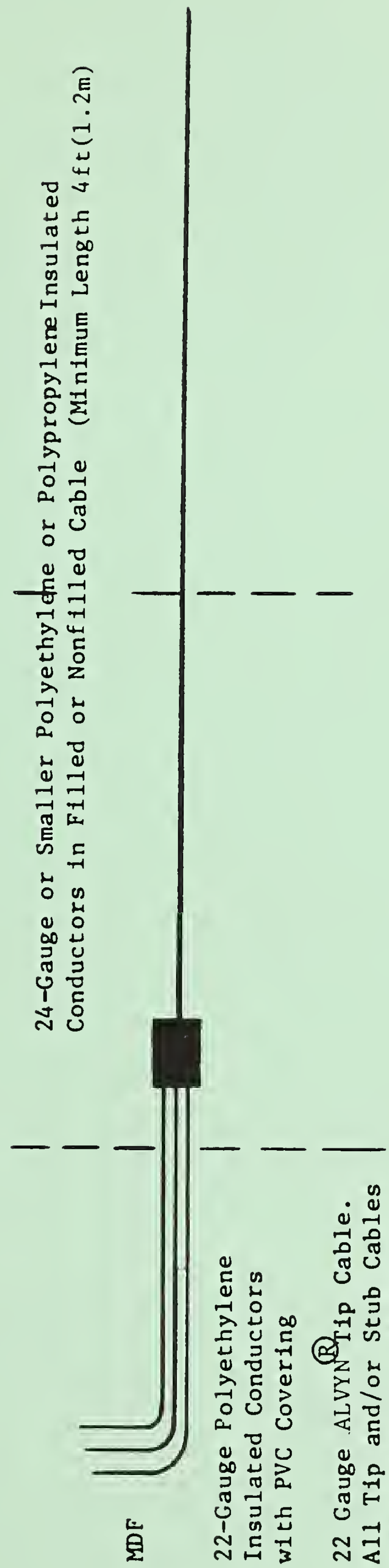


FIGURE 3

Entrance and Tip Cable Arrangements

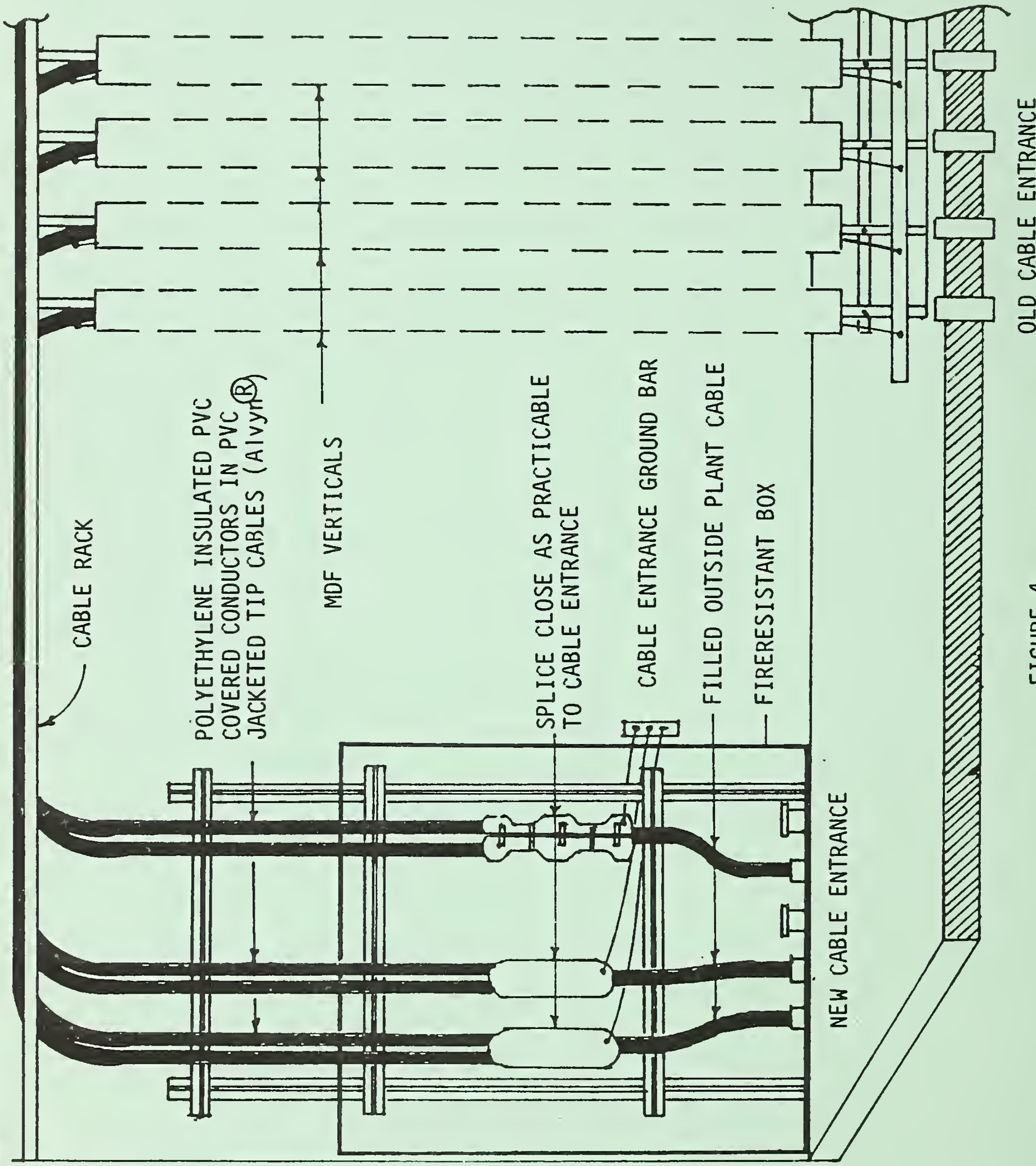
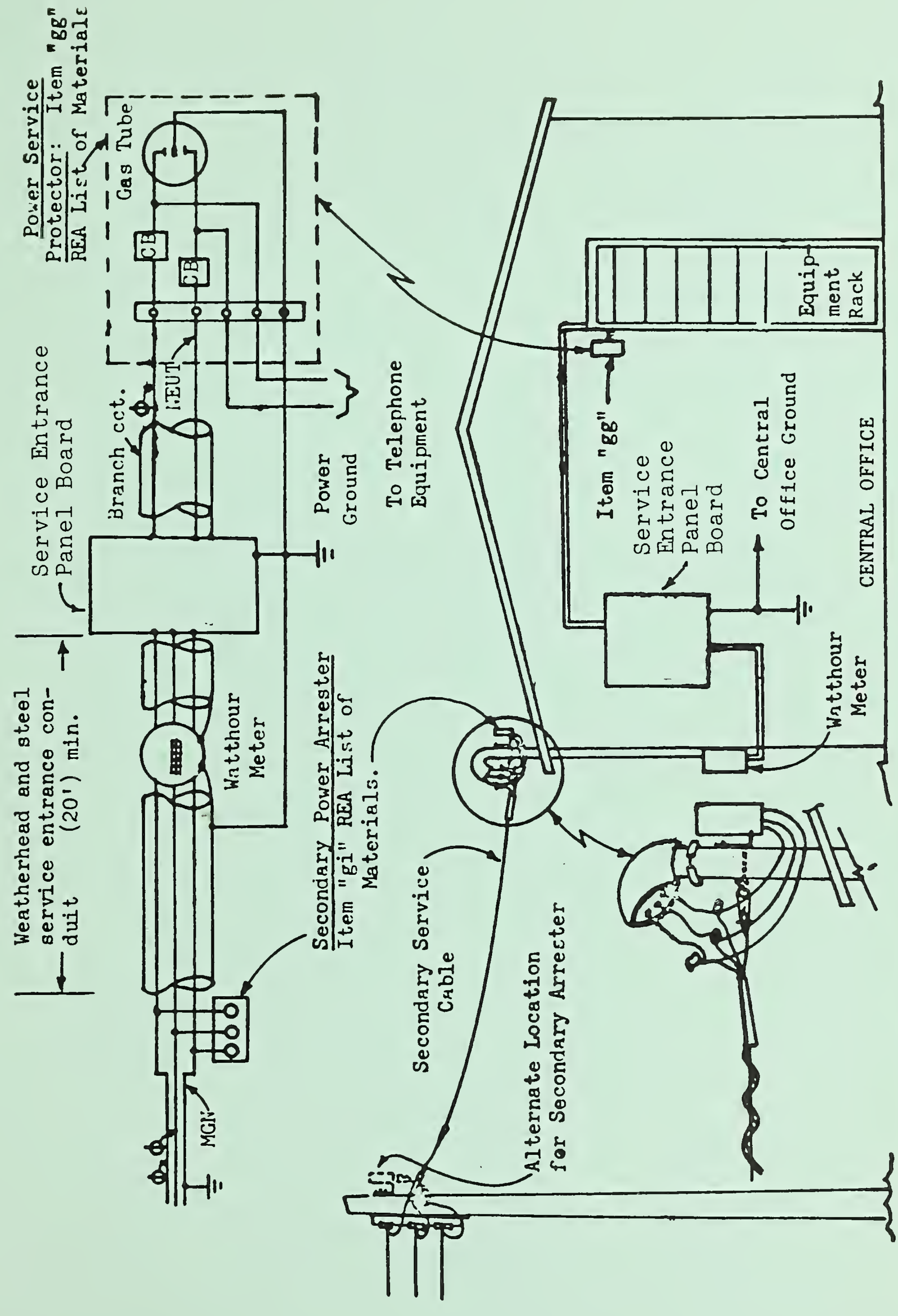


FIGURE 4
CABLE ENTRANCE WITHOUT VAULT



TYPICAL INSTALLATION OF SECONDARY ARRESTER AND BRANCH CIRCUIT POWER SERVICE PROTECTOR

FIGURE 5

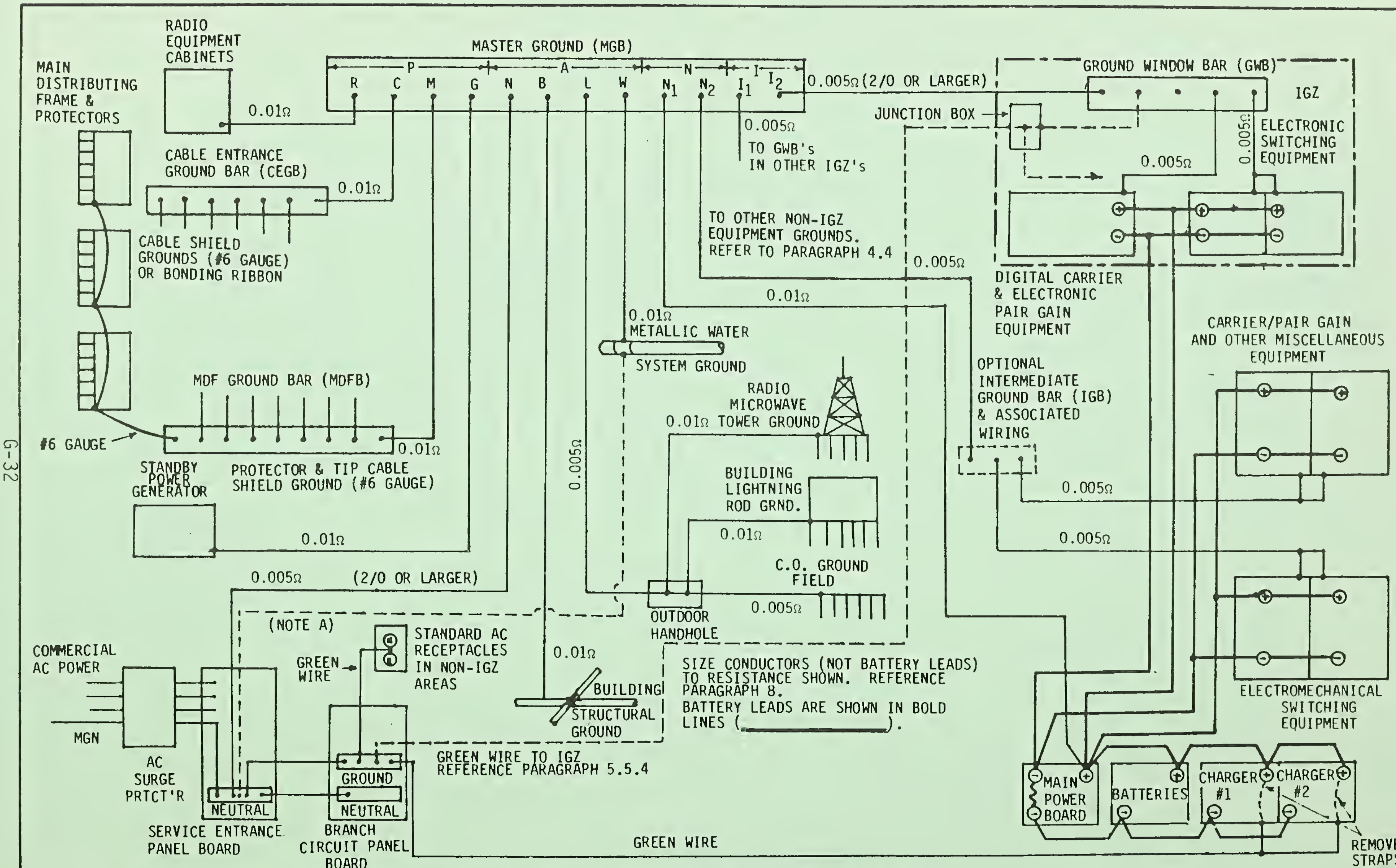


FIGURE 6 - CENTRAL OFFICE PROTECTION GROUNDING

(A) Per NEC 250-91(a)
Other than the wire covered by Note A, grounding connections provided by the electrical contractor during installation of the electrical system have not been included in this drawing.

TABLE A

Characteristics of Bare Copper Wire at $20^{o}C/68^{o}F$

CONDUCTOR SIZE		AWG #6		#4		#3		#2		#1	
dc RESISTANCE		.4110/kf	1.348/km	.2548/kf	.8478/km	.2050/kf	.6726/km	.1625/kf	.5331/km	.1289/kf	.4229/km
Obj. R	0.005Ω	12'	3m	19'	5m	24'	7m	30'	9m	38'	11m
	0.01Ω	24'	7m	38'	11m	48'	14m	61'	18m	77'	23m

Characteristics of Bare Copper Wire at $20^{o}C/68^{o}F$

CONDUCTOR SIZE		AWG 1/0		2/0		3/0		4/0		MCM 250	
dc RESISTANCE		.1022/kf	.3353/km	.0802/kf	.2631/km	.0636/kf	.2087/km	.0505/kf	.1657/km	.0440/kf	.1444/km
Obj. R	0.005Ω	48'	14m	62'	18m	78'	23m	99'	30m	113'	34m
	0.01Ω	97'	29m	124'	38m	157'	47m	198'	60m	227'	69m

Characteristics of Bare Copper Wire at $20^{o}C/68^{o}F$

CONDUCTOR SIZE		MCM 300		350		400		500		750	
dc RESISTANCE		.0367/kf	.1204/km	.0314/kf	.1030/km	.0275/kf	.0902/km	.0220/kf	.0722/km	.0147/kf	.0482/km
Obj. R	0.005Ω	136'	41m	159'	48m	181'	55m	227'	69m	340'	103m
	0.01Ω	272'	83m	318'	97m	363'	110m	454'	138m	680'	207m

MAXIMUM CONDUCTOR LENGTH TO MEET THE

GROUNDING CONDUCTOR RESISTANCE OBJECTIVES

INDUCTIVE COORDINATION

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We were fortunate to receive a copy of a paper, "Inductive Coordination of Power and Telephone" by Mr. S. D. Overby, Staff Manager, Pacific Northwest Bell. The paper was first presented at the Northwest Electric Light and Power Association (NELPA) Engineering and Operations Conference in Portland, Oregon on April 22, 1983, and later at the Northwest Inductive Coordination Committee (NICC) 1983 Spring Conference in Spokane, Washington on May 24, 1983.

The paper presents an outstanding down to earth discussion of inductive coordination. Mr. Overby has granted us permission to reproduce it for the 1984 REA Telecommunications Engineering and Management Seminars. Everbody can benefit from reading his excellent treatment of the subject in the following paper.

INDUCTIVE COORDINATION OF POWER AND TELEPHONE

S. D. Overby
Staff Manager, Pacific Northwest Bell

INDUCTIVE COORDINATION -- ENGINEERING GOBBLEDYGOOK? No, it's another form of cooperation, intended to resolve some of the problems that arise when both power and telecommunications facilities have to be close neighbors. It tends to make close neighbors good neighbors.

IT IS AN ATTITUDE, AS MUCH AS AN ART OR SCIENCE. The ultimate purpose is to allow both power and telecommunications utilities to coexist and to serve their mutual customers economically and reliably.

WHAT CAUSES THE PROBLEMS? They arise from the proximity of telephone lines or equipment to electric power lines, substations or equipment. But there are other factors, too. Let's look at some past history.

WHEN DID IT ALL START? Back in the early part of this century, when telephone lines were operated single wire, with ground return, everything was all right with the telephone service until power lines were built nearby. Then, suddenly, the telephone lines were incrediby noisy.

THE PROBLEM GOT WORSE, BEFORE IT GOT BETTER. It was finally addressed by the Joint General Committee of the National Electric Light Association and the Bell System, and later, by the Joint General Committee of the Edison Electric Institute and the Bell System. The result of their many investigations and experiments was a set of three reports, which were issued as guidelines for handling inductive coordination problems.

THE GUIDELINES HAVE BEEN AROUND SINCE 1921. They were reaffirmed, with minor changes, by the Edison Electric Institute and the Bell System, in 1945. Subsequently, additional Engineering Reports have been issued by the Edison Electric Institute and the Bell System. Most recently, the Electric Power Research Institute has been doing most of the interesting work in inductive coordination, although the Inductive Coordination and Electrical Protection (ICEP) Subcommittee of the IEEE Communications Society has been actively engaged in this work for the past ten years.

A GRASSROOTS MOVEMENT HAS STARTED, TOO. Recently, a number of cooperative organizations, such as our own Northwest Inductive Coordination Committee (NICC), have been engaged in mutual learning/teaching activities, designed to improve understanding of the problems and to enhance cooperation among electric and telecommunications utilities, as well as the large users of electric power. These efforts have brought almost instant popularity to the idea of inductive coordination, and good cooperation among utilities.

SO WHAT'S THE PROBLEM? The problem is interference (noise, hum or hazardous voltages or currents) in telephone lines. As shown in Bell Laboratories' General Interaction Model, Figure 1, the possible reasons are three-fold:

- POWER INFLUENCE -- (Controlled by the Power Utility)
- MUTUAL COUPLING -- (Controlled by either/both utilities)
- SUSCEPTIVENESS -- (Controlled by the Telephone Utility)

INFLUENCE IS WHAT THE POWER UTILITY CONTRIBUTES TO THE PROBLEM. In our earlier example, the telephone line was all right until the power utility provided some disturbing voltages and currents. Influence includes the effects of the following:

- Unbalanced feeders (causing 60 Hertz induction into paralleling telephone lines).
- Overexcited transformers (causing high harmonic content in the exciting current, causing high audible noise in paralleling telephone lines).
- Multigrounded neutral wye (MGN) operation (causing ground-return currents to flow, causing, in turn, much more induction into paralleling telephone lines than currents that flow strictly in metallic paths).
- Solid-state loads without adequate filtering (causing high harmonic currents in the power system conductors, causing, in turn, high audible noise in paralleling telephone lines).
- Grounded power factor correction capacitors (providing a path to ground for harmonic currents, or even enhancing the flow of such currents, due to resonance with the system inductance, causing, in turn, high audible noise in paralleling telephone lines).

COUPLING IS CONTRIBUTED BY THE SECOND UTILITY ON THE SCENE. In the case of our earlier example, the power company contributed the coupling by building its line close to the telephone company facilities. But there are many instances in which the telephone company chooses a route close to a power line. Private rights-of-way are increasingly difficult and expensive to acquire. The easy way is to use common road rights-of-way, joint-use poles and common trenches. But the increased coupling is often undesirable.

BOTH UTILITIES HAVE SOME CONTROL OVER COUPLING. Coupling is related to:

- The geometry of the power and the telephone lines.
- The spacing between the power and telephone lines.
- The distance through which the lines are parallel.
- The crossing angle, if the lines are not parallel.

- The earth resistivity and its lack of homogeneity.

- The frequency of the interfering earth currents.

- The continuity and grounding of shield conductors.

SUSCEPTIVENESS (BALANCE) IS THE TELEPHONE COMPANY'S CONTRIBUTION. It is often also called susceptibility. But by whatever name, it's the responsibility of the telephone company. Balance is affected by the following:

- Differences in telephone conductor capacitance to ground.

- Differences in series resistance of telephone conductors.

- Differences in leakage to ground of telephone conductors.

- Unbalanced impedance to ground of telephone station sets.

- Unbalanced impedances in central office coils and relays.

- Unbalanced connection of ground to circuits or equipment.

- Permanent grounding of telephone carbon block protectors.

GROUND-RETURN CURRENT IS THE REAL CULPRIT. If power current did not return through the earth -- if it was restricted to completely metallic paths, close to the phase conductors -- there would seldom be an interference problem. Ask any telephone company whose neighboring power utility has recently converted its distribution from delta to multigrounded neutral wye.

GOOD LOAD BALANCE CAN HELP MINIMIZE STEADY-STATE 60 HERTZ INDUCTION. But even a well-balanced feeder is subject to the flow of triple-odd harmonics, or "triplins." These "residual" or zero-phase-sequence harmonics (180 Hz, 540 Hz, 900 Hz, etc.) can be thought of as "wiggling in phase" down the three phase conductors, and returning in the neutral and in the earth, where they spread throughout a very large volume of earth.

SINGLE-PHASE TAPS CONVERT ALL HARMONICS TO GROUND RETURN. So not only the triplins, but <u>all</u> the odd harmonics of 60 Hertz can flow deep in the earth.

HIGH EARTH RESISTIVITY MAKES THE PROBLEM WORSE. The earth-return components are forced to occupy an even larger volume of earth, as the current filaments spread out. The earth-return current tends to follow the route of the power line, because of the self-inductance of the circuit, unlike direct current, which spreads out radially (approximately) from an earth electrode. An earth-return alternating current (fundamental or harmonic) produces a magnetic field which is the same as the field which would be produced if all the earth-return current were constrained to flow in an insulated ground wire, deep in the earth beneath the power line. The lower the frequency, the deeper the location of the fictitious ground wire.

THE POWER LINE IS ONE WINDING OF A GIANT SINGLE-TURN AIR-CORE TRANSFORMER. The telephone line is the other winding, as shown in Figure 2. The actual coupling can be calculated by Carson's Equations, which show that the coupling increases with longer exposure, closer spacing, higher frequency and higher earth resistivity.

THE TRANSFORMER ANALOGY CAN BE EXTENDED TO THE GENERAL INTERACTION MODEL. Figure 3 shows the power influence as a controlled voltage source, which energizes the primary winding of a three-winding transformer. The primary winding represents the power line. The secondary winding represents the telephone line. The tertiary, which is grounded at both ends, represents the shielding effects of the grounded neutral (if present) and the grounded telephone cable sheath.

A SHIELDING CONDUCTOR ACTS LIKE A SHORTED TURN ON THE TRANSFORMER. It supplies "back ampere-turns," to reduce the overall induced voltage in the disturbed conductor(s).

TELEPHONE LINE BALANCE IS ANALOGOUS TO A BALANCED BRIDGE CIRCUIT. It is shown like that in the figure. A set of telephone protector blocks is also shown, indicating that a permanently grounded carbon block would badly degrade the balance of the circuit, which would then have a loud "power hum."

THE LOUD HUM ALSO APPEARS IN THE MODEL. It is shown as the noise issuing from the telephone receiver at the right side of the figure. Telephone companies fairly uniformly accept the same figure for acceptable noise at a subscriber's telephone set. What they say is that the C Message Weighted noise-metallic (or circuit noise) should not exceed 20 dBrnC. These terms are widely used in the telephone industry by engineers and technicians, alike. They will be explained on the following page. But first, let's look at how a telephone set responds to various harmonic frequencies.

FORTUNATELY FOR EVERYONE, A TELEPHONE SET IS NOT HI-FI. Even if it were, low frequencies cannot pass through repeat coils (telephone transformers) well. Most telephone channel bandwidths are specified as 300-3000 Hertz.

YOU CAN'T HEAR 60 HERTZ THROUGH A TELEPHONE RECEIVER. Do you believe that? When people say that they hear "60 cycles," what they are really listening to is harmonics of 60 Hertz. And there are, unfortunately, plenty of those. Figure 4 shows the frequency response of a 500-type telephone, which is one of the most common types around. This curve is known as the C Message Weighting curve. In the early 1960s, it supplanted an earlier response curve for the older F1A telephone set. Note that the frequency response at 60 Hertz is down by about 55 dB with respect to the 1000-Hertz response. This is fortunate, because there is much more 60 Hertz voltage on telephone lines than, say, 1020 Hertz, although sometimes there is some of that, too.

WE NOW HAVE TO RESORT TO SOME "TELEPHONESE." Here are some terms used frequently in dealing with telephone noise:

dB - This stands for "decibel," and was named in honor of Alexander Graham Bell, the inventor of the telephone. It is a logarithmic measure of a power ratio:

$$dB = 10 \text{ Log } (Po/Pi) \qquad (1)$$

where Pi = Input power (in milliwatts, for example)

and Po = Output power (in the same units of power)

dBm - This is a logarithmic ratio of power with reference to one milliwatt of power. 0 dBm represents 1 milliwatt.

dBrn - This stands for "dB with respect to Reference Noise." Reference noise is -90 dbm, or one picowatt.

dBrnC - This stands for dBrn measured with C Message Weighting.

NOTICE THE EXTREMELY SMALL AMOUNTS OF POWER FOUND IN TELEPHONE CIRCUITS. The standard telephone test level, 0 dBm, is one milliwatt of 1000 Hertz tone. This is the same as 90 dBrnC. If a -60 dBm 1000 Hertz tone were measured on a telephone circuit, that would be only one millionth of a milliwatt, but it would represent circuit noise of 30 dBrnC, which is the upper limit of tolerable noise on the circuit. 20 dBrnC is the almost universal objective.

HOW ARE SUCH SMALL VALUES OF NOISE POWER MEASURED? With noise measuring sets. Several manufacturers have responded to the needs of the telephone companies with spectrum analyzers and with noise measuring sets. The Wilcom T-136B, for example, can be and is used by installation and repair personnel to measure a number of characteristics of the telephone line. In addition to providing for a dial-up connection to the telephone pair under test, this set will permit a battery check and measurements of dc current, circuit loss, circuit noise and power influence.

THERE'S SOME MORE JARGON. Let's see what these commonly-used terms mean:

"Circuit Noise" or "Noise-Metallic" is the noise which is measured or heard across the telephone pair, between the "Tip" and "Ring" conductors. It is measured with C Message Weighting. That is, in terms of dBrnC.

"Power Influence" or "Noise-to-Ground" is the noise which is measured, or can be heard, between either telephone circuit conductor and ground. It is also measured in terms of dBrnC.

"Circuit Balance" is a measure of the balance or susceptiveness of the telephone circuit. Balance is calculated by subtracting the circuit noise, in dBrnC, from the Noise-to-Ground, in dBrnC. The balance, in dB, should ideally be greater than 60 dB.

"Circuit Loss" is the 1000 Hertz attenuation in the telephone pair, due to series resistance and shunt capacitance, primarily, although other factors can affect it, also. It is expressed in dB, although this particular test set actually gives a reading in dBm.

"Longitudinal induction" is a term that is frequently used to mean Noise-to-Ground, because that's where it comes from. It is induced longitudinally into each telephone conductor, by the disturbing current(s).

NOW FOR THE REAL GOBBLEDYGOOK. In the old days, the inductive coordination community, seeking a way to characterize the influence of the power system, invented a term called "Telephone Influence Factor," abbreviated "TIF." Not content with that, they also invented "I•T" and "KV•T", pronounced "eye tee" and "kay vee tee." Inductive coordinators have spent the intervening years trying to avoid the use of these terms, but to no avail. They are now firmly entrenched in the literature, so we're stuck with them. Here's what they mean:

> TIF is a weighting factor, decided upon by a committee of experts, which takes into consideration the frequency of a particular harmonic, and its ability to cause disturbing noise in a particular telephone set receiver. The 1960 TIF Weighting curve is depicted in Figure 5, along with its predecessor weighting curves from 1941 and 1935.
>
> At any particular harmonic frequency, the I•T for current of that frequency is the product of the current in amperes times the TIF Weighting Factor for that frequency.
>
> Similarly, for a voltage harmonic, the KV•T is the product of the kilovolts at that frequency times the TIF Weighting factor for that frequency.
>
> The "Overall I•T" is the root-mean-square of the individual values for the harmonic currents.
>
> The "Overall KV•T" is the root-mean-square of the individual values for the harmonic voltages.

WHAT GOOD ARE ALL THESE TERMS? Actually, they can be quite useful in controlling the purity of the power system voltage and current waveshapes. Power utilities such as TransAlta Utilities, for example, use these terms in dealing with large industrial customers, where they wish to limit the "harmonic effluent" from the various solid-state devices in their plants. Bonneville Power Administration has an ongoing Harmonic Surveillance Program, in which they regularly check the I•T and KV•T of their transmission lines, to keep tabs on their direct service customers.

NOW FOR A WEE BIT MORE TECHNICAL JARGON. To do justice to this discussion, we need to understand the difference between the effects of currents that are confined to the metallic phase conductors (the positive- and negative-sequence currents, if you will) and those that flow in phase in all three phase conductors and return in the earth (zero-sequence currents). We speak of the "Balanced" circuit, which is exclusively metallic. And we speak of the "Residual" or "Ground-return" circuit, which consists of the three phase conductors in parallel, with ground return.

NOW WE CAN SPEAK ABOUT BALANCED I•T AND RESIDUAL I•T. When a power utility places limits on the harmonic effluent from an industrial plant, the limits are usually expressed in terms of both balanced and residual overall I•T. TransAlta Utilities limits their customers to a Residual I•T of 100, for any voltage, but allows a balanced I•T of 1500 on 25 kV service and 3000 on 138 kV and above, measured on the primary of the supply transformer.

GROUND-RETURN CURRENTS ARE ALWAYS THE WORST ACTORS. That's why the disparity in limits. The residual (ground-return) circuit coupling is so much greater than the balanced circuit coupling; and, therefore, the limits have to be smaller.

THE WAY IT'S ACCOMPLISHED IS UP TO THE CUSTOMER. TransAlta allows them complete freedom to choose their own methods of controlling the harmonic effluent, so long as they meet the utility's objectives, when they come back to measure them.

NOW LET'S LOOK AT THE PROBLEMS. THEY COME IN THREE DIFFERENT "FLAVORS":

- Steady state 60 Hertz induction.

- Steady state harmonic frequency induction.

- Fault conditions (60 Hertz).

STEADY STATE AC VOLTAGE GREATER THAN 50 VOLTS IS HAZARDOUS TO YOUR HEALTH. There are a number of other "limits" accepted by various organizations and administrations, but for the telephone industry, the 60 Hertz limit is 50 volts rms. (For direct current, it is 150 volts.)

POOR LOAD BALANCE ON DISTRIBUTION SYSTEMS IS THE MAIN CONTRIBUTOR. If the phasor sum of all currents flowing in the metallic conductors is other than zero, there is a possibility for induced 60 Hertz voltage in nearby telephone conductors.

STEADY STATE 60 HERTZ INDUCTION CAN BE CONTROLLED. Sometimes the "fix" is expensive, however. Here are some of the ways to do it:

- Maintain good balance on power feeders. (It doesn't help power induction to have good balance at the substation, if the individual feeders are unbalanced.)

- Install multipair induction neutralizing transformers in the telephone cable(s). These provide a bucking voltage to reduce the total induced voltage in the telephone conductors.

- Install longitudinal inductors (chokes) in series with the telephone conductors to minimize the flow of longitudinal current in the telephone circuit.

- Install ac drainage devices on the telephone pairs, to drain off the longitudinal currents to ground.

- Rebuild one of the lines farther away from the other.

TELEPHONE CUSTOMERS HATE STEADY STATE HARMONIC FREQUENCY INDUCTION. They usually don't know that that's what it's called, but they do associate it with the local power utility. Sometimes it's a combination of harmonics causing the "power hum" and sometimes it's a single tone that causes them to complain to the telephone company or to the Public Utility Commission. But they do complain.

OVEREXCITED TRANSFORMERS ARE A MAJOR SOURCE OF 540 HERTZ INTERFERENCE. They also generate other odd harmonics in their exciting current, but the triple-odd harmonics are the worst. And because of the C Message Weighting, the ninth harmonic is absolutely the worst.

POWER FACTOR CORRECTION CAPACITORS CAN MAKE THE SITUATION EVEN WORSE. It frequently happens that a resonance occurs between the line and transformer reactance and the shunt capacitance, at or near 540 Hertz. But occasionally, the resonance will occur at a different frequency, thus enhancing some other harmonic. The usual ground at the wye point of the capacitor bank completes the path for the so-called residual circuit, allowing the ground-return currents to flow easily.

THE OTHER MAJOR SOURCE OF HARMONICS IS UNFILTERED SOLID-STATE DEVICES. Large 6-pulse rectifiers will produce the 5th, 7th, 11th, 13th, and, in general, the (6k+1)th harmonics of 60 Hertz in the ac side of the installation. A 12-pulse rectifier would produce the 11th, 13th, 23rd, 25th, etc., harmonics. Occasionally, such higher-order harmonics can be propagated over long distances in the transmission grid and produce high local interference hundreds of miles away.

IT IS NOT REALLY NECESSARY TO HAVE NOISE FREQUENCY INDUCTION. Try this:

- Avoid overexcitation of transformers, both in the substation and on poles and at padmounts. Do not exceed 105 percent of rated voltage at any transformer.

- Insist on adequate filtering of rectifiers, dc drives, and other solid-state devices.

- Detune resonant shunt capacitor banks by inserting a neutral reactor (Harmonic Shunt Reactor) in the neutral connection.

- Alternatively, "float" the wye-point of the capacitor bank, either with or without automatic switches.

- Absolutely avoid the use of single-phase capacitor banks.

- Maintain surveillance of the harmonics present on your system.

- Install multipair induction neutralizing transformers in the telephone cable(s). This is not guaranteed to work in all cases, however, if the longitudinal noise gets converted by cable unbalances into metallic noise before the transformer gets a chance to suppress it.

- Install individual noise chokes in the noisy cable pairs at the telephone central office.

- Install ringer isolators on telephone party lines, to keep the balance of the telephone sets high.

- Provide shielding for telephone cable(s) by proper bonding and grounding and verification of cable sheath continuity. Frequent interconnections between telephone cable sheaths or shields and power system multigrounded neutrals is a good way to help insure proper shielding.

- Replace telephone voice-frequency circuits with carrier systems, but making sure that 60 Hertz induction is controlled.

- Rebuild one of the lines farther away from the other.

IT IS BOTH DIFFICULT AND EXPENSIVE TO CONTROL 60 HERTZ FAULT INDUCTION. Some of the ways it can be done, however, are:

- Install multipair neutralizing transformers of the power substation type in the telephone cables.

- Install less expensive induction neutralizing transformers, of the noise mitigation type, in the telephone cables.

- Provide "full-count" gas-tube or carbon block protection at frequent intervals on the telephone cables, to avoid damage to cable conductor insulation.

- Install quick-acting secondary protection devices, such as metal-oxide varistors (MOVs) at telephone repeater equipment inputs and outputs, to (hopefully) avoid equipment damage.

- Limit fault current on distribution feeders, through the use of neutral reactors at the substation.

- Rebuild one of the lines farther away from the other one.

- Avoid long, close parallels between telephone facilities and power transmission lines. A transmission line right-of-way is the worst possible place for metallic telephone facilities.

- Replace metallic telephone facilities with microwave radio or with fiber optic cable.

HOW ABOUT SUBSTATION GROUND POTENTIAL RISE (GPR)? That's a whole other subject which has been treated extensively by the IEEE ICEP Subcommittee. Two guides produced by that body are worthy of study. They are:

- ANSI/IEEE Standard 487-1980, "IEEE Guide for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations."

- ANSI/IEEE Standard 367-1979, "IEEE Guide for Determining the Maximum Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault."

THE SIXTY-FOUR (OR MORE) DOLLAR QUESTION IS, "WHO PAYS?" Now we come back to the fundamental concepts embodied in the EEI/Bell System "Principles and Practices of Inductive Coordination."

THE BEST ENGINEERING SOLUTION, FOR THE LEAST MONEY. That's the first important idea. All possible solutions should be examined, and the acceptable ones, engineering-wise, should be compared to find the most economical one, regardless of whose plant the changes or additions have to be made in.

THE SERVICE NEDS OF BOTH UTILITIES SHOULD BE CONSIDERED. But at the same time, the rights of their mutual customers must be considered. "In order to meet the reasonable service needs of the public, all supply and communication circuits with their associated apparatus should be located, constructed, operated and maintained in conformity with general coordinated methods which maintain due regard to the prevention of interference with the rendering of either service. These methods include limiting the inductive influence of the supply circuits or the inductive susceptiveness of the communication circuits or the inductive coupling between circuits or a combination of these, in the most convenient and economical manner."

THE TWO UTILITIES HAVE TO GET TOGETHER TO FIGURE OUT THE COST-SHARING. So what else is new? Several suggestions are offered in the "Principles and Practices":

- "Each utility should at its own expense design, construct, operate and maintain its plant in accordance with general coordinated methods."

- "Specific methods of coordination should be paid for by such equitable apportionment of the costs as may be agreed to by the utilities affected. It may be found reasonable in some cases for each part to bear the costs of such specific methods of coordination as result in net capital additions in its own plant. Care must be exercised, however, that this be not carried to a point where the best engineering solution is prejudiced. In cases where it is not clear as to what constitutes an equitable apportionment a fifty-fifty division of the costs may be found the most practicable solution."

- "All carrying charges, repair, operating or other current expenses incident to specific coordinated methods and all subsequent replacement costs arising after and due to the installation of specific coordinated methods should be borne by the utility on whose system the costs are incurred."

SO THREE PARTIES ARE INVOLVED. We have to look out for our own needs and rights, while at the same time looking out for the other utility's needs and rights. But we still have to watch out for the needs and rights of our mutual customers.

COMMUNICATION AND COOPERATION ARE THE KEYS TO INDUCTIVE COORDINATION.

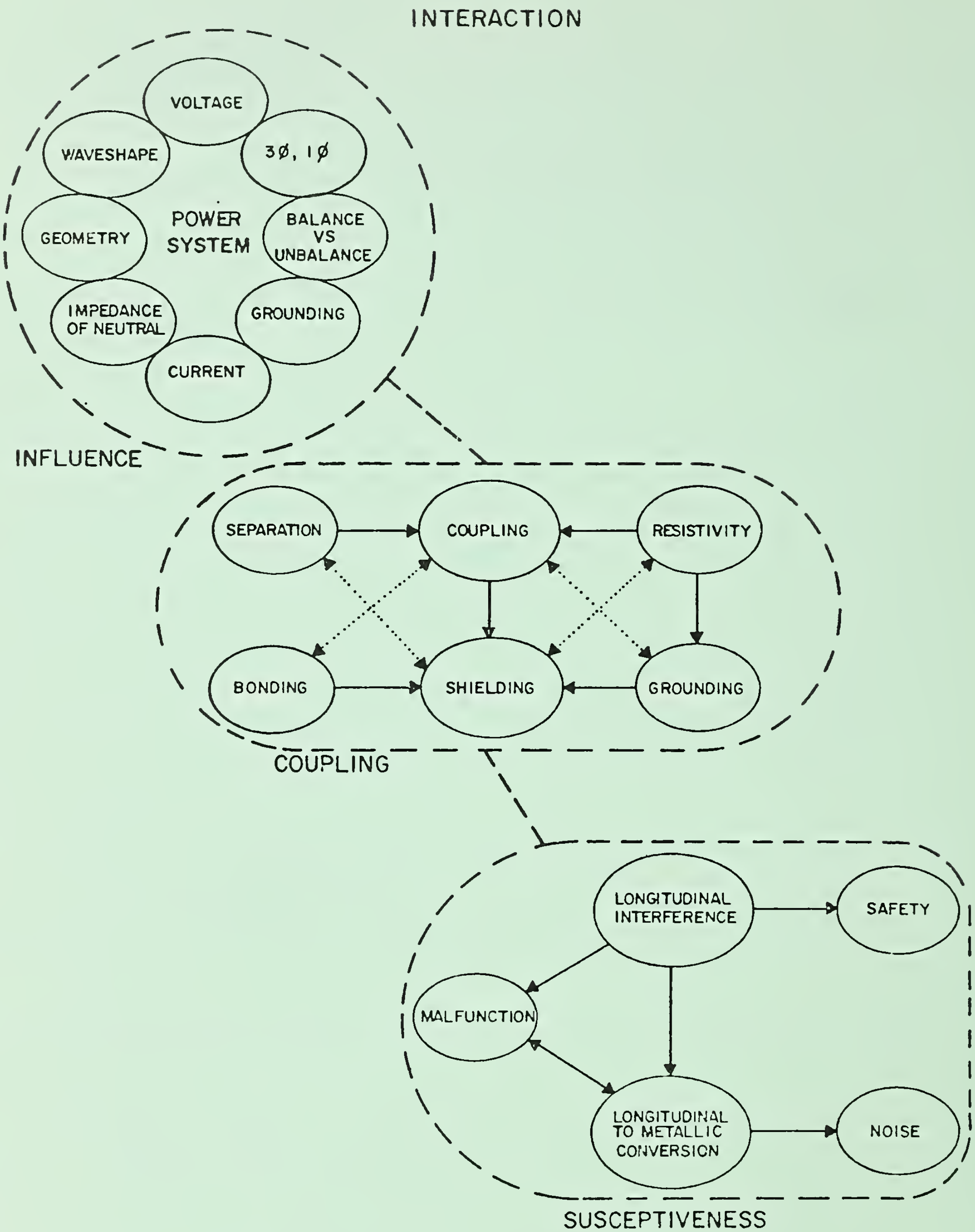

Figure 1 — General Interaction Model

From Bell Laboratories' <u>Inductive Interference Engineering Guide</u>, 1974

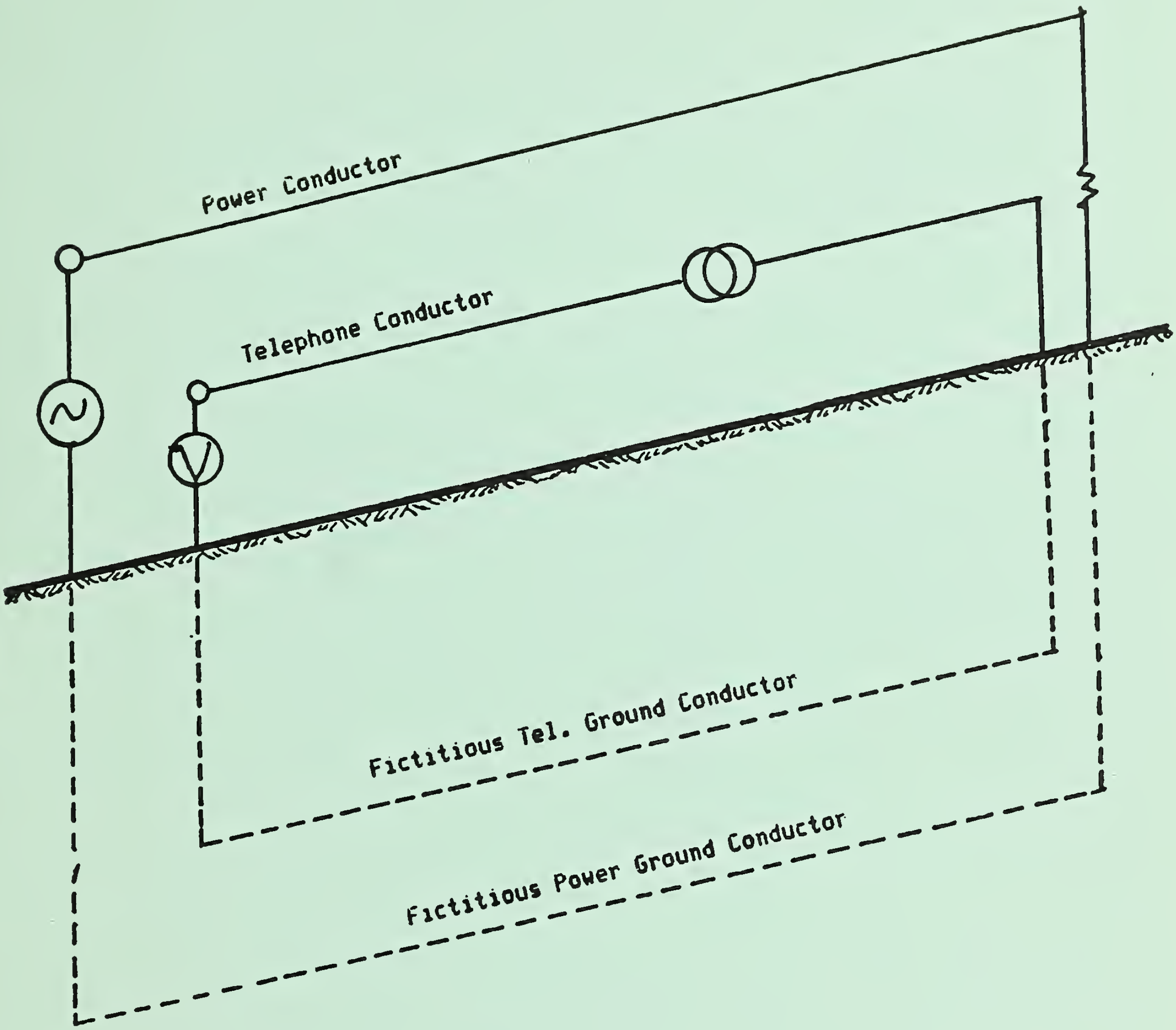

Figure 2 -- Parallel Wires with Ground Return (Two-Winding Transformer)

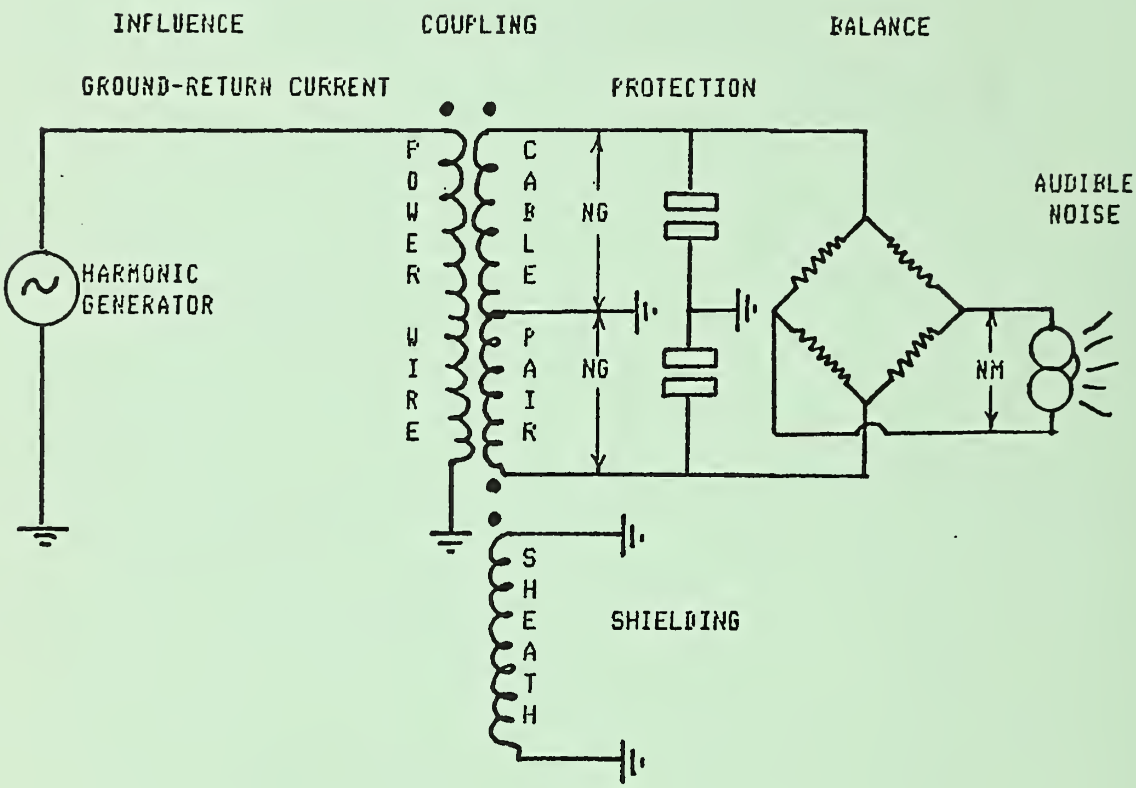

Figure 3 -- Air Core Transformer Analogy of General Interaction model

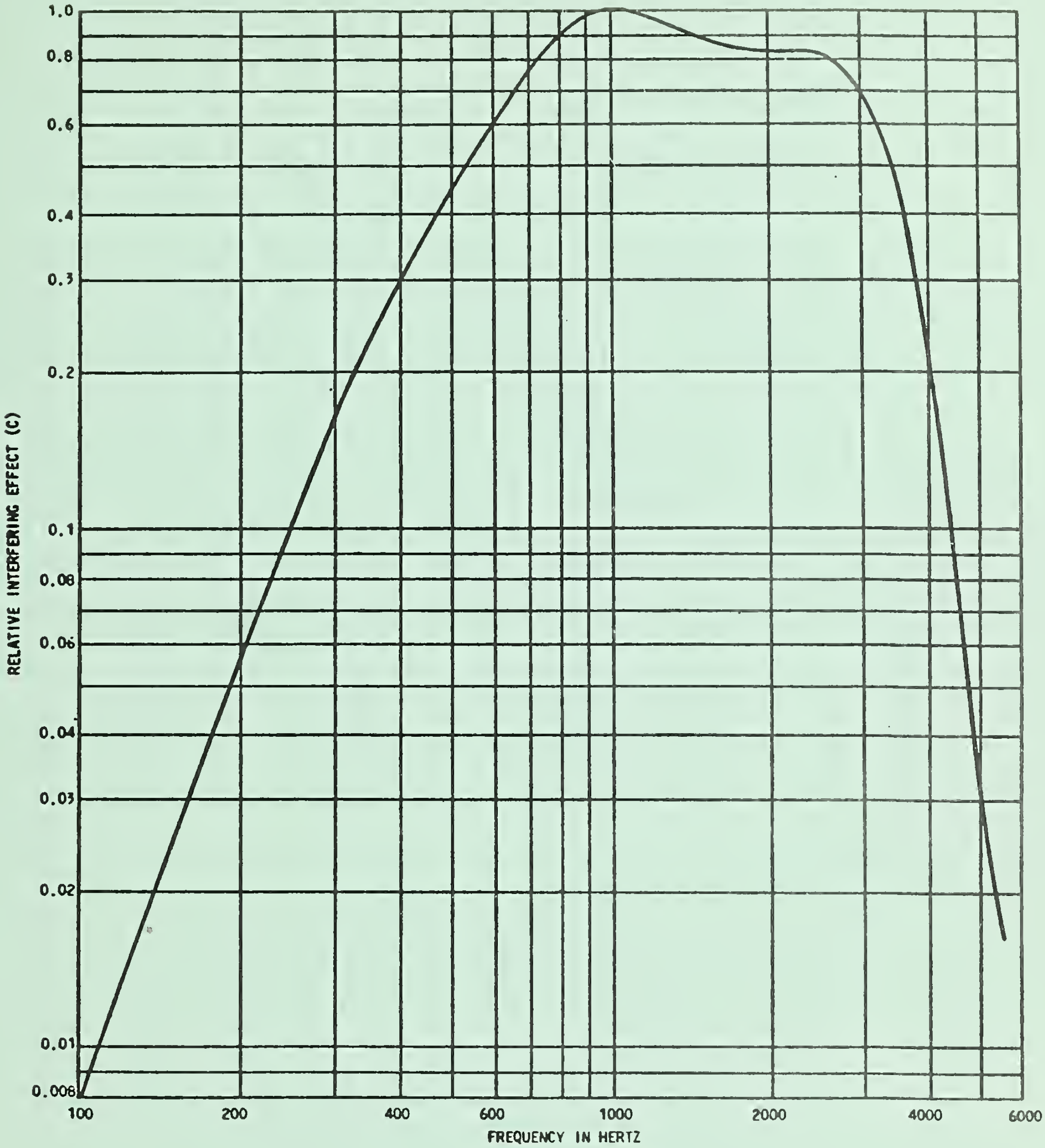

Fig. 4—C-Message Weighting Curve

1960 SINGLE FREQUENCY TIF VALUES							
FREQ	TIF	FREQ	TIF	FREQ	TIF	FREQ	TIF
60	0.5	1020	5100	1860	7820	3000	9670
180	30	1080	5400	1980	8330	3180	8740
300	225	1140	5630	2100	8830	3300	8090
360	400	1260	6050	2160	9080	3540	6730
420	650	1380	6370	2220	9330	3680	6130
540	1320	1440	6650	2340	9840	3900	4400
660	2280	1500	6680	2460	10340	4020	3700
720	2760	1620	6970	2580	10600	4280	2750
780	3380	1740	7320	2820	10210	4380	2190
900	4350	1800	7570	2940	9820	5000	840
1000	5000						

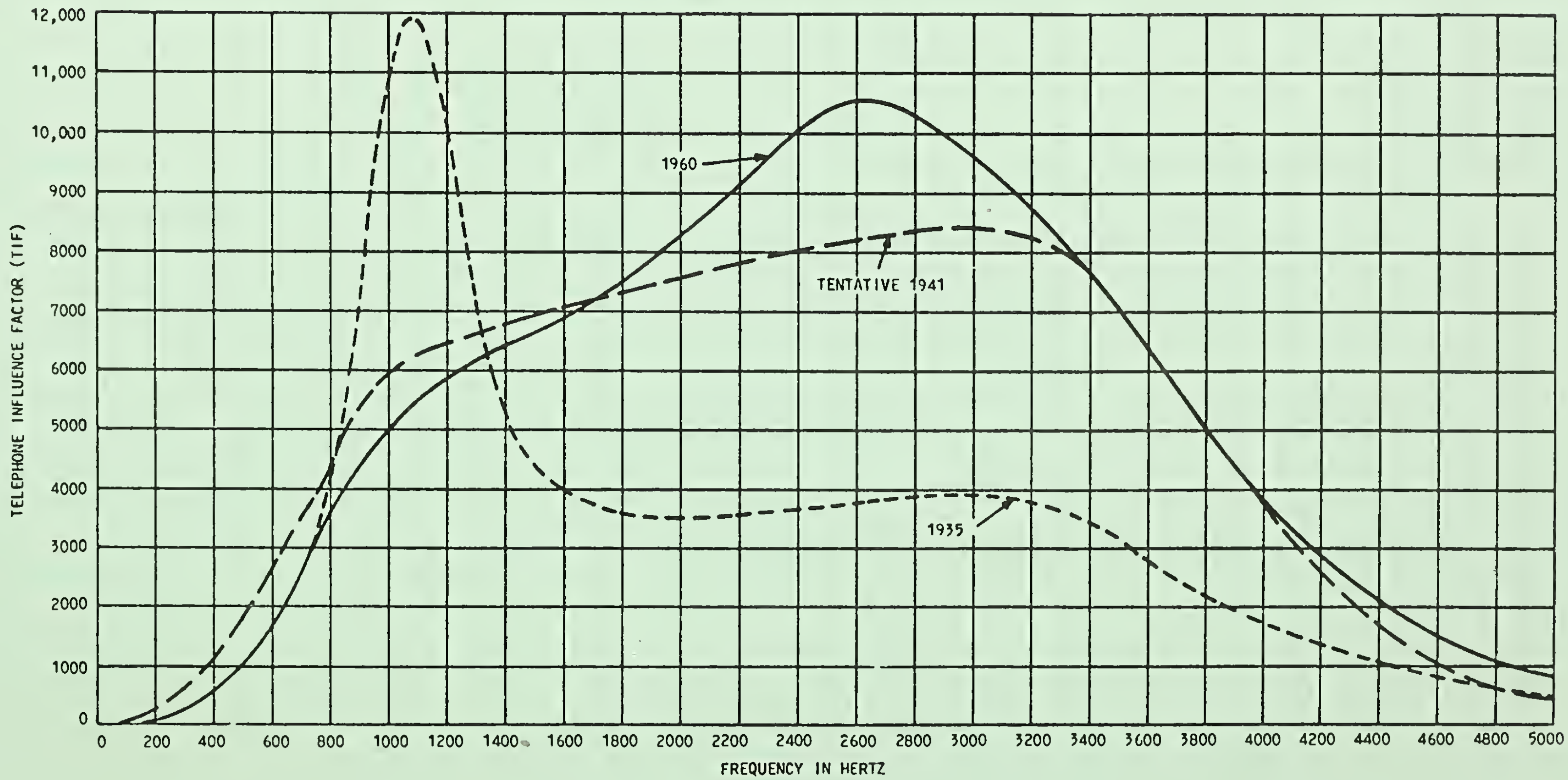

Fig. 5—1960 Weighting Curve Comparison With 1935 and Tentative 1941 Curve

INNOVATIVE METHODS FOR SERVING RURAL SUBSCRIBERS

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One of the earliest innovations for providing telephone service was that of using the earth as the other half of the electrical circuit. This "ground return" circuit provided excellent transmission in areas where there was no AC power influence and it cut the cost of copper in half (Figure 1). Manually cranked magnetos allowed customers to send many coded ringing combinations and thus call many individual customers on the same line. Local batteries, maintained by the customers, provided an excellent power source for the carbon transmitter. When a particular customer's voice sounded weak, he was so informed and knew what to do to correct the problem.

The introduction of AC electric power played havoc with the ground return circuit by causing constant bell tapping and an intolerable hum on the line. It was quickly learned that a second copper conductor in place of the ground alleviated this problem, especially when the two conductors were transposed at intervals along the way. The metallic circuit (Figure 2) made the open wire an excellent transmission facility which was used (and still is in many areas) for many years. Unfortunately, the lack of leadership and funds to upgrade the ground return lines to metallic circuits caused many of these early systems to deteriorate and leave areas without any telephone service for the next 20 years.

CARRIER DERIVED CIRCUITS

Aside from the introduction of phantom circuits, multipaired cable, loading coils, voice frequency amplifiers (repeaters), etc., the carrier derived circuit stands out as the next important innovation. To better understand the relationship of carrier derived circuits to physical circuits the electromagnetic spectrum (Figure 3) must be visualized and understood. Direct Current (DC) power and voice frequency signals are the basis for physical circuits while carrier, whether it is transmitted over wire or through the air, makes possible high density circuit routes. The frequency bands for analog and digital wire line carriers lie within the range between that of human speech and the upper end of the standard AM broadcast band. Mobile radio such as IMTS and Cellular and the rural radio fixed subscriber service lie in the 150 megahertz (MHz) to 900 MHz range while the point-to-point microwave radio, used in terrestrial and communication satellite applications, extends upward through 14,000 MHz or 14 Gigahertz (GHz) and beyond. Extending the graph upward would finally include light frequencies where modern day lightwave transmission takes place.

By superimposing speech on a much higher frequency signal, or carrier, many additional circuits are derived without adding physical plant (Figure 4). The first application of this pair-gain technique for serving subscribers was in 1945 when the Bell System, in cooperation with the REA electric program, put 5 voice channels over an electric power distribution line. This "M" carrier was installed throughout the country and was thought to be the logical means for providing service to rural subscribers. But this system was fraught with problems. Distribution power lines were constantly being reconfigured as new electric customers were connected for service. The constantly changing lengths of the electric lines and the attendant change in electric power loads caused the carrier derived telephone circuits to become very noisy and, in many instances, to cease functioning. Line treatment to enhance carrier transmission as used on electric transmission lines was not feasible because of the dynamic growth of rural electric power distribution and the resulting problems of administration. This led to the demise of power line carrier for providing telephone service.

During the 1950's REA and Bell efforts' produced versions of subscriber carriers that operated over open wire and multipaired cable. However, there was no frequency coordination or a standard to follow and the equipment suppliers at this time opposed a standard frequency plan. Consequently, the supplier who got the first order for its equipment to provide subscriber service over a specific cable route locked up that route insofar as other suppliers were concerned.

In 1965 an IEEE Conference Paper titled "Objectives for a One-Party Subscriber Carrier System" written by A. H. Flores and J. M. Flanigan of REA, became the informal guideline for a new type of distributed subscriber carrier, which would operate over a single wire pair. It was called "station carrier" (Figure 5). This was indeed innovation because it was self regulating, using the strength of the incoming carrier signal to automatically set the level of the outgoing signal. Further, it was designed to go into service without the need for adjustments. A spin off of this development produced an inexpensive single channel carrier (Figure 6) that could be added on to a non-loaded physical circuit to provide a second line to an existing subscriber or to serve another subscriber next door.

During the early 1960's digital carrier using Pulse Code Modulation (PCM) was placed into service for trunks by Bell and Independent telephone systems. Equipment suppliers later made versions of this new carrier for subscriber applications.

Digital carrier, which requires two wire pairs, provided a grouped subscriber configuration rather than a distributed configuration as in station carrier. Innovative methods for dropping and inserting a channel or channels are now available which offer a degree of flexibility enjoyed by station carrier. Most of these designs are for dropping groups of channels that terminate in a building. While the cost of dropping a single channel along the route is considered prohibitive at this time it will, undoubtedly, become feasible as demand and production levels increase. The basic connecting facility is the

T-1 span line using conventional cable pairs. However, digital radio and lightwave are also suitable facilities for connecting the subscriber terminal with the central office (Figure 7).

RURAL RADIO

An understandable first impression would make radio facilities synonymous with rural telephony. In reality this has not been the case except for mobile applications. Although relatively successful isolated efforts occurred using radio to serve fixed subscribers in lieu of wire lines, the most successful was in dial mobile radio. This followed REA's venture into this field in late 1957 when it prepared performance specifications consistent with dial telephone operating requirements and submitted them to suppliers along with the promise of "seed" money to develop dial mobile radiotelephone equipment. The rationale being that if mobile telephone service was to serve rural areas it would have to be automatic because there were few exchanges with operators. Further, this type of system could serve a few fixed subscribers in highly remote locations along with the mobile traffic.

This effort produced the pre-IMTS dial mobile radio systems which were installed all over the United States. While mobile subscriber use flourished, fixed subscriber applications never really caught on and for obvious reasons: 1) the disproportionately high monthly charge, 2) large party-line (sometimes 20 or more), 3) less than equal to wireline transmission quality and 4) more than normal maintenance requirements. Historically, mobile subscribers generally accept these adverse conditions because the overall advantages outweigh the disadvantages.

The single channel rural radio (Figure 8) dedicated to one or a typical party line group of subscribers should be the answer to a telephone system manager's prayer for serving those hard-to-reach subscribers - and it often is. However, it too, is fraught with problems. The few available channels may be used only on a secondary basis to mobile use. The FCC will permit such an application only if it does not interfere with a mobile system and, provided a showing can be made why it is impracticable to provide the service with wireline facilities. Further, it is often not cost-effective because of the added expense of overcoming poor radio path situations due to terrain. It does, however allow the use of the standard telephone set with the convenience of extensions - an important feature that the dial mobile systems do not have.

A spin off of the multichannel access feature of IMTS led to the development of a multichannel rural radio (Figure 9). It was produced primarily for export to developing nations where wireline facilities are non-existent and radio channels are plentiful. This equipment also found relatively high usage in the southwestern part of the U.S. When enough unused radio channels were available to meet traffic requirements and reliable radio paths to subscribers were not too expensive to achieve, this system proved to be a highly useful and cost-effective facility. However, because of the lack of a sufficient market in this country, the only supply source discontinued domestic production. Other reliable sources of this type facility are being sought.

SUBSCRIBER MICROWAVE

For more than two decades those responsible for coming up with innovative cost-effective methods of serving rural subscribers wished for a "novel" microwave system. This system would have an omni-directional radiation pattern from the central or base station. Subscriber stations would use directional antennas pointed toward the central station. So far, this describes the multichannel rural radio, but the similarity ends there. While the multichannel rural radio uses discrete carrier frequencies for each channel, the "novel" microwave system would have one radio frequency carrier multiplexed with many voice channels. Because the central station receiver must be capable of receiving many subscriber stations at the same time, the subscriber stations must use a time division transmission scheme synchronized to allow all stations to be received simultaneously. Such a system (Figure 10) was developed about 1977 by Farinon of Canada. However, it operated only in the 1500 MHz band which is not allocated for common carrier use in this country. Efforts to get the equipment manufactured for operation in a suitable frequency band for use in the U.S. and efforts to get the FCC to allow operation in the 1500 MHz band failed. The search was renewed in 1983 when it was learned that this equipment was being manufactured in Canada by SR Telecom. It is used world wide except in the U.S. Hopefully, this will change because the equipment is being made for operation in a wide range of frequency bands including the 2000 MHz band allocated to common carrier operation in this country. FCC type acceptance is required to allow its use here.

This equipment is, in effect, a radio concentrator having 15 voice channels and 94 subscriber lines. Each subscriber station is equipped to serve up to six lines. Typical installed equipment costs including antenna supporting structures for "ideal" terrain range from approximately $2200 per subscriber in a 30 subscriber cluster to $14,000 for one subscriber at a single location.

Phillips of Holland also makes a similar system for operation only in the 1500 MHz band. It can serve up to 128 subscribers over 10 voice channels.

CELLULAR RADIO

Cellular radio has probably created more excitement than any other technological development in the field of telecommunications. Developed by Bell Labs and originally called "High Capacity Mobile System" (HCMS), it uses frequency modulation with 12 kHz deviation. Its 30 kHz channel spacing and relatively high deviation make it a very forgiving transmission medium where propagation is not a problem. Reliable radio coverage at 850 MHz in rough terrain and through foliage is far more difficult than at 150 and 450 MHz used in rural radio applications. Cellular was designed and optimized for mobile application to densely populated areas to serve the existing pent up demand. Hand held portable units (Figure 11) are being promoted by some suppliers and users for service in the home or office in lieu of the wireline telephone. Such a drastic departure from conventional telephone service appears naive, at least for the forseeable future. However, this application is certainly plausable in special cases such as remote cabins requiring only seasonal use and where long holding times are not prevalent. Existing equipment and operational restrictions do not permit such generally accepted conveniences as extensions throughout a house or office. However, if the market demands it and the FCC allows it, a subscriber terminal could be made that would accommodate standard telephone instruments as is now done with the rural radios described above. This application would, of course, require a different traffic handling system design than normally used in mobile systems. Further, it would not need the costly and sophisticated capability for initial call set-up paging and cell-to-cell hand off.

COMMUNICATIONS SATELLITE

This technology has become commonplace as evidenced by the growing appearance of earth station antennas on roofs of city buildings and in the back yards of rural dwellings. Generally these are television receive only (TVRO) earth stations, but the same type of facility with added two-way capability can provide telephone serve to an individual or small group of subscribers. Fixed or preassigned (PA) circuits allocated to a relatively few subscriber stations are very costly and generally use double-hops to establish a connection. The signal time delay incurred by the two round trips (approximately 100,000 miles) to and from the satellite is generally unacceptable for two-way voice transmission.

Innovative techniques such as Demand Assignment Multiple Access (DAMA) reduce the cost and delay (Figure 12). There are no fixed or pre-assigned circuits because they are only used on demand. The control station assigns a circuit to its intended destination and then drops out of the action, leaving only one earth-to-satellite hop thus halfing the transmission delay time. Even though this technique is technically acceptable, the cost for serving one rural subscriber can be as much as $45,000 for the earth station alone.

POWER LINE CARRIER

Near the beginning of this paper the aborted efforts to serve rural subscribers with power line carrier was discussed. Technology has gone full circle. Westinghouse Electric is now offering this equipment for telephone subscriber application (Figure 13). This electric power oriented company has adapted a 13 channel station carrier manufactured by a telephone oriented company to form a unique equipment package for the telephone industry. Successful field trials show promise for this recalled early innovation. The problems that plagued the early systems may not be as difficult now because distribution power line construction is relatively little compared to the early days when the REA electric program was in full swing. Modern technology has improved the carrier equipment and created effective means for reducing the effects of power line noise and signal failures. Added to these positive developments is the fact that power lines are constructed to better withstand the ravages of storms than aerial telephone plant. Perhaps power line carrier can help serve some of those hard-to-reach rural subscribers.

NEW RADIO SYSTEMS UNDER DEVELOPMENT

In addition to the known available equipments for serving subscribers there are several interesting developments in progress.

A subscriber radiotelephone using digital compression techniques to derive several voice channels per FCC allocated channel is under development by International Mobile Machines Corporation located in Philadelphia. Radio Switch, a company located in the San Francisco Bay area, is developing a radio system for telephone subscriber application and the Peninsula Engineering Group, also in the San Francisco Bay area, is developing a 2 GHz digital microwave system for subscriber application.

The above companies' efforts are known to the author, perhaps there are others.

SUMMARY

All of the methods discussed are, indeed, innovative. However, all may not necessarily be desirable for offering modern telephone service. We have come to expect certain basic features and services from our telephone system. Some are summarized as follows:

1. Good voice quality and free of perceptable noise.

2. Reasonable monthly cost for the service and reasonably priced telephone sets.

3. Freedom from service interruption for any reason.

4. The ability to enjoy relatively long conversations at affordable costs.

5. Multiple extension telephones that provide the facility of having more than one person, at the same telephone number, participate in the conversation.

6. Custom calling services.

7. Special Services such as 1) full period (24 hour) circuits between specified locations, 2) foreign exchange service and 3) alarm capability - including fire, burglary, medical, etc.

Emerging services such as the Integrated Switched Digital Network (ISDN) must be in the minds of modern telephone management if not in some degree of the actual planning stage. Because someday some form of this new technology is just as sure to be a part of telecommunications as the telephone set itself. Unless history repeats itself with another era of telephone service deterioration and ultimate demise and forces us back to using the Dixie cup and string (Figure 14), society can look forward to new and better telecommunication innovations in the future that will rival everything we have seen or heard thus far.

Grounded Return with Local Battery and Magneto

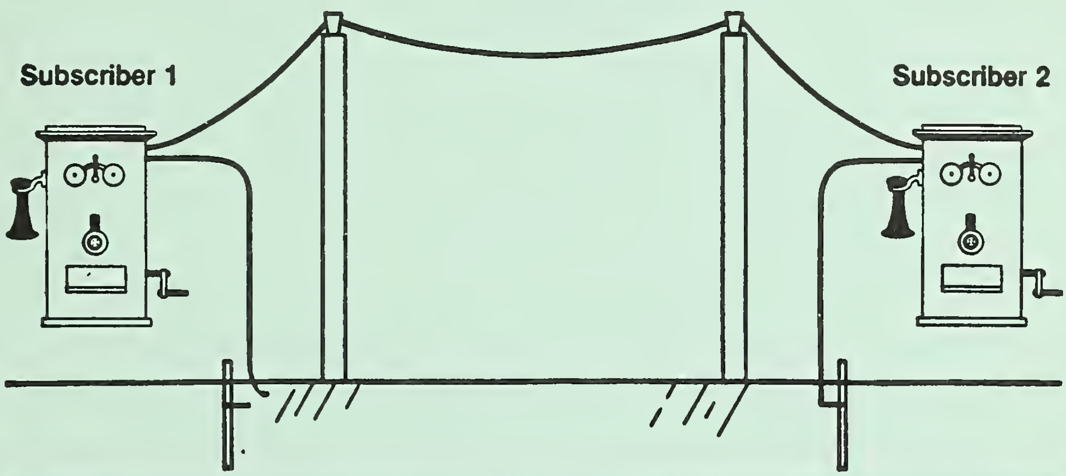

FIGURE 1

Metallic Circuit with Common Battery and Switch

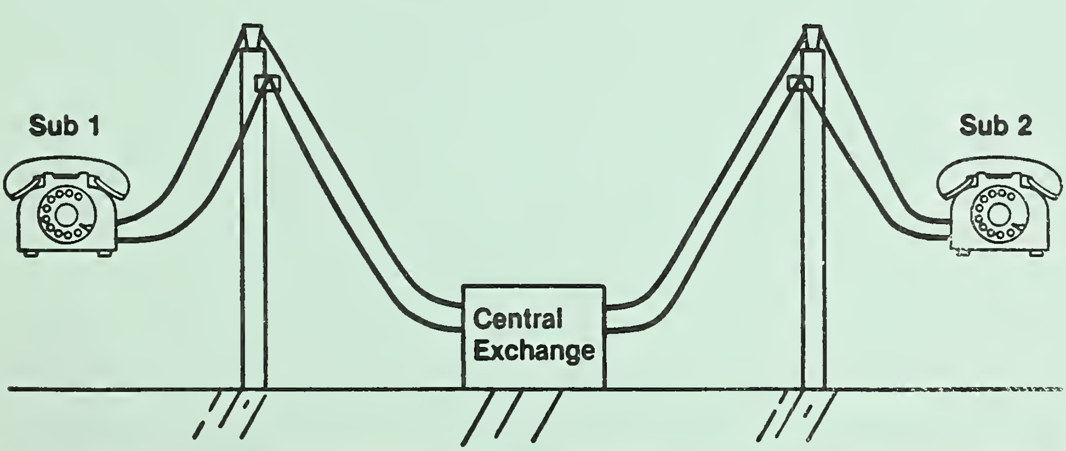

FIGURE 2

Electromagnetic Spectrum

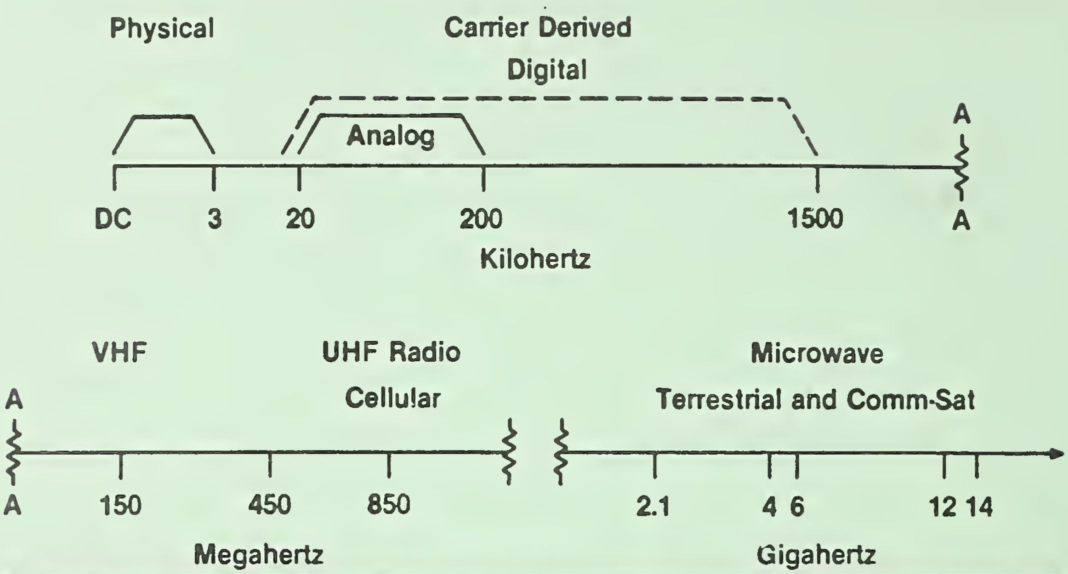

FIGURE 3

Carrier Derived Circuits

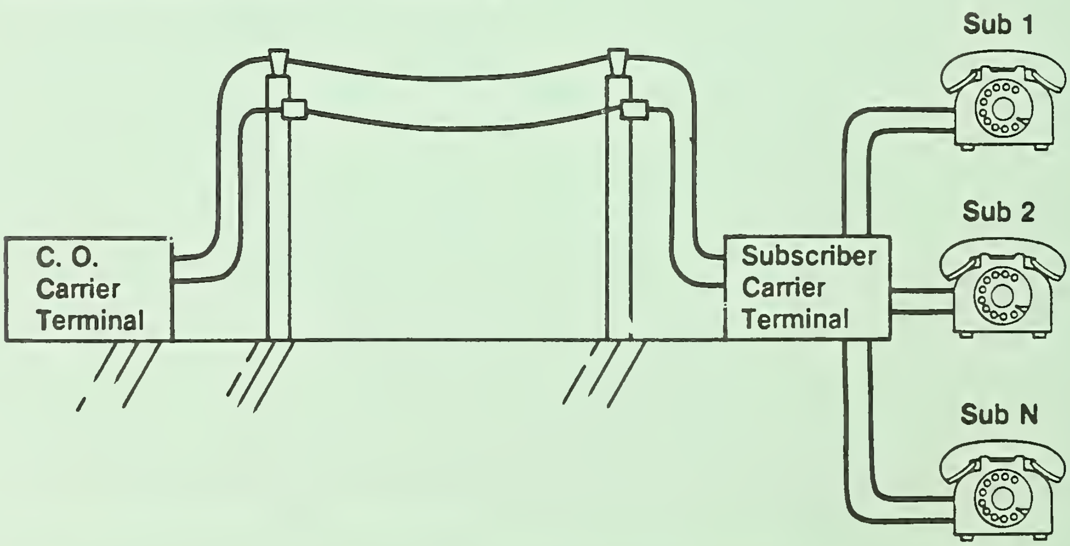

FIGURE 4

Distributed Carrier

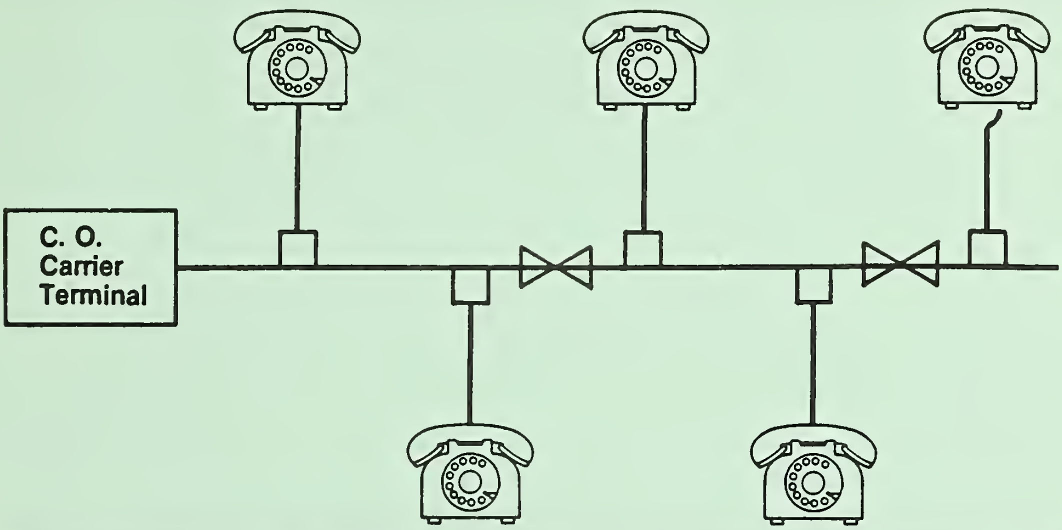

FIGURE 5

Physical Plus Single Channel Carrier

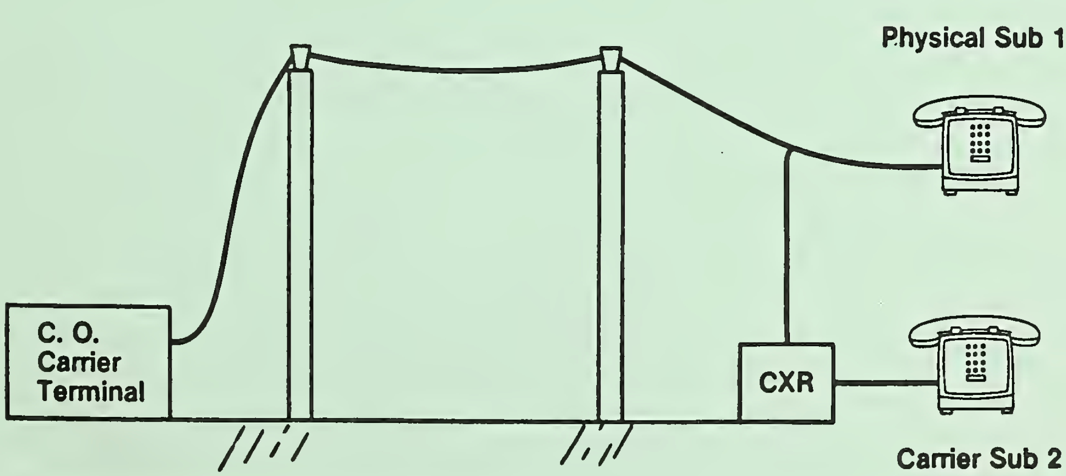

FIGURE 6

Grouped Carrier

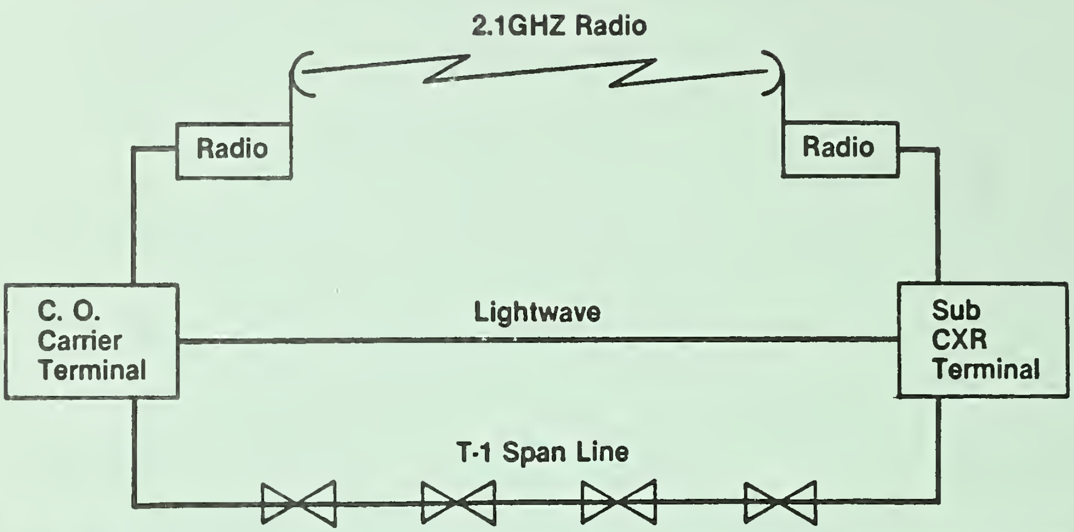

FIGURE 7

Rural Radio Single Channel (Optional Repeater)

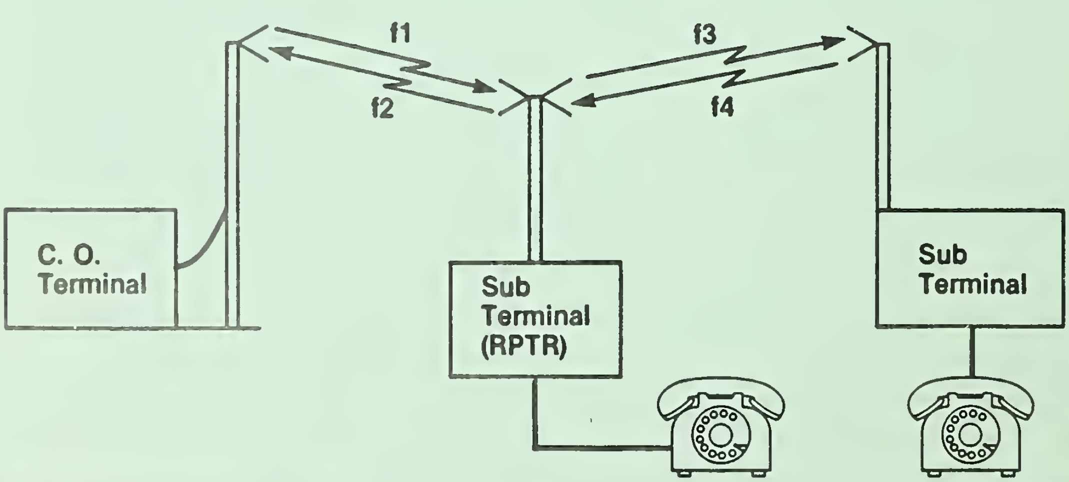

FIGURE 8

Rural Radio Multichannel Multiaccess

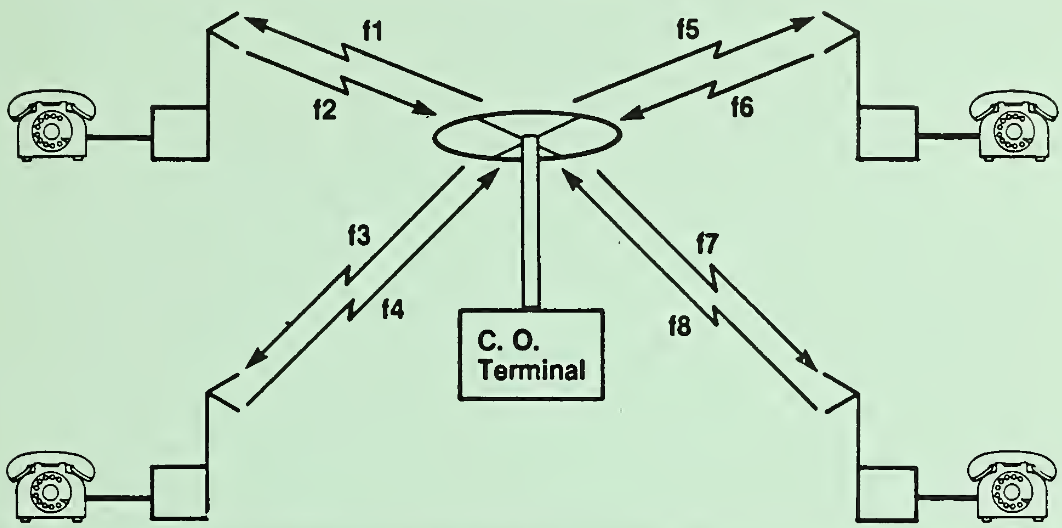

FIGURE 9

Subscriber Microwave Multichannel TDMA

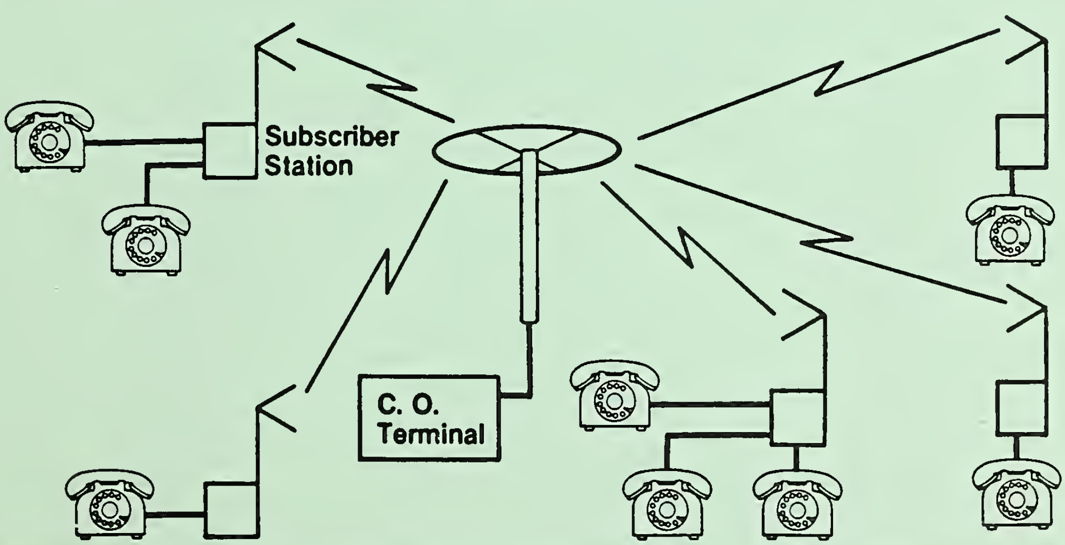

FIGURE 10

Cellular Radio
Residence/Office

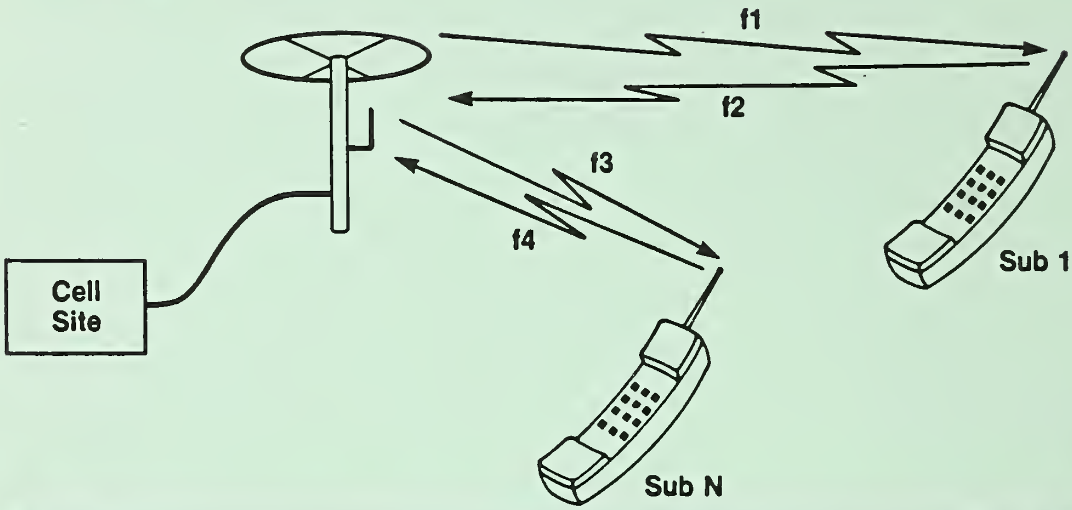

FIGURE 11

Communications Satellite DAMA

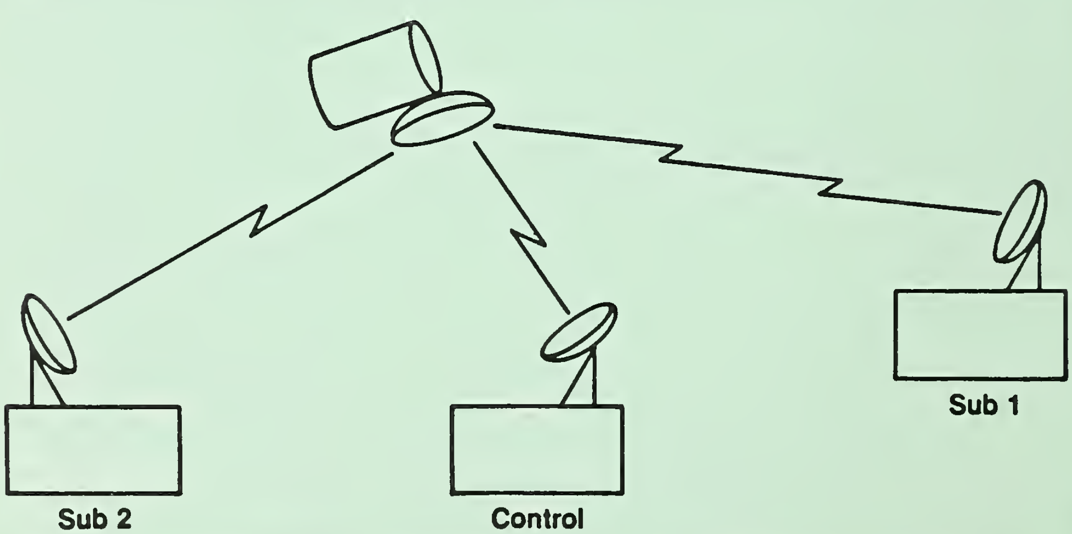

FIGURE 12

Power Line Carrier Derived Circuits

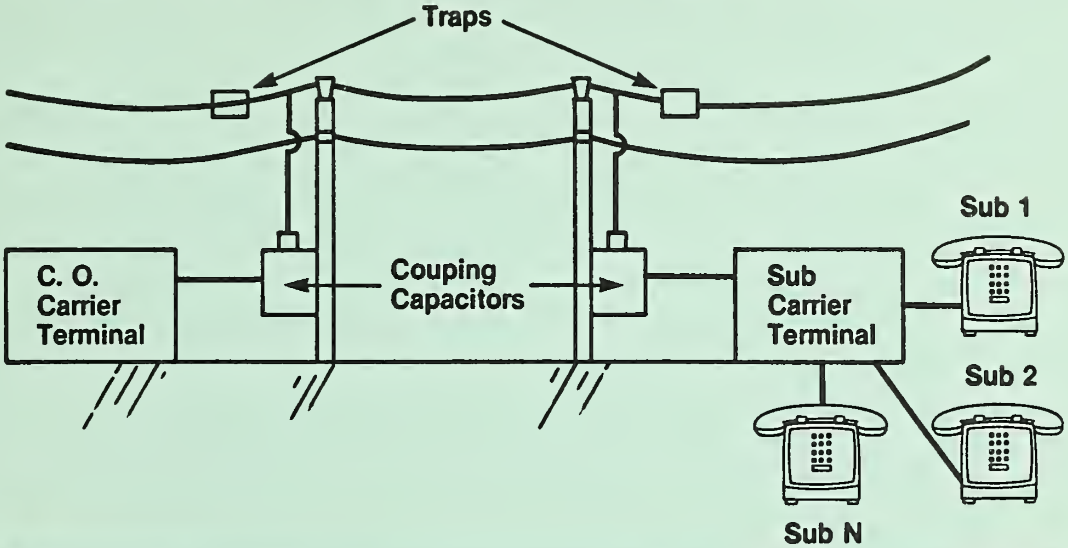

FIGURE 13

The Most Innovative

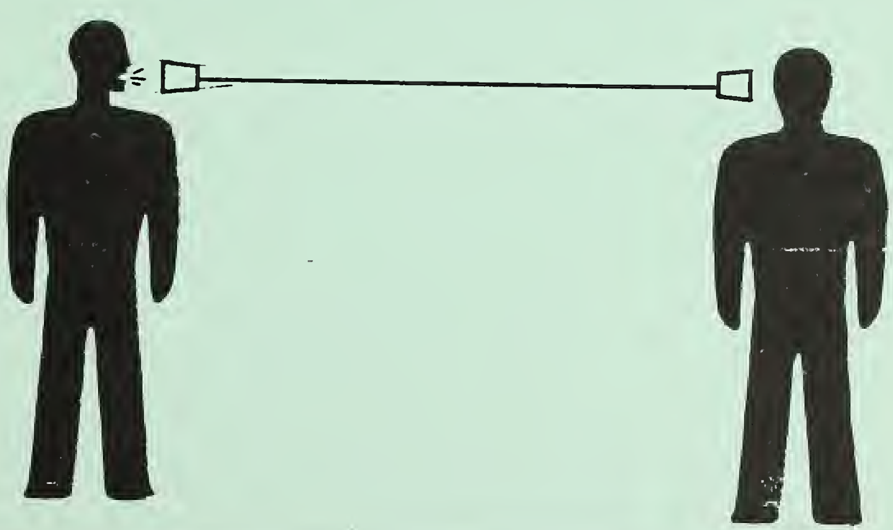

FIGURE 14

LIGHTWAVE TRANSMISSION SYSTEM DESIGNS

William O. Grant
Transmission Branch
Telecommunications Engineering and Standards Division

For most of us working in telecommunications, the evolution of lightwave technology has meant a lot of hard work and an entirely new learning experience. Certainly we at REA have had to hit the books and I imagine many of you did also.

We thought it might be useful to generally review the REA lightwave experience to date.

The initial objectives were easily identifiable of course. We had to familiarize ourselves quickly and thoroughly with the techniques and equipment so that we might evaluate the transmission capabilties and costs of this intriguing new alternative.

It became quite evident early in the game that what we were addressing was perhaps more scientifically oriented than a practical transmission technology should be, at least it seemed so at that time. There were fibers and cables available all right, and several sources of terminal devices also, but there was little unanimity in how to design links or systems and even less on splicing, testing, or test equipment and procedures.

If lightwave technology was going to transition to a useful, practical option for REA clientele it was going to need some help. Not additional scientific development, you understand. It seemed every other scientist of any stature at all was already deeply involved and contributing.

What seemed to be really needed was to move it out of the laboratory and get it into the field.

This became the major orientation of the REA effort. Not simply to encourage or support an operating installation, but to do so in a manner that would identify the difficulties, if any, of placing, splicing, testing and maintaining such plant with the in-house, in-place staff available in REA borrower companies.

This then became the Game Plan. Get some systems into the field, get some practical experience and history, and at the same time try to get specification and practice writing underway. With this definition we were prepared to structure Field Trials which were responsive to the objectives.

If I might take you back to those thrilling days of yesteryear, at that time it was very difficult to prove in a lightwave system against the economics of the available alternatives such as microwave radio or digital carrier on twisted pair telephone cables. This inhibited, and could have seriously delayed, any practical experience if a cost effectiveness criteria were too rigidly imposed. Certainly this was a serious problem but in 1978 REA management took the long term view that development effort of this type was worthy of support. They authorized an installation, even though at that time it could not be demonstrated that it would be the least expensive alternative for that particular application.

In retrospect this decision and action, and the early experience gained as a result, has been the single most significant factor in our "getting on board" if you will, in launching REA into an effective lightwave program.

We are happy to report that in this case, our first lightwave project, the Field Trial procedure was completely effective. Of course the lightwave system worked well and transmission through it was satisfactory but that was never seriously in doubt. I say this effort was effective because our objectives had been much broader in scope than transmission performance alone, and they had all been achieved.

We had hoped to find out if telephone craftspeople could place optical cable in ducts, aerial and direct buried types of construction. We had hoped to find out how difficult it was to splice optical fibers, not for the factory expert, but for local telephone people. We wanted to find out how tough it was to test, maintain, and trouble shoot a lightwave system.

And we found out all of these things.

None of it was too tough. Certainly it was different and of course there was some learning to do, but by and large it wasn't too tough, it was well within the capabilities of the local telephone staff.

Pretty obviously we monitored this project closely as time passed. And we got lucky. Through the help of some local gophers we had an interruption of cable continuity. This gave us and the local telco some very useful exposure to fault location and restoration operations. Again, this was different from our earlier telephone experience perhaps, and we had to learn, but it wasn't too tough.

There's no reflection on the telco for this rodent damage. In this rather rocky area they had not used any significant amount of direct buried cable construction

Without doubt this particular project, at this particular time, was exactly the kind of experience we'd needed and hoped for. And without doubt, lightwave technology was well within the capabilities of independent telephone companies. Throughout this one project REA staff had been exposed to system design, optical cable characteristics, construction, in short, every facet of practical exposure we needed if we were to effectively proceed further.

Based upon this experience we were certainly encouraged and prepared to go further, and we did. We participated in a number of field trials including various cable configurations and new splicing techniques. We then settled in to the difficult tasks of generating specifications for both cable and terminal equipments.

How has it all gone, how well has it all worked? To date we have in place, or in progress, about 16 lightwave projects. These involve over 300 route miles of optical cable and about 1500 miles of individual fibers in place.

These projects ran at transmission bit rates up to 90 Mb/s with all the attendent sophistication of digital multiplexing and protection switching. Several have intermediate repeaters.

We've been exposed to fusion and mechanical splicing and have experienced several fiber restoration problems.

I think it's a fair statement that we've had enough experience and exposure to draw some reasonably authoritative conclusions.

In general, the technology is mature enough to produce a very high level of confidence in new construction. Every system we've been involved in has produced the transmission capacity and quality that was predicted.

There are no extraordinary difficulties in placing fiber optic cables either aerially or underground and cable placement, even plowing, is well within the capabilities of REA borrower staff or the contracting forces they might usually employ. There are, at this time, no serious obstacles to constructing systems using either fusion or mechanical splicing.

After some infant mortality, we believe terminal devices can and do provide satisfactory reliability and performance. We have a specification for lightwave terminal devices under review now and hope to be issuing it soon.

The supporting TE&CM program is a more difficult task but we have some draft copies in cirulation for comment now.

In summary, the principle components of lightwave systems such as fibers and cable, and terminal devices have all developed satisfactorily. There are new developments to be expected of course, but the materials and equipments avilable now can be used with a comfortably high level of confidence.

But there is still work to be done.

The design of lightwave systems to date has been less gratifying. It's not that the transmission performance has been substandard, quite the contrary. Almost every installation to date has outperformed the design itself, and also presented higher traffic capacity in some cases.

Perhaps this is understandable in the earlier installations. A conservative approach to fiber and cable specifications, and the universal provision of protection switching and dual facilities, may even be commendable. But surely, as the uncertainties become resolved, we need to readdress cost effectiveness. For example, the provision for extra fibers within a cable, even when duplicate facilities have already been included for protection purposes, needs to be reexamined and some cost justification required.

Our experience with wavelength division multiplexing is woefully inadequate, in fact it is conspicuous by its absence. This appears to be a technique which might dramatically improve the efficiency of every optical fiber placed, and we intend to investigate this intensively. It may well alter the present lightwave system design philosophy, and could have a significant impact on future system costs.

We also believe there is much room for improvement in the test techniques and test equipment used in lightwave systems today. It's not the precision or sophistication that we take exception to. It seems to us that the questions of practicality and simplicity have been addressed, if at all, only superficially. To borrow a phrase from the computer industry, we should put more emphasis on making lightwave systems "user friendly" _____ easier to maintain and test.

In following up on these projects we have maintained contact with the telephone personnel involved. Their input is reflected in our comments here of course, but there was another point that was brought up by several of these people which merits mentioning.

When you install a lightwave facility you usually provide some capability for growth. For example, we commonly find a digital multiplexer whch is not fully utilized initially. Several of the REA projects have been in service long enough now to have had circuits added in the form of more DS-1 signals.

Implementing such additions on a lightwave system already in service is almost absurdly simple, particularly if the terminals served are digital switches which can accept the new circuits on a DS-1 digital signal basis. There is no individual circuit alignment or testing necessary at all. One experience was that one man, working alone, had equipped and activated a T-1 addition (24 channels) in this manner in one half hour.

Even when interfacing with an analog office at one end the operation is greatly simplified and expedited.

An analogy might be made with a conventional T-1 system which has been in place but which did not initially equip all 24 channels. Adding channels in such a system is largely an insertion of cards or modules.

The point is that some of the inherent advantages of lightwave installations are less obvious than others, and may be easily overlooked or understated.

By and large the REA experience is very encouraging. Lightwave systems perform very well and are relatively trouble free.

Although almost all the REA borrower installations have been high traffic trunking applications, we believe that modifying the system design philosophies somewhat can expand the use of optical fibers into lower density situations effectively, eventually into the subscriber loop itself perhaps.

And we are encouraged by the trend to lower costs both in fibers and in terminal equipments but we need further cost reductions if we hope to get into the subscriber loop optically.

The scientists and laboratory people who have brought us this fascinating technology certainly merit our admiration and applause. But the application and effective incorporation of this technology into the rural telephone network is really our responsibility now isn't it?

I'd like to talk to you a bit about lightwave system configurations and design. There has been enough optical fiber put in place, and enough operating experience gained, to establish beyond reasonable doubt that lightwave transmission is a practical alternative to other systems.

But how does it fit into your network, your system, your traffic requirements? That's not just an interesting academic question either. If you are involved in telecommunications today you are obliged to address these points, you have no choice, you must ask these questions. And within REA we must do so also, and we have.

We're not completely satisfied with some of the answers we found.

Sure, lightwave systems work and deliver excellent transmission performance, and yes, they are pretty easy to maintain, but how do they fit the applications.

If you're talking high traffic density and significant distances between service terminals they fit very well indeed. But are these the majority of situations facing the smaller, rural telephone operations?

Perhaps we could try a different perspective. Up to now, by and large, we have simply transposed the high density techniques into lower traffic density situations without any changes at all. The philosophy of multiplexing all traffic up to a single, higher level digital signal, and providing duplicate transmission links with sophisticated protection switching equipments, which are persuasive arguments in the high traffic applications, seems to be almost automatically applied to all situations.

Perhaps if we review the lower density situations we could more effectively apply the basic technology.

Perhaps we could make the shoe fit the foot, rather than insert the foot into an undersized shoe simply because one is available.

A good point of departure may be protection switching. There seems little need to apply lightwave in single T-1 applications and we have seen none considered. But as soon as the traffic load escalates above the single T-1 level there is reason to consider digital multiplexing. But we're not talking about traffic loads on the order of 500 circuits or so, we're talking 100 or 150 circuits and less. Maybe we should look for alternatives here.

Examine Figure 1 for a moment. Here we see the conventional approach applied to a requirement for say six T-1 systems which would provide 144 equivalent voice circuits. Assuming some traffic growth, the average application we see at REA would project 5 year requirements to perhaps 9 or 10 T-1 systems.

And the design we're looking at right here would be typical, almost universal I might even say.

Using MX 13 multiplexers we're up to 45 Mb/s for the transmission bit rate and this system can accommodate 28 T-1 systems, that's 672 equivalent voice channels. Now the moment you arrive at this point the arguments for duplicate transmission facilities and protection switching are difficult to ignore, aren't they? The project quickly escalates to four optical fibers, with four light wave transmitters and four lightwave receivers, and when you add in switching sophistication, the costs escalate also. Note the fact that the MX13 multiplexers are common equipment to all traffic carried. Surely this justifies protecting them.

But have we considered alternatives at all? We quickly arrived at the DS3 signal level, 45 Mb/s, and at that point the protection requirements seem self-supporting and most persuasive. But suppose we didn't escalate to DS3 at all. Suppose we addressed the requirement as two separate DS2, 6 Mb/s, signals to be transported.

Figure 2 shows one approach along these lines. We still require four fibers as before in Figure 1, and we still use four lightwave transmitters and four receivers also. The multiplexers are only M12 units however, which are less sophisticated and less expensive. But these multiplexers are not common to all traffic, only to 50% of it, if we equally divide the T-1 systems across both DS2 signals.

A failure of any multiplexer, lightwave terminal, or individual fiber will only affect half our traffic. Since we expect such outages to occur only a very small percentage of the time, we might very reasonably forgo any protection switching at all in this configuration, which should provide a significant reduction in cost.

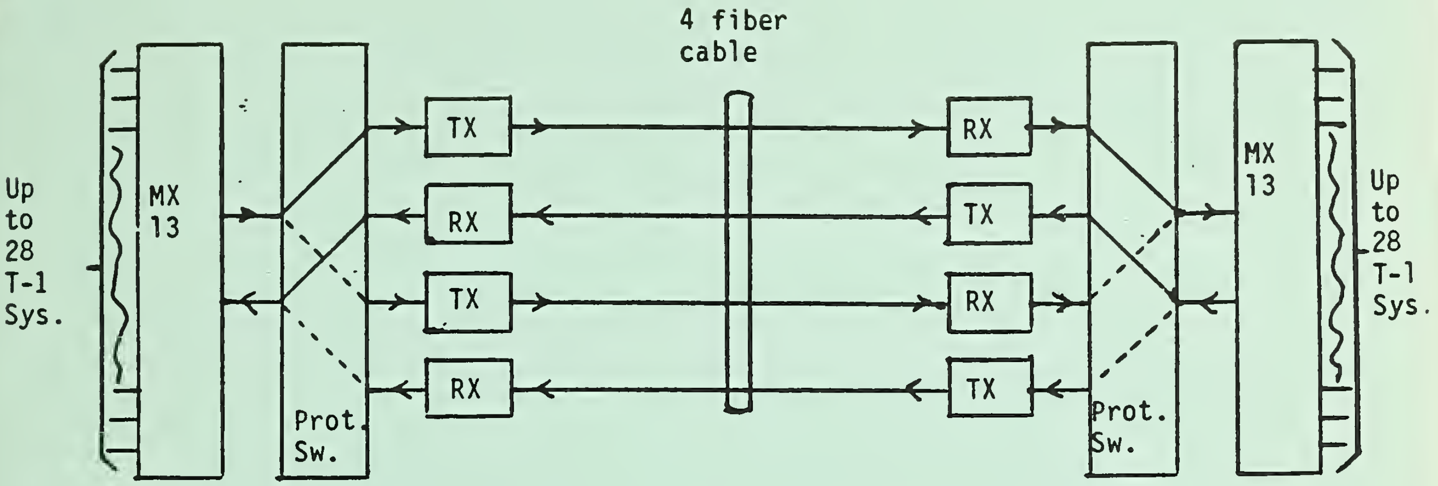

Figure 1 - High Level Digital Multiplexing

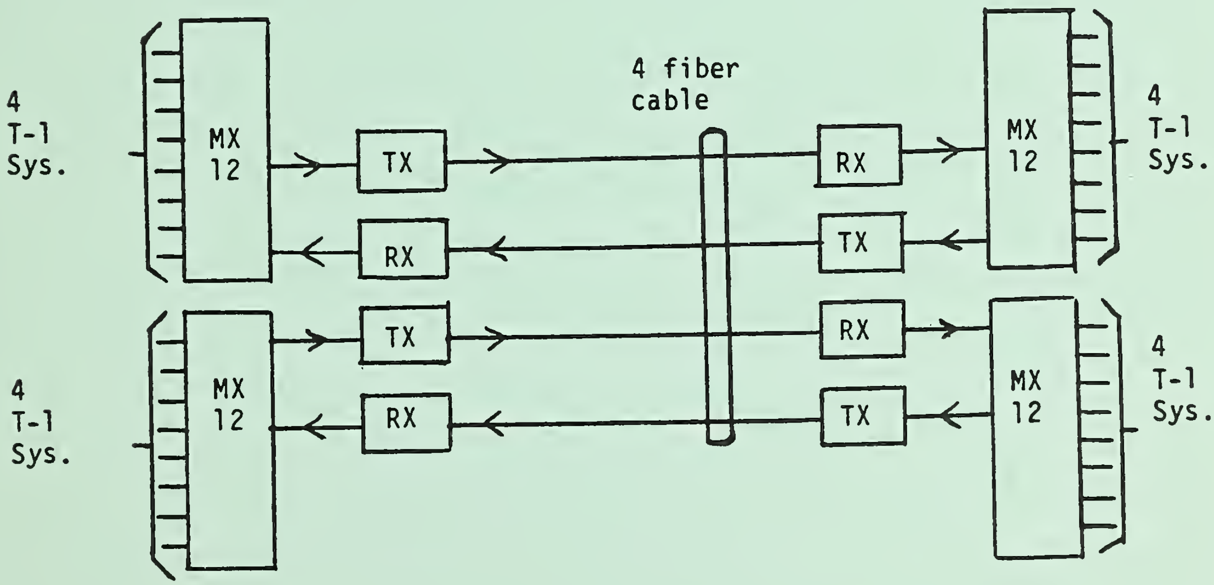

Figure 2 - Low Level Digital Multiplexing

The addition of T-1 systems for growth is limited to two more T-1 systems without major addition of equipment, but that's 48 additional circuits. This may well be sufficient for many rural situations. And we need not limit this expansion capability. If the optical fiber and lightwave terminal devices were selected such that an escalation to 45 Mb/s transmission was possible at some later date, then the upgrade to 45 Mb/s, and 28 T-1's, need not be precluded at all.

If we look at Figure 2 again for a moment, there may be another possibliity we should consider. If we actually have saved money by eliminating the protection switch and using lower level digital multiplexers, we might utilize some of the savings to improve the actual grade of service the system provides.

This isn't really my strong suit, but as I understand it, the number of circuits actually provided is developed using statistical input and a traffic load formula. It is expected, in every transmission system, that an "all trunks busy" condition may be imposed for some short periods of time. This establishes the grade of service the system provides.

We could apply some of our cost reduction to equipping more circuits initially couldn't we? If our traffic required 144 circuits (as we arbitrarily assumed earlier for our example) we could install 8 T-1's right now which would increase the circuit count to 192 from the original 144. And with 192 circuits evenly divided between two independent lightwave systems, a loss of 50% of circuit capacity for small percentages of time would be even more acceptable.

The point which we sometimes overlook perhaps is that the most sophisticated, most reliable, service protection scheme does nothing at all to improve the grade of service. It improves the reliability all right, but not the grade. An alternative which limits the risk of total isolation of a terminal and does improve the grade of service may have real merit.

Well that was an interesting exercise and gives us a little food for thought perhaps, but we haven't exhausted all the possibilities yet.

Take a look at Figure 3. This shows a possible configuration of wavelength division multiplexing applied on an optical fiber. This technique of frequency division on a single fiber is usually applied for one direction of transmission, but there is nothing inherent in the fiber itself, or in the optical couplers, that prohibits bi-directional operation. We, in our earlier discussion, were considering two discrete transmission links with traffic distributed across both. We could provide some additional protection for our service if we used a single fiber in a bi-directional operation for each of our independent sub-systems.

Here in Figure 4 we show a single fiber providing both directions of transmission for each of our DS2, 6 Mb/s, signals. Again the fiber specification could be such that bi-directional 45 Mb/s transmission could be implemented at a future time.

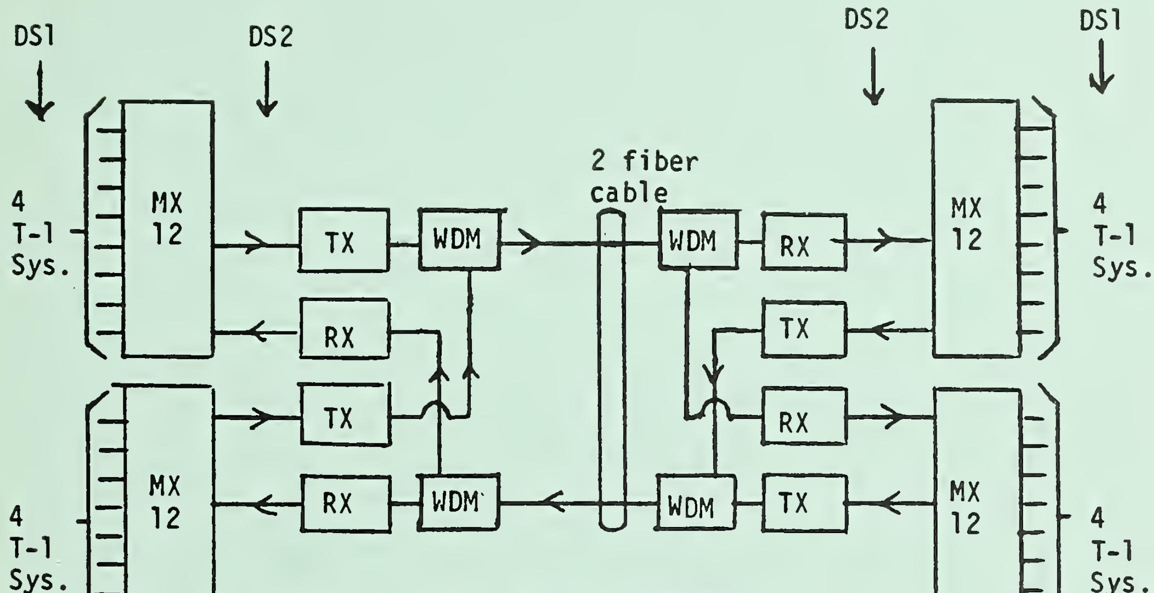

Figure 3 - One Direction Frequency Division

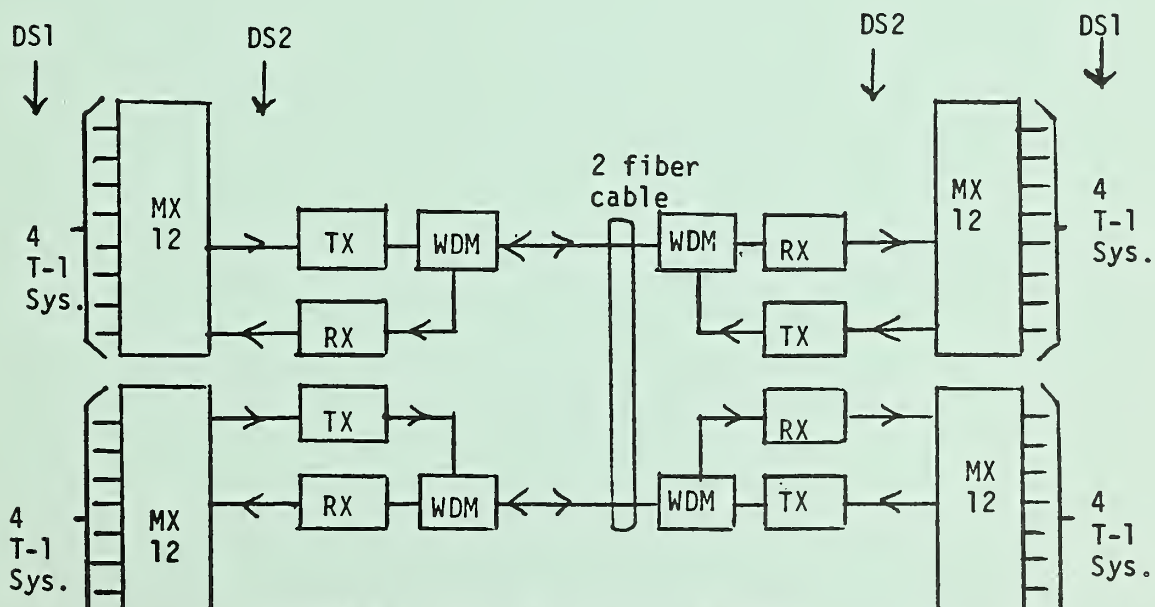

Figure 4 - Bi-Directional Frequency Division

Now, using only two interconnecting fibers as shown in Figure 4, we can preserve the isolation between our two digital signals, and all the options presented by our earlier configuration in Figure 2 are still available to us.

Configurations such as this one may help introduce lightwave technology into, or closer to, the subscriber loop. Perhaps this arrangement, with minimal fiber placement and unsophisticated terminal equipments, could present some cost or technical advantages in many remote switch or concentrator applications, which introduces another interesting line of thought.

Perhaps, if lightwave transmission does transition into lower level plant, and I use the term loosely to differentiate between interoffice trunking, we ought to reexamine our basic philosophy on lower level plant also.

What is the rationale for remote switching and concentrators? Some of the initial impetus undoubtedly came from the prior existence of electromechanical Community Dial Offices with a large number of subscriber loops already terminating in such installations. Some of the thinking was an effort to eliminate long loops and additional multi-pair cable plant also. And a third factor may be the reliability of digital remote equipment itself.

Now if the only practical trunking feed to remote switches is T-1 systems on paired cable plant, then the argument for switching and time shared trunking is pretty sound. Assume the proposed location serves 90 subscriber loops or so. To bring all 90 subscriber lines back into the host digital switch would require 4 T-1 systems. That's a lot of pairs, and if repeaters are required, its' even less attractive.

But as is always the case, there are some unattractive compromises in remote switching.

One is the physical distribution of switching sophistication from one location (the host office) out to several locations. This does involve some higher level of maintenance at widely separated locations.

A second objection is the possible sacrifice of some of the more sophisticated switching features. These may be available in remote switches, but a significant cost penalty can be involved for each such remote unit. You either accept this penalty or forgo the technical advantages.

A third compromise is in the grade of service provided. Trunking for a remote switch may be limiting, and an "all trunks busy" condition, however infrequent, is a lower grade of subscriber service.

And we must consider the cost effectiveness of the digital host switch itself. The more subscriber lines a switch can serve directly, the lower the cost per line becomes. This is a broad statement perhaps, but with some qualification on the basic size of the switch, I believe it's reasonably accurate. Now let me propose two new conditions or alternatives. First, I will assume that the host switch can interface directly with subscriber loops on a T-1 basis, 1.544 Mb/s, inexpensively.

Second, I submit that the cost per channel or circuit for PCM digital carrier derived over optical fibers may be lower than the same PCM carrier costs over multiple paired cable, particularly if the number of circuits derived is high.

Then providing a remote terminal in a digital carrier channel bank configuration, which could interface directly with a subscriber loop, providing talk battery, ringing, and supervision may be a viable alternative.

There's nothing particularly new or revolutionary about this terminal equipment. Its' been used quite effectively on small microwave feed installations on islands, for example.

At the central office, the host digital switch, the interface directly at T-1 rate is straightforward also.

The number of subscriber loops to be served from a particular point will have an impact on whether or not a concentrator or remote switch should prevail over extending subscriber lines out to the service point in a carrier configuration, but a second consideration may well be the subscriber line capacity of the in place digital host switch itself. If the switch were underutilized, that is a large number of subscriber lines were vacant, the carrier configuration using lightwave transmission might make a lot of sense.

In Figure 5 we show a configuration for consolidating subscriber loops in the manner described. Note that although we only show a single fiber using WDM to provide 96 subscriber lines, this could be duplicated on additional fibers of course, or the transmission bit rate could be raised to 45 Mb/s using MX13 multiplexers. Then the single line capacity would be 672 lines.

Where consolidation is more cost effective I cannot say, since we have not done any cost studies along these lines as yet. I submit the argument to pursue such studies is most persuasive though.

There are other ramifications of consolidating rather than switching subscriber loops that are worth mentioning also.

Examine Figure 6A if you will. This presents, in block diagram form, a single fiber equipped to serve 96 subscriber lines just as we looked at in Figure 5. But suppose, when we engineered the interconnecting link, we provided some reserve system gain to accommodate the future insertion of WDM coupling devices.

Now, some time later, after the remote subscriber terminal was installed, we developed a requirement for say 24 circuits (subscriber line circuits) at a point along the initial optical cable route. In Figure 6B we see optical couplers inserted at point A and at the office terminal.

We might now implement a second remote subscriber location at point A and interface with 24, 48, or what ever, subscriber loops at this new location. We could have, in the original transmission engineering, reserved short wavelength frequencies for this additional service point. The losses through the fiber are higher at shorter wavelengths but the distance to the new service point is shorter also.

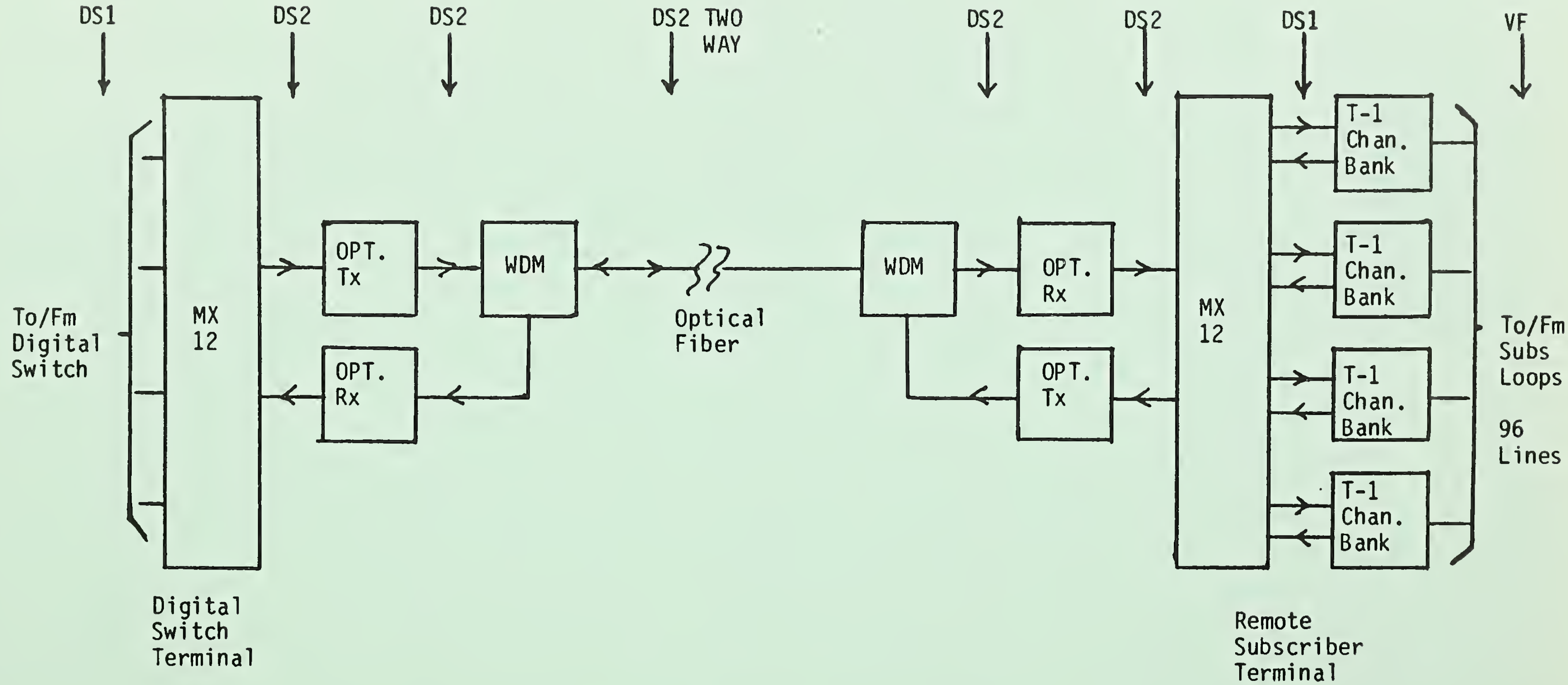

Figure 5 Subscriber Line Consolidation

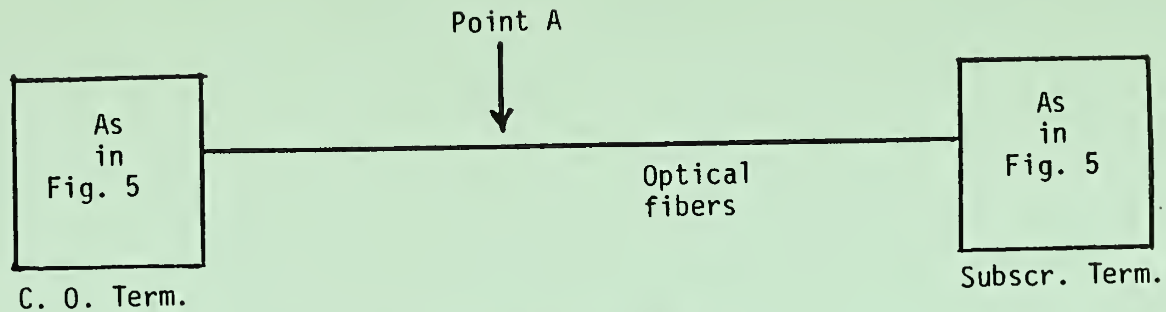

Figure 6A Initial Installation

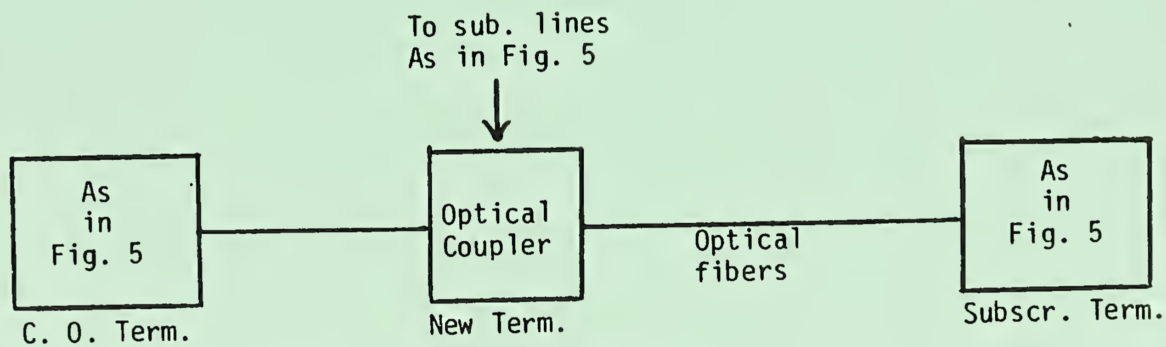

Figure 6B Terminal Added

We don't know of an installation of the type but it certainly seems feasible, and providing this flexibility in many initial fiber installations would be most attractive. Perhaps we'll be able to test this concept in the field.

I haven't put before you any startling innovations in design perhaps, but I hope I have stimulated some thought on how lightwave systems might be effectively used more widely in your telephone network. This is a mature technology which offers substantial bandwidth for use. Defining and developing practical uses is our responsibility, we who work directly with operating systems.

The lab people have presented us with this new capability, but now the field applications become the testing lab.

Whether any or all of these particular configurations I have put before you actually prevails is not the point. It seems obvious that further investigation and development along these lines would have merit.

EMERGING DIGITAL TRANSMISSION TECHNIQUES

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Introduction

A wide array of digital transmission techniques and equipment are being studied, developed and manufactured to provide telecommunications customers with a variety of services. These range from narrowband data (2.4 kb/s) and voice (speech) to wideband data including some form of video for teleconferencing. The penetration of these services will depend on demand, cost and standardization.

The following are examples of digital technology and service now being provided, or in some form of field trial and assessment.

Integrated Services Digital Network (ISDN)
Digital Drop and Insert
Distributed Digital Subscriber Carrier
Speech Bit Rate Reduction

There are few cooperative national and international standards guiding these emerging digital techniques today. Telephone network standards have primarily been established by the American Telephone and Telegraph Company (AT&T) for North America and by the International Telegraph and Telephone Consultative Committee (CCITT) for Central Europe. Cooperative standards for subscriber loops and customer equipment interface have been almost nonexistent. A climate of cooperative agreement may now be emerging. Cooperation is especially important at this time for the continued growth and efficient use of telecommunications services, facilities and equipment.

Integrated Services Digital Network (ISDN)

Today, ISDN is a concept, and not an offered service. Much of the ISDN concept is technologically feasible today, but it is not yet economical. Future costs and benefits will be the key to success. There are experimental ISDN systems in several countries. Standardization is lacking; each organization has a slightly different viewpoint on the optimum standardization of services, interfaces and transmission. Initial standardization efforts have concentrated on the customer interface. Agreement may be reached on a CCITT standard for ISDN customer interface by the summer of 1984. From this base, transmission and terminal standards may evolve.

ISDN will be driven by future needs and perceptions of future needs. The present CCITT direction is toward the standardization of the customer interface with a modular 8 wire plug and jack to deliver two "B" channels at 64 kb/s each, and one "D" channel at 16 kb/s. This requires a transmission rate of 144 kb/s in each direction.

Transmitting 144 kb/s to and from each telephone customer is no small task today. Delivering a large quantity of these signals into the toll network is presently an even greater task. Thus, why are such ambitious standards being considered? The answer is that the CCITT standards are based on perceptions of future needs.

Will telcos and customers be able to participate in ISDN with customer needs and transmission capabilities of less than 144 kb/s? The customer equipment could operate at speeds of less than the telco offered transmission rate. And, the telco may provide less than two B channels and one D channel where 144 kb/s is not feasible. A market may develop for D channel capability (16 kb/s) where B + D or 2B + D channels are not feasible. Even the 16 kb/s D channel may be subdivided by the customer into smaller data units.

At this time ISDN means <u>integrated services</u>, but may not (now or in the near future) mean integrated network. It is intended as a customer interface standard, and should greatly reduce the vast number of "special service" offerings. Even if the 144 kb/s does not prove to be economically feasible, this initial standards work may launch the integrated services and expand the digital communications network. There are plans to offer 56 kb/s dial-up service during 1984. This initial offering would not be ISDN compatible as defined by existing ISDN standards being considered by CCITT (16 and 64 kb/s). The response to this pilot offering should help shape ISDN perceived needs and offerings in the late 1980's.

ISDN Facilities

Proposed subscriber loop facilities for ISDN services include exchange telephone cables, optical fibers and/or coaxial cables. Existing exchange cables present the greatest technical challenge to providing the proposed wideband services to subscribers. However, exchange cables also show the greatest immediate promise of providing these services economically -- <u>because the facilities are in place</u>.

A variety of techniques have been proposed to deliver high speed digital signals to subscribers over exchange telephone cables. The dominant proposal has been to deliver two B channels (64 kb/s each) plus one D channel (16 kb/s), for a total of 144 kb/s in each direction. This is illustrated in Figure 1. Each 64 kb/s B channel can be used for voice or high speed data (up to 64 kb/s). The D channel can be used for signaling, control and low speed data (up to 9.6 kb/s). For rural areas, the offering of a single B channel or D channel may be more practical, or perhaps a combination of one B and one D channel. The following discussion serves to illustrate techniques for transmitting 16 and 64 kb/s channels to and from subscribers.

If two pairs (or 4 wires) are available from the central office to the subscriber, the ISDN system might look like Figure 2. This illustration shows 80 kb/s going to and from the subscriber. A standard digital channel for voice service requires 64 kb/s. The 64 kb/s is transmitted all the way to the subscriber for use as a digital telephone set. The 64 kb/s is generally designated as an alternate voice/data channel. It could be used as a high speed data channel at 56 or 64 kb/s. An additional 16 kb/s is available for signaling, control and low speed data (up to 9.6 kb/s). The interest in a digital telephone is not so much for voice transmission, but for high speed data capability.

As a general rule, only one pair (or 2 wires) will be available to serve each subscriber. This is especially the case very near the subscriber. Several methods have been proposed to transmit a digital bit stream to the subscriber. The most popular concept proposes to use a 4 wire high speed facility such as T1 span lines to a distribution point as illustrated in Figure 3. This 1.544 Mb/s signal serves many subscribers. At the distribution point, the 1.544 Mb/s a signal is separated into lower rates to serve individual subscribers over 2 wire facilities. For this example, one 64 kb/s channel is transmitted to and from the subscriber in bursts.

Figure 4 is a closer look at the two wire link between the subscriber and the remote distribution point. Sixty four kb/s is transmitted in each direction over the two wire line in bursts. Burst mode of transmission is a time separation of signals. Burst transmission is also called time compression modulation (TCM) or "ping-pong". This is in reference to the signal being transmitted in a burst in one direction and then a burst in the other direction, like a ping-pong ball being hit in one direction and then the other direction.

Figure 5 illustrates burst mode transmission. The two wire signal might be transmitted in a 128 bit burst in 0.89 millisecond for one direction, followed by a 0.11 millisecond pause (equivalent to about 16 bits). The signal is then transmitted in the opposite direction with a 128 bit burst for 0.89 millisecond, followed by a pause of 0.11 millisecond (16 bit equivalent). The burst cycle repeats each 2 milliseconds. To transmit 64 kb/s in each direction (burst mode) results in a two wire equivalent line rate of about 144 kb/s, about 2.25 times the one way bit rate. To transmit the proposed 2B + D ISDN channels at 144 kb/s in each direction in the burst mode would require a two wire equivalent line rate of about 320 kb/s, perhaps higher. There are several practical reasons for limiting burst mode transmission to about two miles or so over exchange telephone cables.

In the face of deregulation, some of the intensity behind ISDN has cooled in the USA. Those of you familiar with personal computers for the home and office know that 64 kb/s represents a huge data capability. The most common data rate in use today is probably 0.3 and 1.2 kb/s (300 and 1200 bits per second). This is very slow, but can generate more paper in the personal computer printout than you may want to read. Data rates up to 2.4 kb/s are easily handled on the dial-up telephone network. As computer use increases, there may be a move into more 4.8 kb/s or 9.6 kb/s. But, it will be sometime before 56 kb/s or 64 kb/s is needed for the average home or business.

The economic picture for high speed ISDN is not clear at this time. Claims that 64 kb/s can be provided for modest increases over standard 3 kHz voice charges are not reflected in trends by some telcos toward usage sensitive pricing and message metering. The low bit rates are easy to handle in this emerging digital world. When higher bit rates are needed, exchange cables can be used to handle 64 kb/s and higher -- to the customer. ISDN or similar services will emerge slowly -- first in urban and suburban areas, and later in rural areas (economics verses need). It is relatively certain that digital transmission will increase throughout telephony. It is less certain how digital services will ultimately be delivered to rural subscribers. Time is on the side of rural telcos in dealing with the technical and economic issues of ISDN.

Digital Drop and Insert

It is practical to terminate digital channels in small groups, or even one channel per location. The standard 24 channel D3/T1 type digital system utilizes a bit stream organized in a very simple structure. Drop and insert techniques have been used economically on digital radio systems for several years, generally in trunk applications. At this time, the economics of distributed digital subscriber carrier for general use is marginal when terminated in small channel groups, and almost nonexistent for single channel (64 kb/s) terminations. Distributed digital carrier may be economical in special circumstances such as high speed data for business customers. And these initial special applications may lead to more economical distributed digital carrier for general use. Distributed digital carrier is possibly an essential element to the success of ISDN within the next decade.

Digital drop and insert can be viewed as a special, very flexible digital channel bank. Much emphasis is being placed on drop and insert at this time. The initial emphasis is for special service applications where small quantities of channels (perhaps one) are required at a location. The use of drop and insert terminals allows for more efficient use of digital span lines, and avoids the necessity for nailed up circuits in a digital switch.

Appendix A lists some manufacturers that have stated their intent to provide digital drop and insert systems in some form. Channel offerings include the following.

VOICE: 2 wire E&M, 4 wire E&M, DPO, DPT, 4 wire no signaling, 4 wire SF signaling, FXO, FXS (auto ringdown), DX, and order wire.

DATA: Synchronous data at 2.4 kb/s, 4.8 kb/s, 9.6 kb/s, 48 kb/s, 56 kb/s, and multiples of 64 kb/s up to maximum of 1.544 Mb/s. Asynchronous data up to a maximum of 19.2 kb/s in a 64 kb/s time slot.

PROGRAM: 5 kHZ, 8 kHZ, and 15 kHz program; a 15 kHz program channel requires six 64 kb/s time slots.

Figure 6 illustrates the digital drop and insert concept. Systems are packaged in several arrangements for more economical applications. Typical packages and applications include two way drop and insert, one way drop and insert, and one way drop only (including bridged drop of the same channel at multiple locations).

A larger application of drop and insert at a central office location is called a Digital Access and Cross-Connect System (DACS). The digital bit stream can be patched in 64 kb/s increments between transmission systems, terminal equipment and digital switches. DACS provides for efficient use of digital transmission and switching systems by maintaining maximum digital group capacities.

Drop and insert is an extension of the flexible digital channel banks introduced in recent years. It is an efficient method of providing special services where digital switches and span lines are already in place. Such systems are very flexible, quickly altered to meet service needs, and require no elaborate equalization and testing. This flexibility is expected to increase the market for drop and insert systems.

Distributed Digital Subscriber Carrier

The ultimate use of the digital drop and insert technique is for distributed subscriber carrier. Several manufacturers are developing equipment for this service. The success of ISDN may depend on distributed digital subscriber carrier.

The Bell operating telcos are positioning for digital services to subscribers by using systems such as the Western Electric SLC-96. The SLC-96 is a 96 line digital subscriber carrier or concentrator system applied to 3 or 5 span lines. Bell telcos are planning these digital system terminations within two miles of subscribers. The key word is planning. Hardware is not placed until needed.

Placing digital terminations within two miles of rural subscribers cannot be readily accomplished in 96 line groups, or even in 24 line groups. Distributed digital subscriber carrier will be necessary to provide digital services to rural subscribers. Traditional channel banks do not provide the economics and flexibility to meet these needs in rural areas. Innovations will be necessary. Some manufacturers feel that the time has come to begin the development and marketing of distributed digital systems.

Economic factors that discourage individual subscriber channel terminations are common equipment, housings, local ac power, and perhaps synchronization. With technology advances and mass production, common equipment costs can be reduced. Smaller housings can be used with large scale integration (LSI) technology, provided the need for local ac power is eliminated or drastically reduced. In fact, elimination of local ac power is one of the keys to the economical application of distributed digital systems. One way to minimize the need for ac power along a subscriber cable route is to use "express power". This technique was used to avoid ac power and batteries for long applications of analog station carrier. It can be an even more effective tool in powering distributed digital systems. A separate cable pair can be reserved solely to power digital subscriber channels. This allows the digital span line to be powered in the normal manner which is economical, and provides for standardization and versatility. Synchronization was included as an economic factor. Synchronization is not an economic factor where the distributed digital system analog to digital conversion takes place at the span line access point. If the digital signal (i.e., 64 kb/s) is accessed and transmitted to and from the subscriber, the separate digital signals must be merged and synchronized. This is presently accomplished through the use of buffers or elastic stores. Presently, elastic stores would add significant costs to digital carrier for individual channel (64 kb/s) terminations. This also can change with time.

The technology for distributed digital subscriber has been available for some years. The economics for distributed applications has not been favorable in the past. There is reason to believe that the economics of innovative distributed digital systems will continue to improve. Innovation will be required.

Speech Bit Rate Reduction

In traditional telephony applications, speech bit rate reduction techniques have been used to achieve only modest reductions in transmission bit rates (2 to 1, or less). About 10 years ago, extensive studies were made for military application to achieve large scale bit rate reduction (10 to 1). Eventually, the benefits of this type of work are realized in commercial applications. Large scale bit rate reduction requires computer processing, which in turn requires large scale integration (LSI) electronics technology and mass production to be economically feasible. The following discussion is a simplified overview of standard 64 kb/s pulse code modulation (PCM) and some of the digital bit rate compression techniques now being used or explored. Refer to Dave Matolak's paper on "Speech Bit Rate Compression: Some Techniques and Principles" for a closer review of this subject. Dave's paper is an excellent single source condensed reference with an analytical comparison of a variety of speech bit rate reduction techniques.

Speech bit rate reduction techniques have been available for 10 years in both trunk and subscriber loop telephony applications. Examples of subscriber loop equipment are the WE SLC-40 and ITT DM32S subscriber carrier. These systems use a differential pulse code modulation (DPCM) or delta modulation technique to transmit satisfactory speech quality at rates less than the 64 kb/s per channel required for "standard" pulse code modulation (PCM). These systems provided satisfactory service. However, the economics of integrating switching and transmission led to standardizing on a digital format of 8-bit PCM encoding for wire line and terrestial radio applications in North America.

In satellite radio service, techniques are being used to transmit high quality speech at 32 kb/s or less. This is a two-to-one bit rate compression compared to the 64 kb/s required for 8-bit PCM. Speech is emphasized. Compression is accomplished by taking advantage of speech redundancy and pauses (idle time). Techniques are being explored to compress speech into 9.6 kb/s and possibly 4.8 kb/s. At this time, "there is no free lunch". There is a price to pay for bit rate compression. The more the bit rate is compressed, the higher the cost. Also, speech begins to sound artificial at some point of compression.

Compression techniques are generally effective on a shared bit stream (trunk and subscriber) by taking advantage of statistical characteristics of speech (including brief idle periods). These techniques become less efficient for dedicated circuits where the bit stream is not shared on a group basis. Dedicated circuits are also more likely to be used for the transmission of data and other non-speech (unpredictable) information.

For wire line circuits, alternative techniques are now used in increase channel quantities on exchange cable pairs using standard 8-bit PCM. For trunk (or feeder) applications, 48 channel ternary encoded or duobinary encoded systems can generally be applied to cables with 24 channel T1 applications. These systems have proven effective for a two-to-one expansion of saturated T1 routes. The transmitted signal is altered, but the interface is standard DS1 or DS1C. These ternary and duobinary systems provide the effect of bit rate reduction, but can be used to transmit voice, data, and other signals where the retrival of each bit is important.

The latest draft revision of the AT&T notes on the network (BOC Intra-LATA Network) mentions low bit rate voice (LBRV) digital encoders for the first time. It acknowledges that speech can be encoded at rates much less than 64 kb/s and recognizes the economic benefits. It also states that LBRV could result in a speed up in the evolution toward ISDN. This appears to acknowledge that ISDN may be realized at bit rates less than 64 kb/s. The Notes caution that the effects of LBRV encoders should be evaluated prior to network introduction. The LBRV encoders could affect network transmission (voice quality, transmission delay, etc.).

Several digital coding and decoding techniques will now be outlined. For reference, standard 64 kb/s PCM is illustrated first. This is followed by techniques for voice transmission at less than 64 kb/s.

Digital Techniques

Analog to digital (A/D) converters are used to convert the continuously changing analog voice signals into digital signals (Figure 7). Digital signals are represented by 1's and 0's, pulses and spaces, or simply on and off signals. At the distant end, the digital signal is converted back into an analog signal using a digital to analog converter. The analog signal is restored.

A/D conversion begins by sampling the analog signal at a predetermined rate (Figure 8). The most standard rate is 8000 samples per second. The samples are converted into a pulse amplitude modulation (PAM) signal.

The next step is to code the PAM signal (Figure 9). The most common is an 8-bit pulse code modulation (PCM), based on D3 carrier channel banks. Each 8-bit code represents a specific code level. A +29 code and -107 code are illustrated for channels 1 and 2.

Figure 10 illustrates the serial bit stream (one and zeros) or pulse stream (pulses and spaces). View the pulse stream from right to left, as if the pulse stream is moving to the right across a fixed reference location. The pulse stream illustrated is the standard D3 PCM coding which is the North American Standard. It is a robust code. Each 8-bit group can easily be retrieved and converted into a PAM signal, or decoded into a voice signal.

Standard 8-bit PCM codes and decodes each sample individually, without regard to other samples. Other digital coding techniques generally require "history" information for coding. That is, knowledge of other samples (at least one previous sample) is requried for sample coding. Digital techniques such as differential PCM transmit codes to represent the difference between the present and previous sample.

Delta modulation (DM) is an elementary form of differential PCM (DPCM). DM is a 1-bit DPCM coding technique (Figure 11). DM is generally sampled at 32,000 times per second, or higher. It is transmitted as one equals plus and zero equals minus (1 = + and 0 = -). The ones and zeros represent a fixed plus or minus slope. The DM signal is always trying to "catch up" with the analog signal. If it gets ahead, it will drop back on the next bit. Sometimes it cannot keep up with the analog signal changes. This is called "slope overload".

Other DPCM systems sample at 8000 times per second and transmit several bits to represent the change between successive samples (Figure 12). 4-bit DPCM is a common technique. The 4-bit code provides for 16 steps to represent the change or difference between two samples. As in DM, big changes are difficult to transmit.

DM and DPCM are usually combined with an adaptive technique for coding and transmission (Figure 13). Coding step size is variable or "adaptive", depending on need. (Note: The term "adaptive" is used in a broad general sense in this discussion.) Adaptive coding minimizes slope overload and takes advantage of predictable speech characteristics. Examples of adapative PCM coding are adaptive delta (ADM), adaptive differential PCM (ADPCM), continuously variable slope delta modulation (CVSD), Nearly Instantaneous Companding (NIC) and others. Adaptive coding requires viewing of two or more samples, feedback, prediction and/or batch processing.

Bit rate reduction techniques can be combined or "layered" to further reduce transmission rates. Care must be exercised to avoid multiple compression of the same speech redundacy characteristics. Digital speech interpolation (DSI) is patterned after analog time assignment speech interpolation (TASI), and takes advantage of the "idle time" or pauses in a conversation. Speech idle time results from conversation in only one direction (50 percent activity) and pauses between syllables, words and sentences. DSI can readily be combined with techniques such as ADM and ADPCM for speech transmission.

Bit rate reduction systems are used on satellite systems, congested wire and radio routes, and by interconnect companies. Forty eight or more channels can be put on a 1.544 Mb/s T1 system. This is a 2 to 1 improvement. Speech transmission is emphasized. Data cannot be transmitted over these systems except for low speed voice rate data.

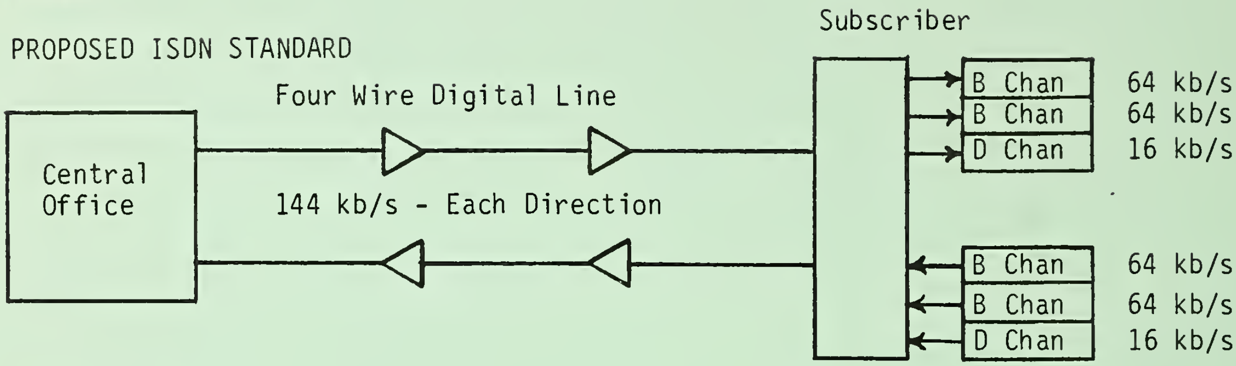
There are disadvantages to these nonstandard low bit rate systems. Interface to standard digital transmission and switching requires decoding and re-encoding. An analog voice interface or the equivalent of an analog interface is required from the standpoint of transmission degradation. The systems may introduce a transmission delay. As much as 4 to 5 milliseconds delay may occur in batch coded systems. These systems introduce more analog to digital conversions, adding degradation to the overall telephone network. The economics of standard 1.544 Mb/s interfaces to digital switches is lost. And, 64 kb/s ISDN services cannot be provided over the low bit rate systems.

There are advantages to these systems. Because they are bandwidth efficient, they may be effective in some applications. They are not yet cost effective in typical rural applications, but may become cost effective in the future. In spite of some disadvantages (especially standardization and transmission) these low bit rate systems will be used by telcos as well as interconnect companies.

Caution is recommended in planning and using these systems to minimize obsolescence and degradation. Standardization of coding techniques minimizes obsolescence. CCITT may issue a standard soon for a 32 kb/s per channel ADPCM system with high speech quality. The issue of degradation must be resolved on a national and international basis. Tandem encoding of standard 64 kb/s per channel PCM results in only minor degradation for each encoding. The effects of tandem encoding of some low bit rate systems can result in severe transmission degradation. Thus, tandem encoding of these systems must be eliminated or closely controlled.

FIGURE 1

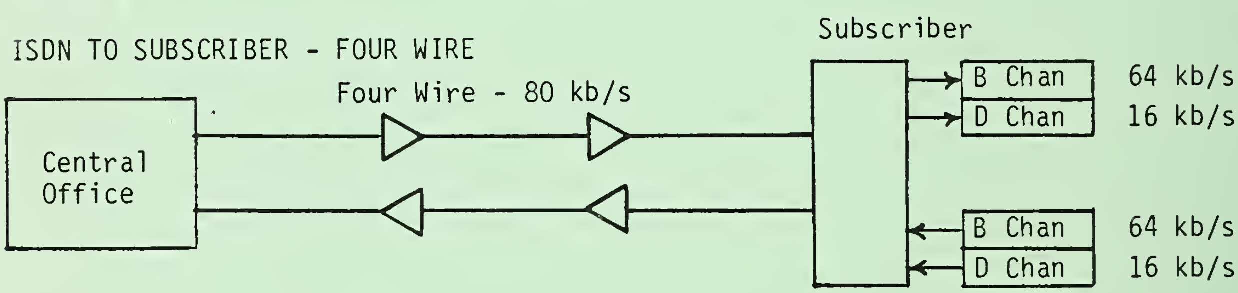
PROPOSED ISDN STANDARD



Notes: 1. Each 64 kb/s B channel can be used for voice or high speed data.
2. Each 16 kb/s D channel can be used for signaling, control and low speed data.

FIGURE 2

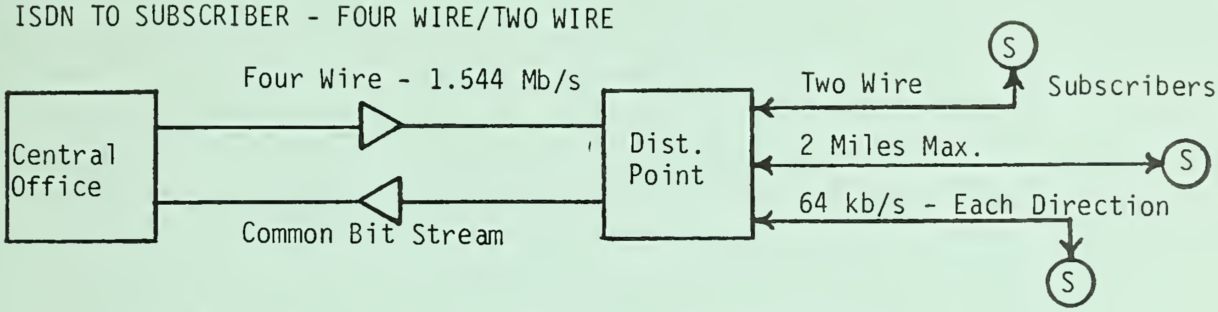
ISDN TO SUBSCRIBER - FOUR WIRE



Notes: 1. The 64 kb/s B channel can be used for alternate voice or high speed data.
2. The 16 kb/s D channel can be used for signaling, control, and low speed data.

FIGURE 3

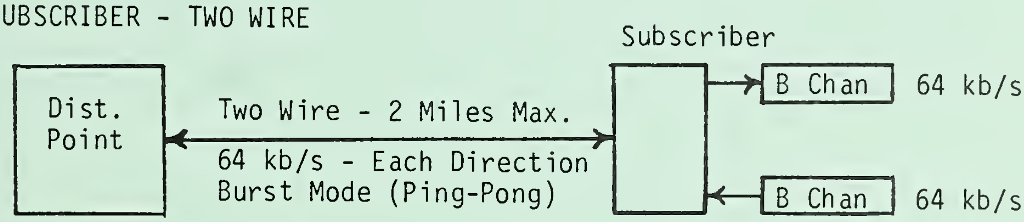
ISDN TO SUBSCRIBER - FOUR WIRE/TWO WIRE



Notes: 1. T1 span lines shared to a distribution point.
2. Individual bit streams to subscribers, up to two miles from distribution point. Transmitted at 64 kb/s in each direction in burst mode.

FIGURE 4

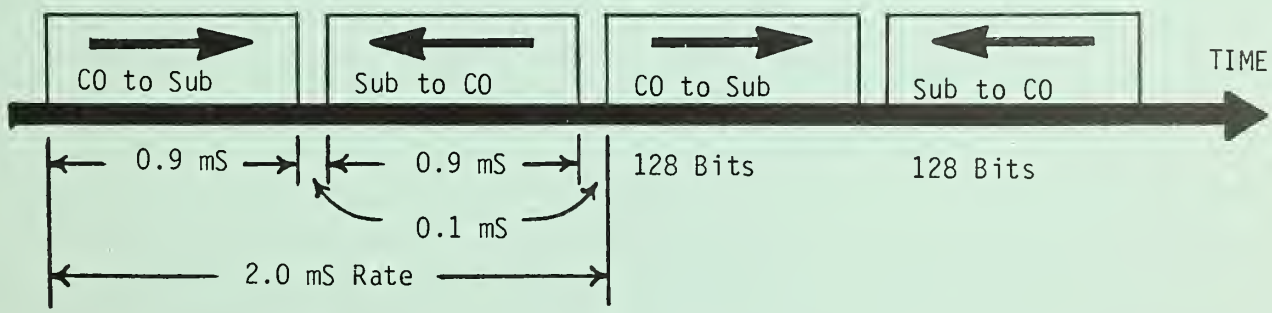
ISDN TO SUBSCRIBER - TWO WIRE



Notes: 64 kb/s is transmitted in each direction over a two wire line in burst mode. This is an equivalent line rate of about 144 kb/s; 64 kb/s to subscriber plus 64 kb/s to CO plus 16 kb/s (equivalent) pause.

FIGURE 5

BURST MODE TRANSMISSION - EXAMPLE

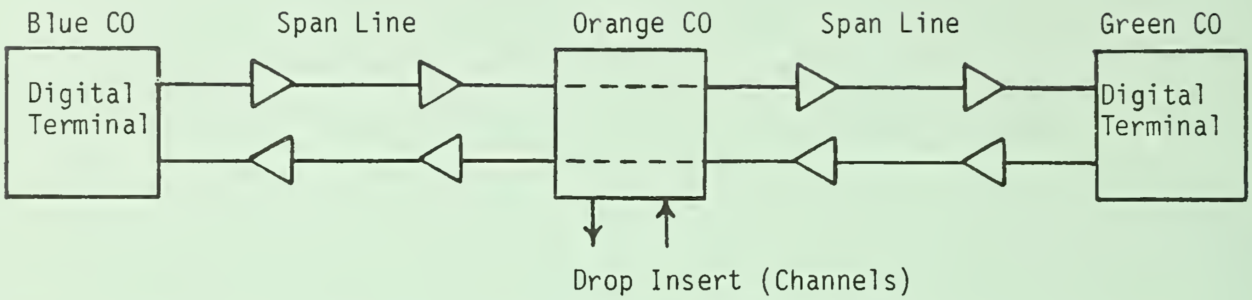


Notes: Burst mode transmission is a time separation of signals. Burst transmission is also called time compression modulation (TCM) or "ping-pong".

FIGURE 6

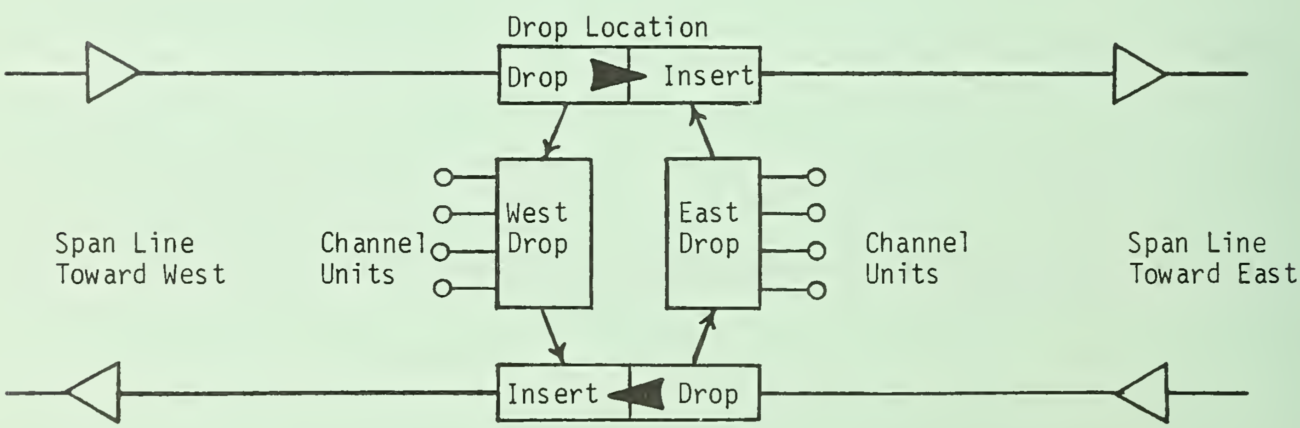
DIGITAL DROP AND INSERT

A. Intermediate Drop and Insert



Note: Some of the channels of a D3/T1 system can be terminated or dropped at an intermediate location. For example, 6 of 24 channels between Blue and Green central offices could be terminated at an intermediate location. This would provide for 18 channels between Blue and Green, 6 between Blue and Orange and 6 between Orange and Green. The DS1 bit stream between Blue and Green passes through Orange without decoding to voice.

B. Two Way Drop and Insert

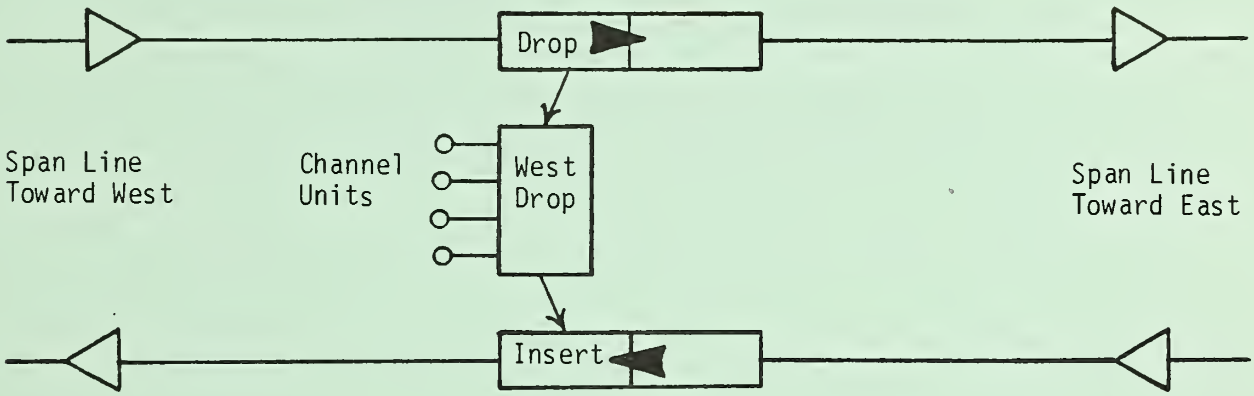


Note: A full two way drop and insert is illustrated. Channels can be terminated in one or both directions. Terminated channels can provide voice, data, or program circuits.

FIGURE 6

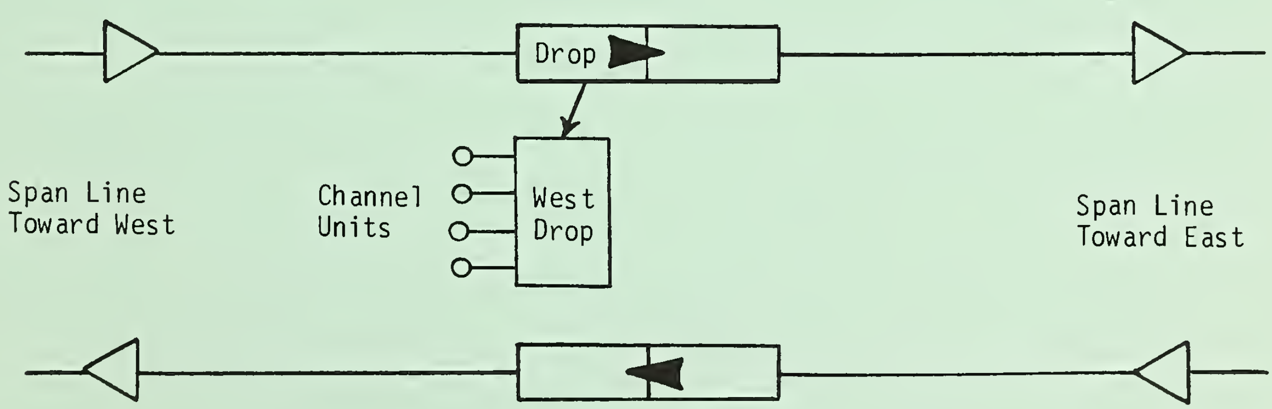
DIGITAL DROP AND INSERT - CONTINUED

C. One Way Drop and Insert



Note: Drop and Insert channels are terminated in only one direction. Distributed digital subscriber carrier would be applied in this manner.

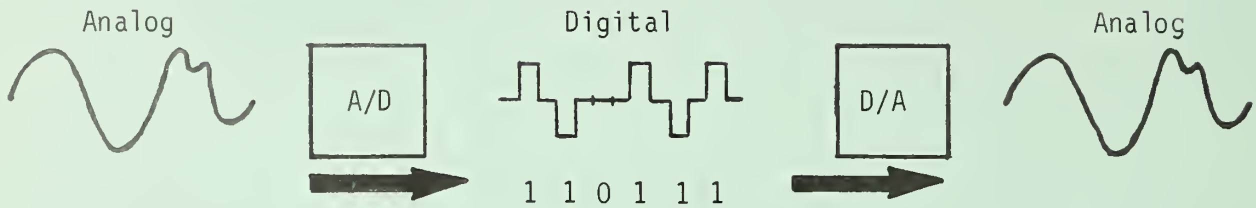
D. One Way Drop Only



Note: Channels are terminated on a drop only basis in one direction. The same channel can be terminated at multiple locations for drop only applications (bridged drop).

FIGURE 7

ANALOG TO DIGITAL CONVERSION

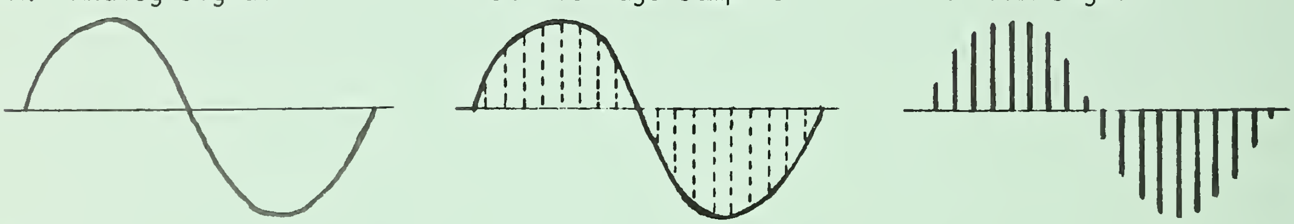


Note: Analog to digital (A/D) converters are used to convert the continuously changing analog voice signals into digital signals. Digital signals are represented by 1's and 0's.

FIGURE 8

SAMPLING

A. Analog Signal B. Voltage Samples C. PAM Signal



Note: The analog signal is sampled at a predetermined rate, generally 8000 times per second. A discrete voltage is determined for each sample. This results in a pulse amplitude modulation (PAM) signal at the sampling rate.

FIGURE 9

DIGITAL CODING

A. 8 Bit Coding - D3

Channel	Bit	1	2	3	4	5	6	7	8
1	Code	1	0	0	1	1	1	0	1
2		0	1	1	0	1	0	1	1
3		ETC.							

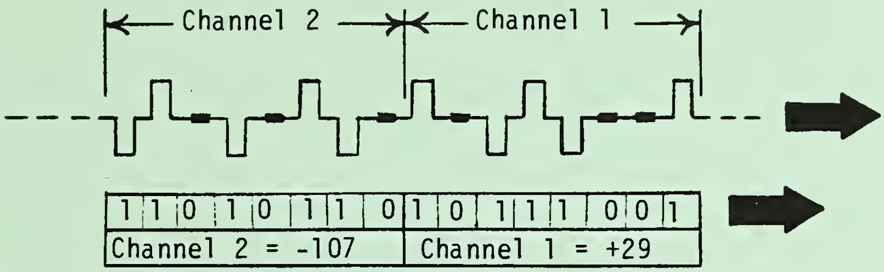
B. Weight of Coding Bits

Bit	1	2	3	4	5	6	7	8
Weight	±	64	32	16	8	4	2	1

C. 8 Bit Code Values

Bit	Ch 1	Ch 2
1	+	-
2	0	64
3	0	32
4	16	0
5	8	8
6	4	0
7	0	2
8	1	1
Value	+29	-107

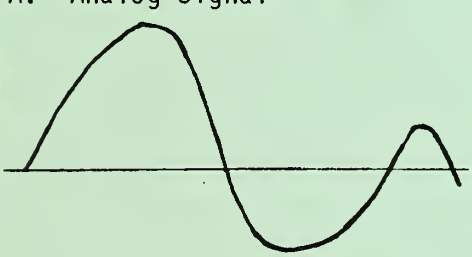
FIGURE 10
STANDARD D3 PCM CODING



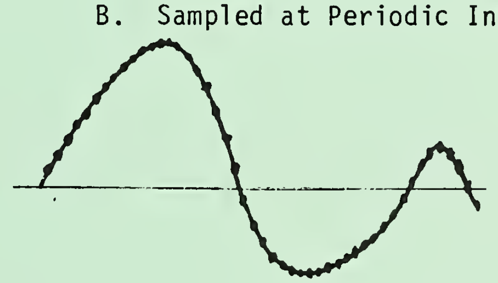
Note: The North American standard D3 PCM coding is transmitted as a 1.544 Mb/s serial bit stream in 8-bit groups. Each 8-bit coding group represents a specific PAM level.

FIGURE 11
DELTA MODULATION

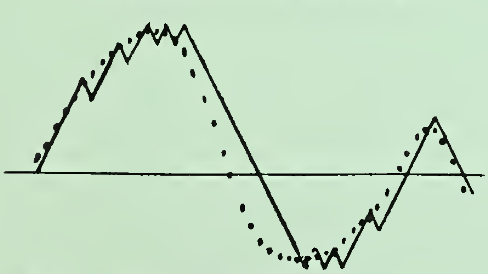
A. Analog Signal



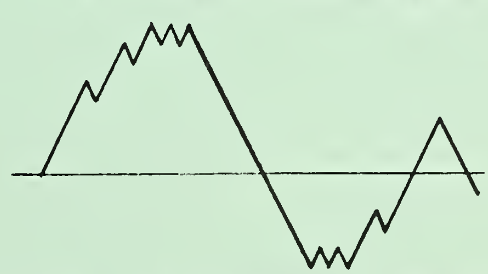
B. Sampled at Periodic Intervals



C. Converted into Delta Mod.

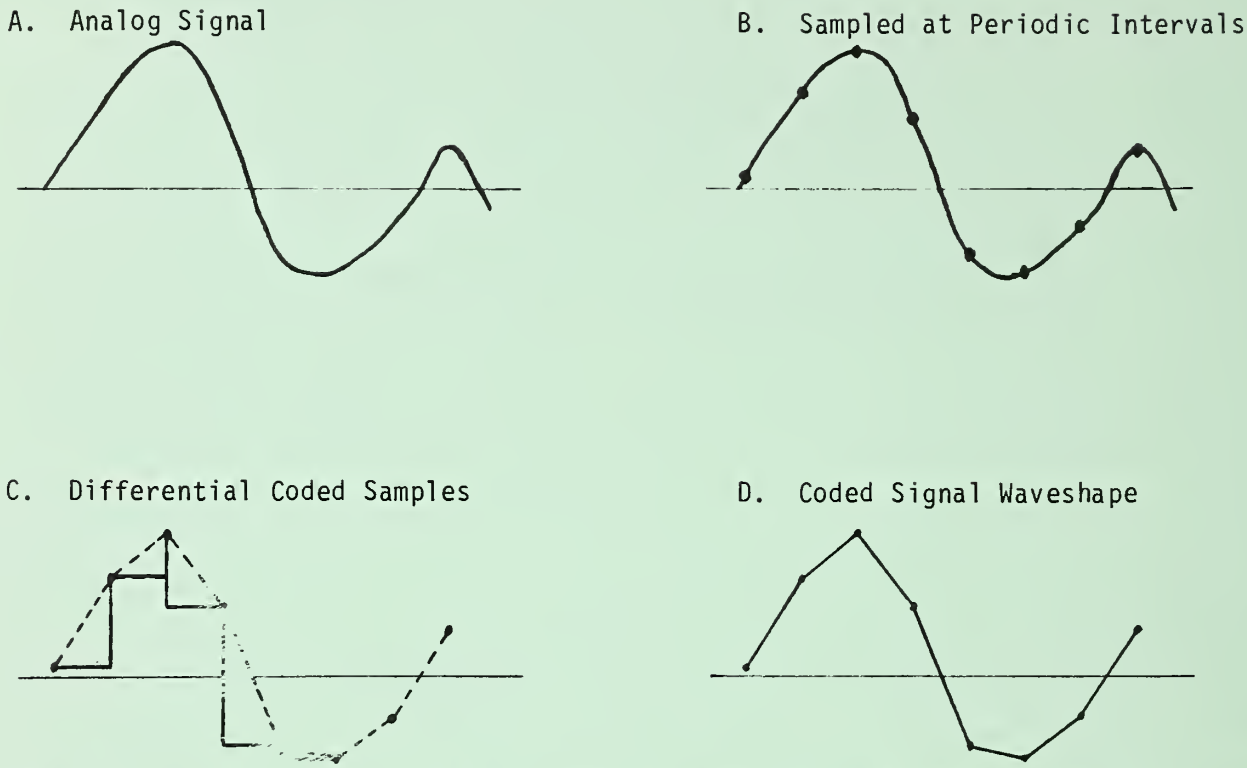


D. Coded Signal Waveshape



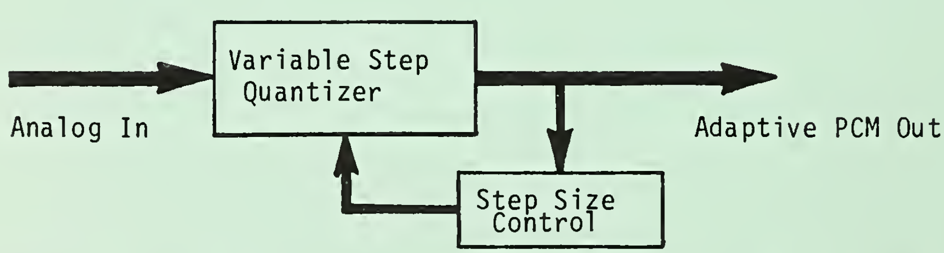
Note: Delta modulation is 1 bit differential PCM. It is generally sampled at 32,000 times per second and transmitted as 1 = + and 0 = -. The samples are coded at a fixed slope, and is always attempting to "catch-up" with the analog signal. This signal would be transmitted as 1111101110110101010000000---etc.

FIGURE 12
DIFFERENTIAL PCM



Note: Differential PCM (DPCM) is generally sampled 8000 times per second and the difference between successive samples is transmitted as a 4-bit code.

FIGURE 13
ADAPTIVE PCM CODING



Notes: Adaptive coding requires viewing of two or more samples, feedback, prediction and/or batch processing. It responds to predictable speech characteristics and minimizes slope overload. Adaptive coding is generally combined with another digital technique such as differential PCM or delta modulation.

Appendix A

DIGITAL AND INSERT

The following is a list of manufacturers that provide, or have stated their intent to provide, digital drop and insert systems in some form.

Grouped (Trunk)	Distributed (Subscriber)	Manufacturer	Telephone No.
D/I MUX	-	Coastcom	(415) 825-7500
TDM-150	-	Tau-Tron	(617) 256-9013
DDI-1A	-	Harris-Farinon	(415) 592-4120
T-DROP	-	Plantronics-Kentrox	(503) 643-1681
DDI-24	-	TeleBit	(312) 932-9180
OMNIPLEXER	-	Bayly Engineering (Canada)	(416) 683-8200
-	DCM-24	R-TEC	(817) 267-3141
-	B325L	Lynch	(702) 786-4020
-	S-24D	Seiscor	(918) 252-1578
-	6000	Thor Telecom	(408) 257-1168

T1 SPAN LINE APPLICATION INFORMATION

FOR
DIGITAL LINE CONCENTRATORS
AND
DIGITAL REMOTE SWITCHING TERMINALS

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The information contained in the attached charts should be helpful in estimating span line requirements for digital subscriber line concentrators and digital remote switching terminals. The charts are based on manufacturers' information available at this time. Evolutionary changes in digital switching hardware and software may require periodic update of this information for accuracy.

The simplified application charts are not a final solution to span line engineering for concentrators and remote switches. The charts can serve as a preliminary quick reference for a variety of equipment. They also assist in a better understanding of concentrator and remote switch architecture. There is some variety in the features and options available for concentrators, and a wide variety for remote switches. The final decision on span line needs must be based on traffic requirements, architecture, subscriber calling patterns, local emergency service, other special service needs and other system features.

The span line application charts show a minimum of two span lines, and isolation between subscribers and the central office will not result from a single span line failure. Local telco requirements and experience should determine the extent that this or other alternate path reliability is implemented.

Three quick reference charts are attached with explanatory notes for each. The first is for concentrators with analog and digital interfaces to the COE. The second is for remote switches. The third is a traffic chart to supplement the remote switch chart.

DIGITAL LINE CONCENTRATORS
T1 SPAN LINE APPLICATION INFORMATION

Equipment Designation	Subscriber Lines	Span Lines	Trunks		CCS/Line		Notes
			Norm	Fail	Norm	Fail	
COE - Analog Interface							
Ericsson Timespan 128	128	2	46	23	9.1	3.8	ALS
	128	2	23	23	3.8	3.8	1:1 APS
GTE 914A	96	2	47	23	12.5	5.0	ALS
ITT 1218	96	2	47	23	12.5	5.0	ALS
	576	6	143	119	7.6	6.2	ALS
NTI DMS-1	128	2	48	24	9.6	4.0	ALS
	256	3	48	48	4.8	4.8	2:1 APS
WE SLC-96	96	3	48	48	12.8	12.8	2:1 APS (A)
COE - Digital Interface							
GTE 914A (GTD-5 EAX)	96	2	47	23	12.5	5.0	ALS
	96	2	23	23	5.0	5.0	1:1 APS
ITT 1218 (1210)	96	2	48	24	12.8	5.3	ALS
	512	6	144	120	8.6	7.0	ALS
NTI DMS-1 RCT (DMS-10)	128	2	48	24	9.6	4.0	ALS
	252	3	48	48	4.9	4.9	2:1 APS
WE SLC-96 (No. 5 ESS)	96	3	48	48	12.8	12.8	2:1 APS (A)

Notes: Full subscriber line to trunk access for alternate path reliability except where noted.
ALS = Automatic Load Sharing.
APS = Automatic Protection Switching.
Norm = All T1 span lines operational.
Fail = One T1 span line failed.

Exception: A = Two co-located 48 line units.

NOTES ON T1 SPAN LINE APPLICATION FOR DIGITAL CONCENTRATORS

General Notes: The following general notes apply to all concentrators unless specifically noted otherwise.

1. The guidelines show a minimum of two T1 span lines, and isolation between subscribers and the central office will not result from a single span line failure. All subscriber lines have access to all trunks (full line to trunk access).

2. Two approaches are illustrated. The first uses all span lines for traffic during normal conditions, and provides for automatic load sharing (ALS) with reduced traffic capacity during a span line failure. The second is to provide a built-in automatic protection switch (APS) on a 1:1 or 1:N basis; the spare span line carries traffic only during failure of the main span line.

3. Traffic is based on B=0.005. Traffic capacity is illustrated with the maximum number of span lines under normal conditions (all span lines operational), and also with one span line in the failed condition.

4. The guidelines are based on span lines that are common to only one subscriber terminal location. Where distributed subscriber terminals are available, the cited characteristics may not apply to multiple locations.

5. The number of subscriber lines illustrated are based on the smallest and largest units that share span lines. Other line to trunk ratios may be available. The ratio shown is generally recommended.

6. Multiple subscriber terminal groups may be co-located to serve larger subscriber quantities. However, co-located subscriber terminals that do not share the same span lines are treated as separate subscriber terminals.

7. A T1 span line may provide 23 or 24 voice frequency trunks, depending on the terminal equipment design.

8. External or separate automatic protection switching (APS) is not considered in the information shown. External APS can be used to maintain a normal traffic level during failure of a span line if space is available in the subscriber terminal housing. This application consideration may be advantageous for co-located subscriber terminals.

9. Where alternate routes are available, service reliability and availability can be improved by dividing span lines into these separate diverse routes.

Exeptions: The following notes apply only when specifically referenced.

A. The 96 lines illustrated for the WE SLC-96 are actually two co-located 48 line units.

DIGITAL REMOTE SWITCHING TERMINALS
T1 SPAN LINE APPLICATION INFORMATION

Equipment Designation (COE & RST)	Subscriber Lines	Min. to Max. Range		CCS/Line (Max Lines & Trunks)		Notes
		Span Lines	Trunks	Normal	Failure	
GTE-AE GTD-5 EAX						
RSU	6144	2-32	46-766	4.0	3.9	
RLU	1536	2-8	46-190	3.9	3.5	(A)
ITT 1210						
1210 RLS-I	320	2	48	3.9	1.6	
1210 RLS-II/Type 1	352	2	48	3.5	1.5	
1210 RLS-II/Type 2	224	2	48	5.5	2.3	
NEC NEAX61K						
KR	768	2-5	48-120	3.6	2.9	
KRS	256	2	48	4.3	1.9	
NTI DMS-10						
REM	212	2	48	5.8	2.4	
NTI DMS-100						
RLM	1216	2-8	46-190	4.9	4.4	
Stromberg Carlson DCO						
RLS (Bldg)	1080	2-8	46-190	5.5	4.7	
RLS (Pad)	360	2-8	46-190	15.9	13.8	
RLG	90	2-3	23-47	13.8	13.8	APS Required (B)
WE 5A						
RSM	4096	4-20	88-456	3.8	3.6	(C)

<u>Notes:</u> Full subscriber line to trunk access for alternate path reliability except where noted.
Normal = All T1 span line operational. Failure = One T1 span line failed.
APS = Automatic Protection Switching. Detailed notes follow.

NOTES ON T1 SPAN LINE APPLICATION FOR DIGITAL REMOTE SWITCHING TERMINALS

General Notes: The following general notes apply to all remote switching terminals unless specifically noted otherwise.

1. The guidelines show a minimum of two T1 span lines, and isolation between subscribers and the central office will not result from a single span line failure. All subscriber lines have access to all trunks (full line to trunk access) which provides for automatic load sharing (ALS) with reduced traffic capacity during a span line failure.

2. The number of subscriber lines illustrated are based on the largest number that share span lines. The number of span lines and trunks illustrated are the range that can be applied with full line to trunk access.

3. Traffic is based on B=0.005. Traffic capacity is illustrated with the maximum number of span lines under normal conditions (all span lines operational), and also with one span line in the failed condition.

4. The guidelines are based on span lines that are common to only one subscriber terminal location. Where distributed subscriber terminals are available, the cited characteristics may not apply to multiple locations.

5. Multiple subscriber terminal groups may be co-located to serve larger subscriber quantities. However, co-located subscriber terminals that do not share the same span lines are treated as separate subscriber terminals.

6. A T1 span line may provide 23 or 24 voice frequency trunks, depending on the terminal equipment design.

7. External or separate automatic protection switching (APS) is not considered in the information shown. External APS can be used to maintain a normal traffic level during failure of a span line if space is available in the subscriber terminal housing. This application consideration may be advantageous for co-located subscriber terminals.

8. Where alternate routes are available, service reliability and availability can be improved by dividing span lines into these separate diverse routes.

Exceptions: The following notes apply only when specifically referenced.

A. The GTD-5 or RSU can serve as host for the RLU.
B. The DCO or RLS can serve as host for the RLG. The RLG requires an external automatic protection switch for alternate data path reliability.
C. WE 5A to RSM: Each of the first four T1 span lines provides 22 voice frequency trunks and each additional T1 span line provides 23 voice frequency trunks.

T1 SPAN LINE APPLICATION INFORMATION - TRAFFIC

The chart entitled "Digital Remote Switching Terminals - T1 Span Line Application Information" illustrated traffic for systems equipped with the maximum number of subscriber lines and span lines only. Actual span line requirements are determined from equipped subscriber lines and telco traffic requirements. It is not practical to illustrate all possible combinations in simplified charts. The following is a quick reference chart based on a traffic capacity of 2.5 ccs/line during normal operation.

Traffic is primarily a function of trunk and line quantities. By design, the RST may contain additional stages of concentration or blocking. This chart is based on an RST architecture of (a) 23 voice channels for each of the first two T1 span lines; (b) 24 voice channels for each additional span line; and (c) no additional concentration stages. The chart is adequate for estimating line, trunk and traffic considerations. Minor adjustments are necessary to accurately illustrate other similar architectures.

Subscriber Lines	Span Lines	Trunks		CCS/Line	
		Normal	Failure	Normal	Failure
468	2	46	23	2.5	1.0
772	3	70	46	2.5	1.5
1086	4	94	70	2.5	1.8
1727	6	142	118	2.5	2.0
2378	8	190	166	2.5	2.2
3834	12	286	262	2.5	2.3
5190	16	382	358	2.5	2.3
6491	20	478	454	2.5	2.4
7795	24	574	550	2.5	2.4
9099	28	670	646	2.5	2.4
10402	32	766	742	2.5	2.4

SPEECH BIT RATE COMPRESSION: SOME TECHNIQUES AND PRINCIPLES

David W. Matolak
Transmission Branch
Telecommunications Engineering and Standards Division

Contents:

1. General Principles of Digital Bit Rate Compression

The use of digital transmission techniques in voice, data, and video processing is spreading rapidly across the telecommunications industry. Most of these techniques are based on the pulse code modulation (PCM) technique. PCM has been in use since the 1960's and is still in use due to the high reproduction quality that can be achieved with it.

Using PCM leads to a 64 kbit/s information rate per telephone channel. In many cases, this is a great reduction in efficiency from analog modulation techniques that require much less bandwidth per telephone channel.

In recent years, there has been significant research and testing of systems employing bit rate compression -- the use of bit rates lower than 64 kbit/s -- to accommodate a telephone channel. Most of the work on digital bit rate compression has been in the area of voice communications but many of the techniques are equally applicable to data communications as well. Most of the results of work regarding bit-rate-reduced systems compare their performance to 64 kbit/s -- a relative standard.

The need for bit rate reduction is questionable in many cases. In systems where transmission costs are high, however, reduction techniques can be an attractive alternative to the installation of entire new facilities. There can be a need for bit rate compression techniques on long-haul microwave radio links, satellite links, and T-carrier lines where it may be impractical to install new lines.

Most bit rate reduction schemes take advantage of some of the properties of human speech and hearing. At a sampling frequency of 8 kHz, most samples of speech do not vary greatly from sample to sample. This redundancy allows coders to reduce the bit rate significantly. In general, there are two ways of classifying redundancy-removing techniques. These are predictive codes and transform codes. Predictive codes operate in the time domain while transform codes operate in the frequency domain. Predictive codes infer information about present samples from previous samples and only encode and transmit the difference between the actual and predicted values. Transform codes convert the input signal into a weighted sum of frequency components as in a Fourier Series. The weighting factors are the transform coefficients and these coefficients can be made to have a much smaller average power than the samples from which they were taken, due to speech redundancy. If the coefficients are small enough, they can be disregarded. This information is inferred in decoding by the receiver. Either or both of these types of coding can be employed to lower the bit rate.

Another characteristic of voice communication that can be taken advantage of is active talking time. In a two-way conversation, a person is actively talking only about 40% of the time. The remaining time is spent on listening or pausing. A speech detector is used to determine the status of the user (talking or not). If a user is talking, he is connected to a channel and if a user is not talking, he is not connected to a channel. This allows a sharing of channels and if the trunk group is large a 2 1/2: 1 gain can be gotten in channel capacity. This technique is called speech interpolation and is in effect bit rate reduction since it allows more users per 64 kbit channel.

The limited bandwidth of speech should also be taken into account. Most digital systems use a bandwidth from approximately 200 to 3400 Hz for a voice channel. This covers the essential range of human speech (4 kHz is usually used as a bandwidth per voice channel. This leads to the 8 kHz sampling rate). By not transmitting any signal in the portions of the spectrum where the voice signal is absent or of a very low level, bit rate can be reduced. This can be achieved by reducing the transmitted spectrum through the elimination of guard bands or compression of the signal by elimination of the low level "gaps" in the short-term voice spectrum.

If a coding scheme that changes as the input signal changes is used, it is called adaptive coding -- the code adapts to the input. Frequently occurring messages can be coded using smaller numbers of bits while infrequently occurring messages can be coded using larger numbers of bits. This is called variable-length, or Huffman coding. The quantizing levels can also be adapted to the input signal. For a large value of input signal, quantizing levels can be farther apart than for a small input signal value -- a sort of adaptive companding.

Taking the received voice signal into account, further transmission rate reductions are possible. The noise perceived by the human ear has certain characteristics that a coding technique can exploit. The ear is most sensitive to noise in the 1000-4000 Hz region (a frequency domain aspect), and it is more sensitive to noise when speech is not present than when speech is present (a time domain aspect). Adapting the coding scheme to reject noise in the more significant portion of the spectrum and to reject noise during lower signal level periods can improve subjective system performance greatly.

A major concern about bit-rate-reduced systems is the possible decrease in performance they may introduce. When bit rate compression techniques are used, there is often a degradation in signal quality relative to 64 kbit/s PCM. The significance of this degradation is the main point of concern. Since subjective quality is usually the main criterion used to evaluate these (voice communication) systems, final distortion and signal-to-noise values are of lesser priority than perceived performance.

Some reduction techniques also introduce a delay in transmission. This delay can produce echoes and can be very troublesome if many tandem encodings are done. The current objective in telephony is to provide at least toll quality (comparable to analog speech transmitted over the telephone network) when using bit rate reduction systems.

At the present time, since many techniques have only been tested in the laboratory or by computer simulations, the cost of implementing them would likely be proportional to system complexity. However, as Very Large Scale Integrated (VLSI) circuit technology progresses, and the popularity of these techniques induces more production, cost and complexity need not necessarily remain proportional.

What follows is a summary of some of the current methods for reducing bit rates. Each is a description given to outline the basic principles behind each technique. Again, as some of these techniques are still in their infancy, not much information is given as regards technical feasibility, detailed transmission characteristics, and technical compatibility with existing facilities. Hence, many of the descriptions are somewhat qualitative and subjective. With further research and development, more specific and concrete quantitative information will become available. The prime reference source for much of the following material was the IEEE Transactions on Communications, Volume COM-30, April 1982.

2. Differential PCM and Related Techniques

Differential pulse code modulation (DPCM) is aptly named. It is pulse code modulation where only the difference between adjacent samples is encoded and transmitted. This difference can be encoded using 4 bits/sample, since the speech signal does not vary too rapidly. Decoding is done by adding the difference to the previous sample. Prediction can also be incorporated into DPCM and most newer DPCM systems now use some level of prediction to take advantage of the redundancy in speech. Diagrams of DPCM systems with and without prediction are shown in Figures 2 and 1, respectively. In Figure 1, the signal path through the DPCM modulator is traced. A short description of the signal processing operations is as follows:

1. Input speech is bandlimited by a low-pass filter.
2. The estimate of the previous sample ($\tilde{x}(t)$) is subtracted from the present sample ($x(t)$) to form the difference signal.
3. The difference signal is sampled at 8 kHz (usually).
4. The sampled signal is quantized and encoded to form a 4 bit/sample word (this is also a typical number).
5. The DPCM signal is sent out to the channel and also fed back to a decoder to reconstruct the sample for subtraction from the next sample.
6. The digitized decoded signal is input to an integrator which forms an estimate of the present sample ($\tilde{x}(t)$ is the estimate of the present transmitted signal).
7. The estimate of the present sample is subtracted from the next sample to be encoded and transmitted.

The demodulation process is the same as the feedback path in the modulator with another low-pass filter inserted at the end to reduce out of band noise.

Figure 2 follows the signal path through the processing in a DPCM modulator that uses prediction. The operations performed on the signal are:

1. Input speech is bandlimited by a low-pass filter.
2. Bandlimited input signal is sampled (usually at 8 kHz).
3. The sampled signal is fed to an adder where the difference signal is obtained by subtracting the predicted estimate of the signal from the signal itself.
4. The difference between the signal and its predicted estimate is input to a quantizer and encoder where it is encoded (usually using 4 bits/sample).
5. The encoder difference signal is sent out to the channel and also fed back to the prediction circuit.
6. The input to the predictor is formed by adding the present sample and the predicted estimate of the previous sample.
7. The predicted estimate of the next sample (determined from a few previous samples) is subtracted from the next sample and also fed back to be used by the predictor in determining an estimate for the next succeeding sample.

The demodulator combines the encoded difference signal with a predicted estimate of it (made from a few previous samples) to form the approximate output of the speech. This approximate output is put into a low-pass filter to reduce the out of band noise.

Although the prediction is described as being based on only two previous samples, many DPCM systems use a more sophisticated predictor that operates on information from a number of previous samples.

While DPCM requires slightly more complex hardware than PCM its quality at 32 kbit/s is very comparable. Signal-to-noise ratio (SNR) is usually not more than 5 dB less than 64 kbit/s PCM.

One recent improvement applied to DPCM is making the quantization adaptive. Adaptive DPCM (ADPCM) adapts the quantization step size to the input signal mean power. If the mean input signal power is high, the quantization step size is large, and the reverse is true for low mean input signal power. The quantizer step size is usually restricted to some number of multiples of the PCM step size (using a formula such as $Q=2^{i}q$ where Q is ADPCM step size and q is PCM step size, i being the number of the multiple). This is done to facilitate compatibility with existing PCM systems. With the $2^{i}q$ rule, ADPCM has coarser steps than PCM and these steps change with the input signal.

The input signal mean power is usually estimated over a few sampling periods to determine a more accurate estimate. Many newer systems are employing prediction filters that are adaptive (prediction filter coefficients are computed from the autocorrelation function of the input signal sequence). This increases the quality of the signal even further. A diagram of an ADPCM system with adaptive prediction is shown in Figure 3. A description of the operations performed on the traced ADPCM signal is as follows:

1. The PCM input speech signal is fed into an expander.
2. The expanded PCM is combined with an estimate from the predictor to form the difference signal.
3. The difference signal is quantized (and encoded) using a step size based on information from the step-size logic circuit, and transmitted as ADPCM.
4. The ADPCM signal is sent out to the channel and also to the step size logic circuit and inverse quantizer to determine parameters for the next sample.
5. The step size logic circuit sends information (determined from mean input signal power estimate) to the quantizer and inverse quantizer to determine the next quantization step size.
6. The output of the inverse quantizer is combined with the predicted estimate of the next sample to form the input for the prediction filter. The inverse quantizer output is also fed directly into the prediction filter coefficients adaptation circuit to adjust the predictor parameters accordingly.
7. The output of the prediction filter (the estimate of the next sample) is subtracted from the actual next sample and also combined with the inverse quantizer output to update the prediction filter for the next succeeding sample.

The reverse operations are performed in the ADPCM-PCM converter save the quantizing.

When adaptive prediction is used, systems are sometimes termed adaptive predictive coding (APC) systems. These are often DPCM systems in which two or more stages of prediction are used. These can be: a high-order short-term predictor based on the spectral envelope of the speech; a long-term predictor based on pitch information, or; another short-term predictor based on spectral fine structure (which uses the quasi-periodic nature of speech). These are utilized together to provide greater prediction capabilities than a single predictor.

ADPCM provides an improvement in SNR over conventional DPCM. The SNR of 32 kbit/s ADPCM is usually not lower than 3 dB below 64 kbit/s PCM for a large dynamic range (-50 to 0 dBm) of input. In fact, ADPCM performs better than 56 kbit/s PCM. Newer ADPCM systems are also fairly insensitive to tandem encodings and accumulation of degradations is minimal.

Another technique related to DPCM is backward adaptive re-encoding (BAR). This technique uses a mixture of direct and differential encoding. The bit rate per sample is varied according to the input signal, and the number of bits per sample is determined by the position of the previous sample relative to its neighboring zero crossings. If the sample value is close to a zero crossing, it is probably a low level signal, so direct encoding is used (for greater resolution) with more bits per sample resulting. If the previous sample is further from a zero crossing, the signal level is probably higher so differential encoding is used with less bits per sample resulting. BAR is an example of variable-length coding.

Coding with 4, 5, or 6 bits/sample reduces the bit rate significantly. A receiver is made part of the transmitter (hence the term backward adaptive) to ensure that both receiver and transmitter operate from the same input. The receiver infers information from past behavior of the input and relays this to the transmitter, allowing it to re-encode the PCM signal at a lower bit rate. A simplified diagram of a BAR-PCM device is shown in Figure 4.

Some comments on the signal processing operations are presented:

1. The PCM input is fed into a pre-processor which separates the incoming sample into its sign, fed into the zero-crossing detector, and its magnitude, which is fed into the quantization selector.
2. The quantizer selector, using information about zero crossings and previous sample envelope energy, selects the type of encoding (direct or differential) to be used. Both the difference signal and present sample magnitude are provided for at the quantizer selector inputs.
3. The ROM 1 (fixed quantizer) has the magnitude or difference input and also the mode of encoding to be used. It outputs the reduced rate PCM and also feeds back to use information for the next sample.
4. The restoration module converts the reduced rate PCM signal back into the normal rate PCM signal.

The receiver (lower half of device) performs the reciprocal operations to those of the transmitter.

The bit rates achieved with BAR range from 32 kbit/s to 48 kbit/s, depending on input. The performance achieved is approximately equal to that of NIC (to be described in a succeeding section).

3. <u>Delta Modulation and Related Techniques</u>

Delta modulation (DM) is a simplified version of DPCM. The transmitted signal only conveys information as to the relative (+ or -) difference between adjacent samples. This requires only one bit per sample. However, if the input signal changes too rapidly, a condition known as slope overload can occur. This results in a larger error in the transmitted signal. Slope overload can be alleviated by using a higher sampling rate. A quality near that of DPCM can be attained at a bit rate of 32 kbit/s -- with a reduction in hardware complexity. A delta modulation transmitter and receiver are shown in Figure 5A. The traced signal's path is described:

1. Input speech is bandlimited by a low-pass filter.
2. The estimate of the previous sample ($\tilde{x}(t)$) is subtracted from the present sample ($x(t)$) to form the difference signal.
3. The difference signal is limited to one of two possible values: $+\Delta$ and $-\Delta$
4. The limited difference signal is sampled (usually at 32 kHz) to form the DM signal $Xp(t)$. Mathematically: $Xp(t) = \sum_k \Delta \text{sgn}\,(x(kTs) - \tilde{x}(kTs)) \cdot \delta(t-kTs)$ where $Ts = 1/fs$ = sampling period and $\delta(t-kTs)$ is the impulse or pulse sampling function.
5. The DM signal is transmitted to the channel and also fed back to an integrator which forms a digitized estimate of the sample to be subtracted from the next sample.
6. The digitized estimate $\tilde{x}(t)$ is subtracted from the next (or present) sample to form the difference signal.

The demodulator is identical to the feedback path of the modulator with an LPF added for noise reduction.

A drawback to DM is idling noise. This results when the sampler oscillates in trying to follow a constant level input. Idling noise can be reduced by making the step size smaller. A waveform diagram showing idling noise is shown in Figure 5B.

Many improvements have been made on the basic DM encoding technique. One of them is continuously-variable slope DM (CVSD). This method of encoding is like DM with a slowly adapting compandor. The quantizer step size is varied according to the slope of the input as in Figure 6A. This adjustment of quantizer step size is usually done at a syllabic rate with the syllabic filter output (polarity controlled by encoder output signal) used as the input to the prediction filter. The prediction filter can be a simple RC integrator. A diagram of a CVSD system is shown in Figure 6B. A short descripton of the CVSD operations is given:

1. The comparator generates an error (difference) signal between the bandlimited input speech (Xn) and the predicted signal that is the output of the prediction filter ($\tilde{X}n$).
2. The one-bit quantizer samples the error signal at the sampling rate (fs).
3. The sampled error signal is transmitted to an adaptive compandor and adjusts the quantizer step size at a syllabic rate (z^{-1} is Z transform notation for a time delay) Δ_n is the n^{th} samples's quantizer step size.
4. The prediction filter estimates the next sample from information about the previous few samples (B is a multiplication factor that depends on the present, and past two sign bits) and transmits the prediction to the comparator for subtraction.

The CVSD decoder is simply the feedback path of the encoder. As in other predictive coding schemes, the number of past samples used for estimation is variable.

Some other DM systems use companding adjusted at every sampling time. These are called instantaneous companding adaptive DM systems. When the companding quantizer step size is adjusted both at each sampling time and at a slower syllabic rate (based on slope energy of the decoded signal), this is called hybrid companding DM (HCDM). Hybrid companding DM systems outperform those using only syllabic or instantaneous companding. At a 32 kbit/s rate, HCDM gives good toll quality and at 24 kbit/s adequate toll quality is achieved. A diagram of an HCDM system is shown in Figure 7. The operations of the HCDM encoding are briefly described:

1. The comparator generates an error (difference) signal between the band-limited speech (Xn) and the predicted signal ($\tilde{X}n$).
2. The one-bit quantizer samples the difference signal at the sampling frequency (fs).
3. The logic rule circuit adjusts quantizer step size at each sampling time based on information from its previous output and a few previous samples.
4. The prediction filter estimates the next sample based on previous predicted value, average slope energy of previous input signal slope, and a few previous samples.
5. The syllabic basic step size estimation is made by predicting input signal slope and is scaled to help determine the next sample's step size (α is a scale factor, step size $\Delta = \alpha$ E where E is average slope energy of the decoded signal).

The decoder is just the feedback path of the encoder minus the scale factor amplifier. A low-pass filter is also inserted at the end.

A recent upgrading of HCDM systems involves changing the actual sampling rate according to variation of the input signal slope. This is termed variable sampling rate HCDM (VSHCDM). The greater the number of sampling rates used, the better the performance. The technique is essentially an adaptive sampling rate HCDM (see Figure 8A).

Two types of VSHCDM have been developed. These are feedback VSHCDM (FB-VSHCDM) and feedforward VSHCDM (FF-VSHCDM). Feedback VSHCDM uses the predictor output to estimate slope energy (see Figure 8B), while feedforward VSHCDM uses the actual input signal to estimate slope energy (see Figure 8C). This slope energy must be coded as side information and multiplexed with the output binary signal for transmision in FF-VSHCDM. Hence FF-VSHCDM is slightly more complex than FB-VSHCDM, but with a small performance improvement.

As seen in the figures, both types use a buffer for synchronization and for storage when the sampling rate exceeds the transmission rate. The buffer naturally causes a delay in transmission. Maximum delay can be 188 ms for the low transmission rate of 16 kbit/s and large buffer size of 3 kbits. Delay is substantially smaller for higher transmission rates and smaller buffers.

In VSHCDM systems that have been tested, three or four different sampling rates were used and, at a channel transmission rate of 24 kbit/s or 32 kbit/s, a 3 to 4 dB improvement over HCDM was gained. A modest increase in hardware complexity over HCDM is necessary. VSHCDM can achieve quality equal to 24 kbit/s HCDM at a rate of 16 kbit/s.

4. Time Domain Harmonic Scaling

Time Domain Harmonic Scaling (TDHS) is a bit rate reduction technique that employs a compression scheme to reduce the short-term spectrum of speech. TDHS can be viewed in the frequency domain as the elimination of "gaps" in the speech spectrum by compressing the "peaks" into the "gaps" (see Figure 9A). In the time domain, TDHS is accomplished by weighting samples of speech and adding these weighted values to form the transmitted signal. In the receiver, the adjacent samples are again weighted and added, but in a reciprocal manner (see Figure 10). The details of the waveform processing are shown in Figures 10A and 10B. Some notes on the processing further describe the operations:

Compression:
- pitch period = p, input speech is divided into blocks of speech of length 2p samples
- 1^{st} block weighted by sample window w(m), linearly decreasing
- 2^{nd} block weighted by sample window 1-w(m), linearly increasing
- the sum of blocks produces one block of p samples which looks mostly like the first block at the beginning and mostly like the second block at the end.
- The next block of Xc(n) is computed using the next 2p samples of X(n).
- Xc(n) forms continuous waveform by concatenation of blocks of X(n).

Expansion:
- 3p samples of $\tilde{X}c(n)$ are used to compute 2p samples of $\tilde{x}(n)$ using the 2p sample overlapped windows.
- After computation of a sample, the windows are moved over by p samples and the next 2p samples of $\tilde{x}(n)$ are computed similarly.
- For every p samples of new input signal $\tilde{X}c(n)$, 2p samples of the expanded signal $\tilde{x}(n)$ are computed such that $\tilde{x}(n)$ is continuous across the boundaries of the concatenated output blocks.

This technique is called pitch-synchronous processing and is achieved with shift registers, adders, and special amplifiers.

By reducing the bandwidth of the input signal, TDHS reduces the needed sampling rate at the input of the coder. TDHS is often combined with other techniques, such as CVSD or sub-band coding (SBC, to be described next), to further reduce the bit rate or increase the quality at a given bit rate. Since TDHS operates only on blocks of speech samples at a time, a substantial delay may be introduced (up to 60m sec). With TDHS alone, very low bit rates (9.6 kbit/s and below) do not perform well since the error in quantizing the pitch harmonics introduces a distortion in the form of reverberance -- which can be quite noticeable in telephone speech. However, at bit rates around

32 kbit/s, TDHS performs better than CVSD. A simple block diagram of a TDHS system is shown in Figure 9B.

5. Sub-band Coding

Sub-band coding (SBC) is a bit rate reduction technique that divides the voice spectrum into a number of sub-bands, each of which is encoded separately using a lower sampling rate. In essence, SBC is a frequency domain technique. The encoding of each band is done using block companding PCM or ADPCM. The voice spectrum is usually divided into four to eight sub-bands (see Figure 11A). These sub-bands are frequency translated down to a low-pass spectrum where the encoding at a lower (than 8 kHz) rate is done.

A separate PCM or ADPCM coder is used for each of the sub-bands. For a system with more than two bands, each band's samples are fed into a multiplexer and transmitted as a complete "frame". The band's samples are demultiplexed in the receiver.

SBC techniques have been implemented at bit rates of 9.6, 16, 24, and 32 kbit/s At 24 kbit/s, SBC gives quality comparable to 32 kbit/s ADPCM. The delay in processing signals using SBC is less than that encountered with TDHS systems. As previously mentioned, SBC is often used with TDHS (TDHS/SBC) to achieve a further bit rate compression. This increases the system delay slightly and also its complexity. Using these techniques together does increase the quality at lower bit rates however. A diagram of a simple two - band sub-band coder is shown in Figure 11B.

6. Nearly Instantaneous Companding

The technique of nearly instantaneous companding (NIC) is based on the fact that the dynamic range of speech signals does not vary greatly when samples are in small groups as compared to the dynamic range of speech as a whole. An NIC coder accepts blocks of companded PCM speech samples and re-quantizes each block. The samples are usually normalized according to a scale factor based on the maximum magnitude found in each block. A buffer is used to store the block of PCM samples while the search for the maximum and the scaling operations are done. This causes a small delay (around 6 msec). Since the scale factor must be transmitted, the bit rate of an NIC coder is slightly higher than a multiple of 8 kbit/s (i.e., 34.66 instead of 32 kbit/s).

An advantage of NIC is its relatively simple hardware implementation. But, at 34.66 kbit/s NIC performs no better than 32 kbit/s CVSD. A diagram of a basic NIC system is shown in Figure 12. A descripton of the operations performed is as follows:

1. Analog speech is input to a PCM encoder prior to NIC.
2. The PCM signal is delayed for N samples (one block) to facilitate detection of the maximum magnitude and the scaling process. The PCM signal is also fed into a maximum detector to provide amplification and error information.

3. The block of samples is amplified appropriately (multiplication corresponds approximately to addition in the log domain -- for both μ and A law PCM).
4. The amplified PCM signal is encoded using a reduced bit rate (usually 4-6 bits/sample). The bit rate used is determined by the maximum detector.
5. The sample bits and scale factor are transmitted to the digital channel. The scale factor is determined from the maximum detector -- the larger the maximum value, the larger the number of scale factor bits.

The NIC decoder consists of the reciprocal devices to all those used in the encoder.

A recent technique introduced by a manufacturer that is related to NIC is variable quantizing level (VQL) coding. This technique is nearly identical to NIC except that the quantization steps of the PCM encoder are continually adjusted. This coding is not an adaptive scheme, as the precision and sample rate are not changed as a function of the input but rather in a block fashion as in NIC. This VQL technique lowers the bit rate to 32 kbit/s -- lower than the corresponding NIC bit rate. The delay is the same as for NIC (around 6 msec). Quality performance is better than NIC and is near that of ADPCM.

7. Digital Speech Interpolation

Digital speech interpolation (DSI) takes advantage of the "idle time" in a telephone conversation. As mentioned in the opening section, by only connecting a user to a channel when he is actively talking, a gain of up to 2 1/2:1 can be achieved in channel capacity for large trunk groups. This is equivalent to a bit rate reduction of down to 26 kbit/s per telephone channel. A similar technique developed by the Bell System, Time Assignment Speech Interpolation (TASI), was implemented on analog facilities in the early 1960's.

The major component in a DSI system is the speech detector. Speech detection is based on the short-time energy, zero-crossing rates, and sign bit sequences of the input signal. There are some inherent limitations to DSI which become especially noticeable when two or more systems are used in cascade, due to the presence of noise. These limitations are front-end clipping, false triggering, and noise contrast. Front-end clipping occurs when the detector fails to recognize that a speech burst has begun and consequently clips the first few milliseconds of the speech signal. False triggering is when the detector mistakes high level noise for speech and assigns a channel to this noise, thus decreasing channel-use efficiency. Noise contrast is when the listener hears bursts of speech plus noise between intervals of complete silence. A DSI speech detector is shown in Figure 13A.

A technique called hangover is used to bridge short silent periods in speech and reduce its bursty nature. Hangover is the time that the channel is left "on" after actual speech has stopped. Hangover reduces clipping but also increases speech activity slightly, thus possibly reducing channel-use efficiency.

If a large number of users attempt to use a DSI system at once, an overload condition can result. This situation can effectively "freeze-out" a user. However, this condition can be alleviated by using another bit rate reduction scheme in addition to DSI.

If the speech signal is encoded via ADPCM, a reduction in the chance of freeze-out is achieved. A diagram of a DSI-ADPCM transmitter is shown in Figure 13B. A few notes on some of the details of the processing operations give some numerical data:

Notes:
- Narrowband sounds (also low-power sounds) are encoded using 2 or 3 bits.
- Wideband sounds are encoded using 3 or 4 bits.
- The voiceband is frequency shifted down to allow for a lower sampling rate (6 or 6.4 kHz).
- Voiceband data is processed by 5 bit ADPCM encoding.
- Overall delay ≈ 60 ms due to buffers and frequency domain manipulations.
- DSI-ADPCM receiver follows reciprocal operations.

DSI can also be used in conjuction with VQL to achieve up to a 3:1 gain in channel capacity. Quality achieved with VQL/DSI is very near that of ADPCM when a bit rate of 32 kbit/s is used.

A predictive coding scheme used with DSI is predictive-wordlength assignment (PWA). Just as the name implies, PWA uses a variable wordlength per sample (3-8 bits per sample) while sampling at 8 kHz. A prediction is made based on the signal history, and the speech signal is encoded using DPCM. By using a variable wordlength per sample, no freeze-out can occur -- wordlength is reduced according to channel demand. Speech clipping is also reduced. The DSI/PWA system can achieve toll quality down to 21 kbit/s and no distortions are audible at a rate of 16 kbit/s. A block diagram of a DSI/PWA transmitter is shown in Figure 14. Additional details and data are presented to describe further the DSI/PWA transmitter:

Notes:
- Adaptive prediction is used with both PCM & DPCM.
- A table is used as lookup for the required wordlength -- predicted using signal history (even inactive source must participate in transmission (1 bit wordlength) otherwise source couldn't signal need for increasing wordlength when changing from inactive to active state. Auxiliary information is used to exclude completely inactive signal segments from transmission. Auxiliary information is approximately 1% for 128 sample segment -- N = 128).
- The channels (transmitters) request the number of bits/sample (wordlength), CCU determines wordlength assignment and type of encoding (DPCM or PCM) by looking at channel capacity.
- In overload condition, wordlength is reduced--1st low priority channels.
- In underload condition, wordlength is increased--1st high priority channels.
- Above 20 kbit/s, quality is comparable to 64 kbit/s PCM

8. Transform Coding

Most of the techniques discussed thus far have used methods of bit rate reduction that operate principally in the time domain. Transform codes operate in the frequency domain. These techniques transmit and encode information about the frequency characteristics of short-term speech samples.

Adaptive transform coding (ATC) is done by the taking of a discrete Fourier transform (DFT) of a block of speech. The resulting transform coefficients (frequency components) are quantized using an adaptive quantizer. This adaptive quantization is based on a smoothed spectral estimate of each speech block. This smoothed spectral estimate of the speech block is provided by the coefficients of the logarithm of the DFT. The log DFT coefficients furthest from the origin (higher frequency) provide pitch information.

Due to the absence of pertinent (non-redundant) information at certain frequencies, the needed bandwidth is reduced for each speech block. In actuality, some transform coefficients are so small they need not be trans mitted. Approximately 2 kbit/s is needed for side information (quantization step size and pitch and envelope information).

ATC is a very efficient method of reducing the needed bit rate. Excellent quality is achieved at a bit rate of 24 kbit/s and adequate toll quality at 16 kbit/s. However, there is a cost for this quality and efficiency. The complexity required for this system is great -- an array processor is currently necessary for its utilization. The delay introduced by the transform procedure is also prohibitive, as it can be up to approximately 130 msec.

Another technique that operates in the frequency domain is linear predictive coding (LPC). This technique is used to model the speech waveform as a linear system. LPC models the human vocal tract as a finite order all-pole or autoregressive filter driven by some signal. Rather than encode actual samples of the speech signal, other frequency information such as gain, frequency, pitch and other voiced and unvoiced information is encoded and transmitted. The gain encoded is the mean-square value of the speech. LPC attempts to track the underlying process of the speech waveform, and not the waveform itself.

In LPC, the error between the present sample and the predicted sample (based on a weighted sum of past samples) is transmitted. Weighting factors are calculated to minimize the average energy in the error signal. These weights are calculated over short time periods (10-30 msec) and thus change as the speech statistics vary. The weighting factors may be a linearly increasing time series since the speech waveform will probably resemble its most recent preceding samples more than its distant (much earlier) samples.

At the receiver, the signal is reconstructed using linear interpolation techniques after decoding.

LPC has been used in very low bit rate (2.4 kbit/s) systems for speech synthesis, with intelligible speech resulting. At 9.6 kbit/s, LPC offers adequate toll quality and at higher bit rates correspondingly better quality. As with ATC, LPC requires a high level of complexity and also introduces a large time delay. A simple block diagram of an LPC system is shown in Figure 15. Some details on the LPC operations are as follows:

Transmitter:
- Along the lower branch, LPC parameters (gain, pitch, voiced or unvoiced information) are extracted, quantized and encoded.
- Along the upper branch, the linear prediction residual (result of passing speech waveform through LPC analysis or energy difference between actual and estimated signal) is computed.
- Baseband extraction is a low pass filtering -- less than speech bandwidth.
- Decimation is downsampling to the Nyquist rate and quantizing.
- Higher frequencies are estimated via linear interpolation from the baseband information and pitch information.
- Long delay -- up to 300 ms.

The bit rate reduction technique known as vector quantization (VQ), list coding, or codebook coding is not conceptually new, but has only recently been researched in any detail. VQ is a coding system that assigns a reproduction vector y to each input x where the reproduction vector is obtained from a stored list or codebook. The criterion for determining which y to choose to represent x is the least squared-error value.

The stored list of reproduction vectors is a finite table A = (yi, i = 1, 2, 3, . . . N) where i is the index, or unique value associated with each unique y. Only the index i is encoded and transmitted. This system usually delays transmission for a few samples and uses this time to determine the accuracy of the suggested optimum y_i, thus checking itself and allowing for adjustment in the assignment of reproduction vectors.

The major difficulty encountered in implementing VQ coding is deciding on how to search the table of reproduction vectors for the optimum estimation. A number of strategies, such as tree searching (see Figure 16) and trellis searching (a variation of tree searching) have been proposed.

At this point, there is little in the way of hardware realization for VQ techniques. Most of the estimates of system performance have come from computer simulations. These simulations reveal that the bit rate and quality for VQ techniques can approach those of LPC. But, since a table of reproduction vectors must be stored, and a buffer must be available to contain a number of samples, memory requirements are rather large and time delay is substantial.

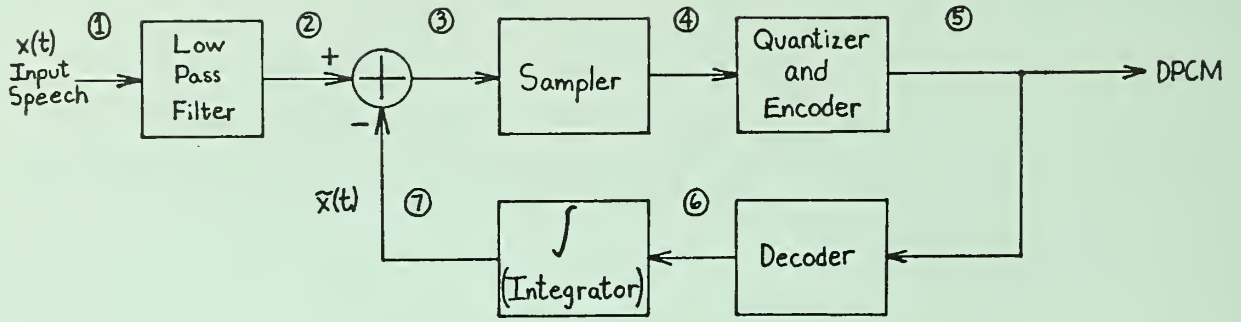
VQ is sometimes paired with LPC. The LPC code is used to "color" the output sequences when the optimum VQ estimate of the input is not very precise. A block diagram of the operations necessary in a VQ coder is shown in Figure 16. The LPC scheme used with a VQ coding system operates on some different principles than the VQ and hence permits an independent improvement to the system's performance.

9. Conclusions

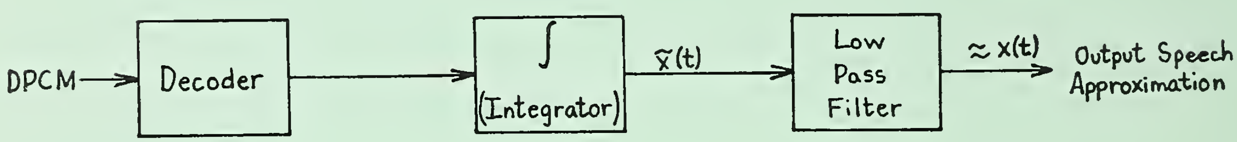
A few other simple diagrams are included to further illustrate some important principles of bit rate reduction. Figure 17 shows the amplitude spectrum for speech and 4.8 kbit/s data. It is seen that they are markedly different. It also points out the "important" regions of the spectrum for voice communication. Also shown in Figure 17 is a graphical comparison of a few bit rate reduction techniques in terms of SNR and channel bit-error rate. A very rough graphical comparison of most of the techniques discussed is given in Figure 18. This outlines the inter-relationships between the techniques by quality and complexity. This is in no way an absolute rating of the techniques, and is intended only to illustrate the relative positions of these techniques with each other. As technology progresses, there may be some shifting on both charts.

In nearly all cases (except 64 kbit/s PCM), quality decreases nearly linearly for each successive encoding-decoding stage. Usually the more complex methods show a larger effect on quality when tandem encodings are done. This would preclude their usage in most telephony applications. However, they could be used for large trunks and satellite links where tandem encodings are few. The degradation mentioned is probably caused, at least in part, by the distortion introduced by a single encoding. If this will change with the development and refinement of these techniques remains to be seen.

The CCITT is currently engaged in setting standards for transmission at 32 kbit/s. This should induce manufacturers to take part in further development of bit rate reduction techniques. And even though bit rate reduction techniques are currently a rarity, greater use of them can be expected in the near future.

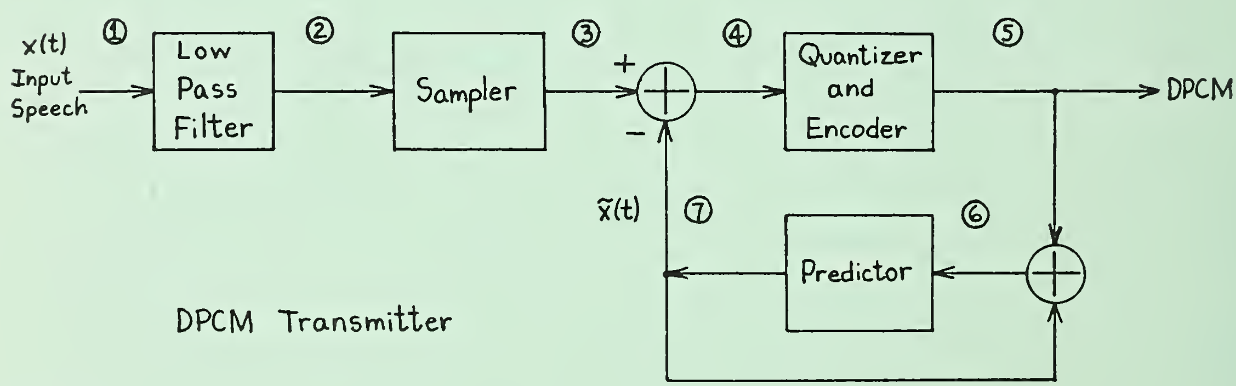


DPCM Modulator

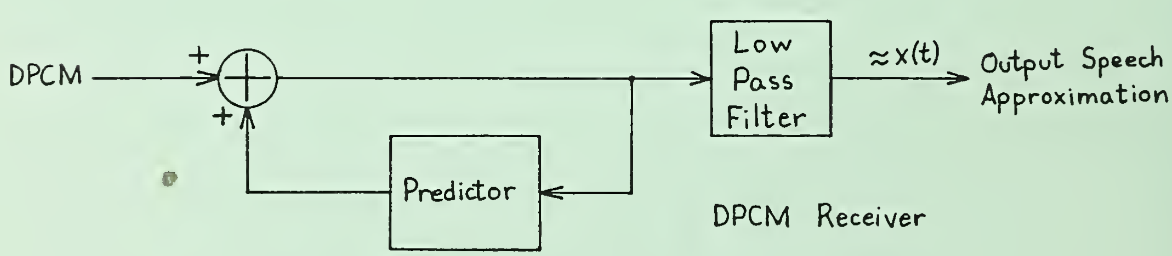


DPCM Demodulator

Figure 1

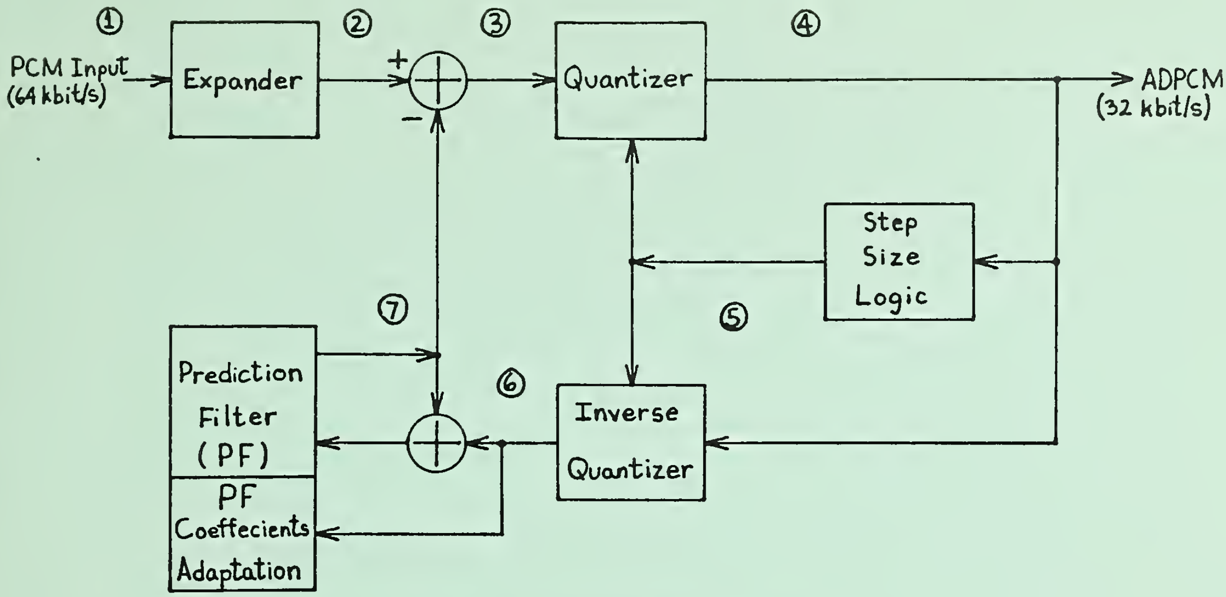


DPCM Transmitter



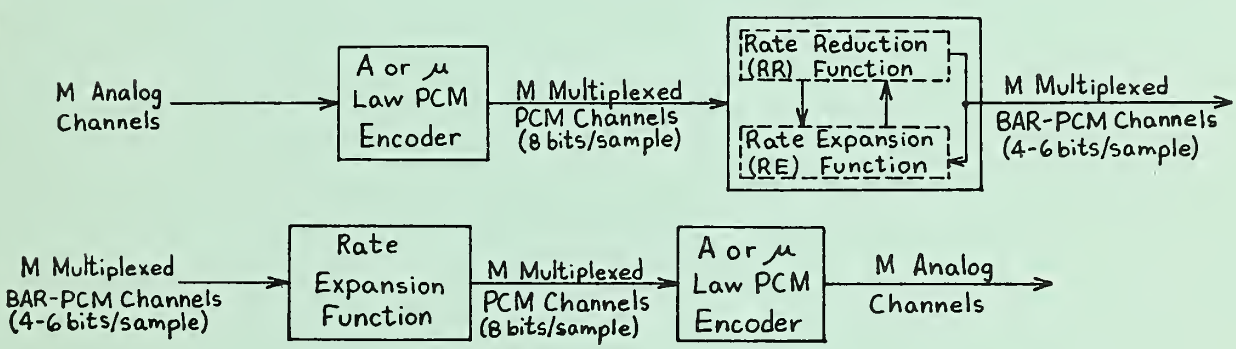
DPCM Receiver

Figure 2

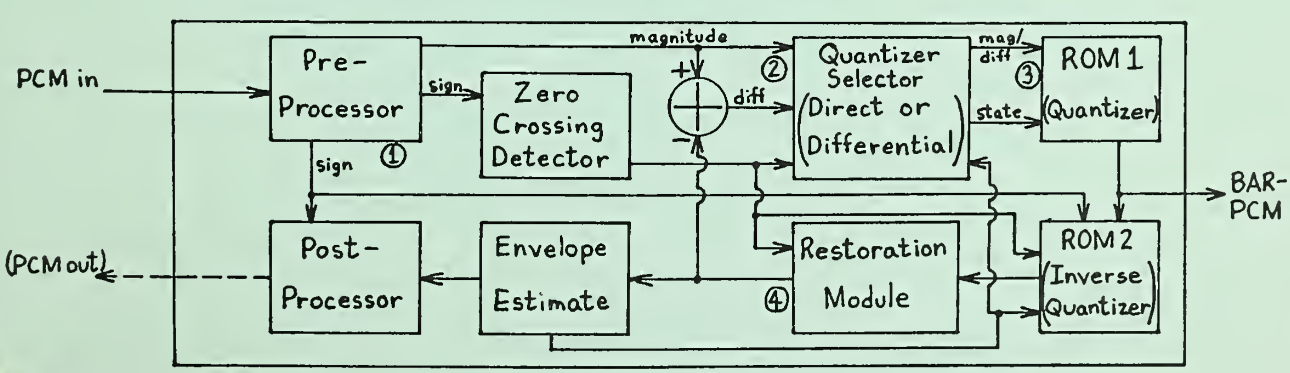


PCM-ADPCM Converter

Figure 3

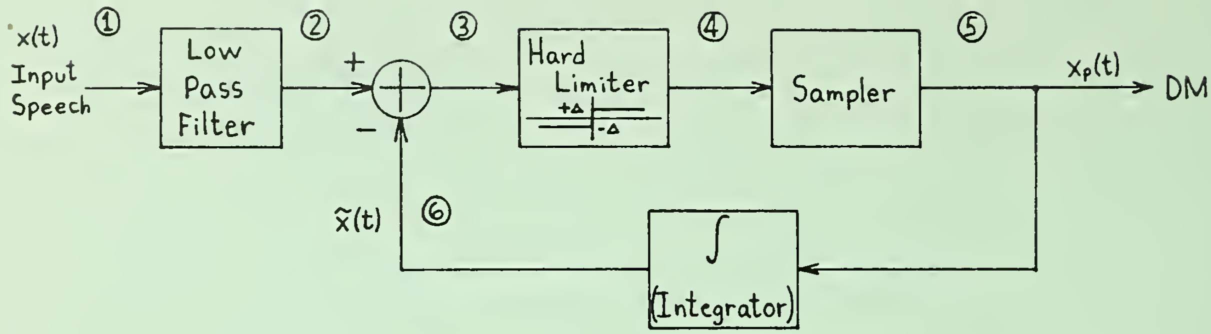


BAR-PCM Transmitter (top) and Receiver

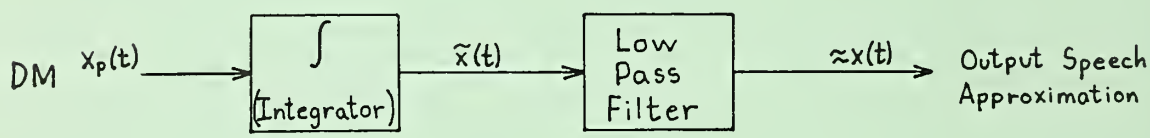


BAR-PCM Device

Figure 4

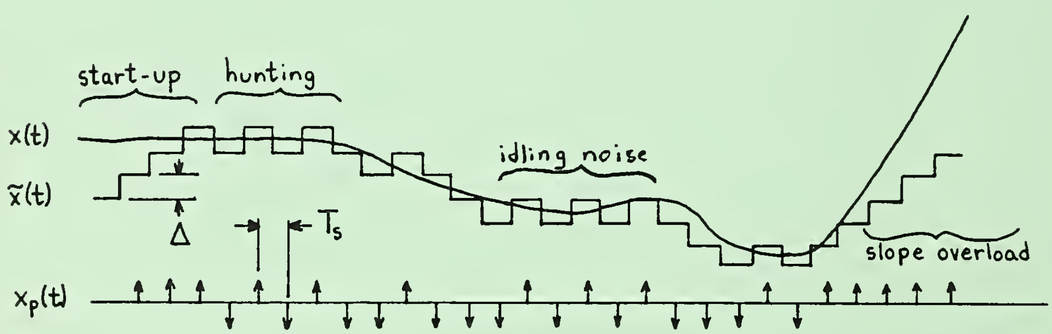


DM Modulator



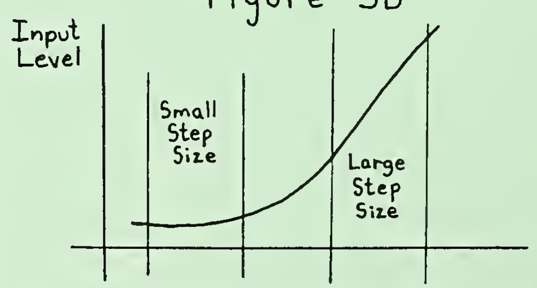
DM Demodulator

Figure 5A



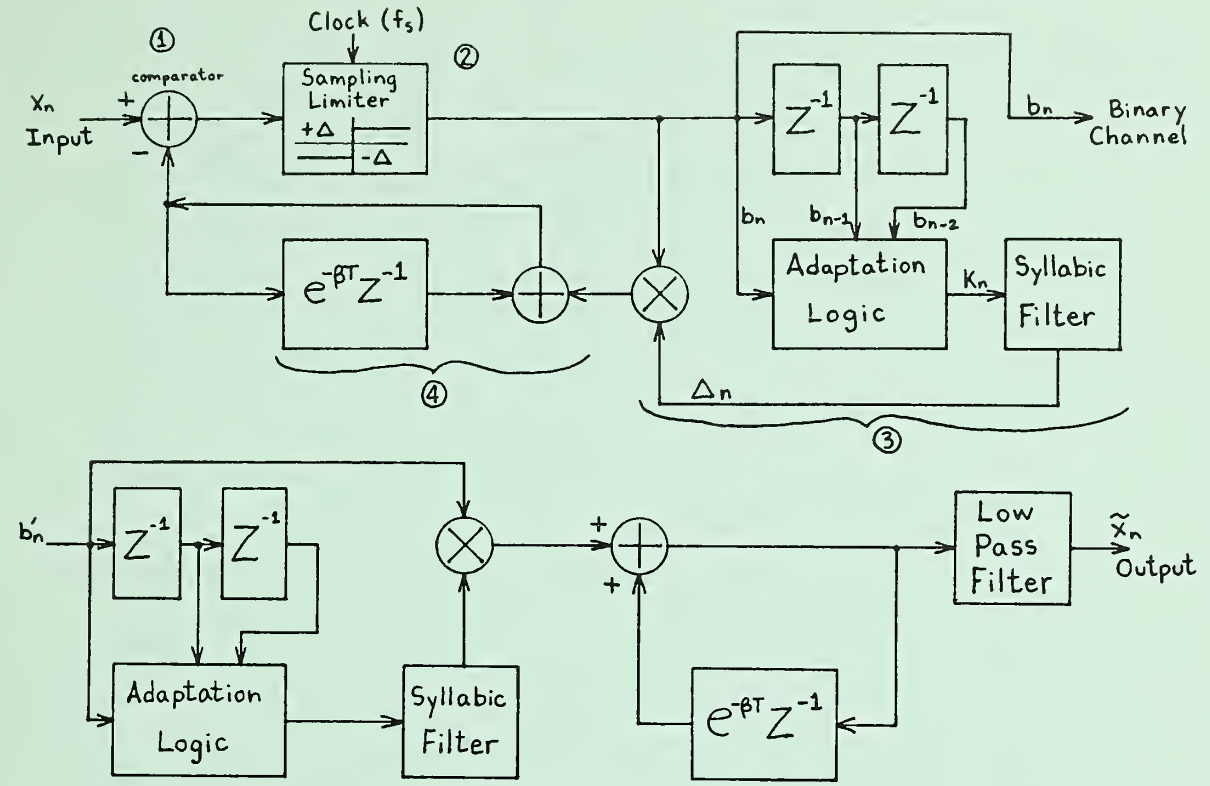
DM Waveforms

Figure 5B



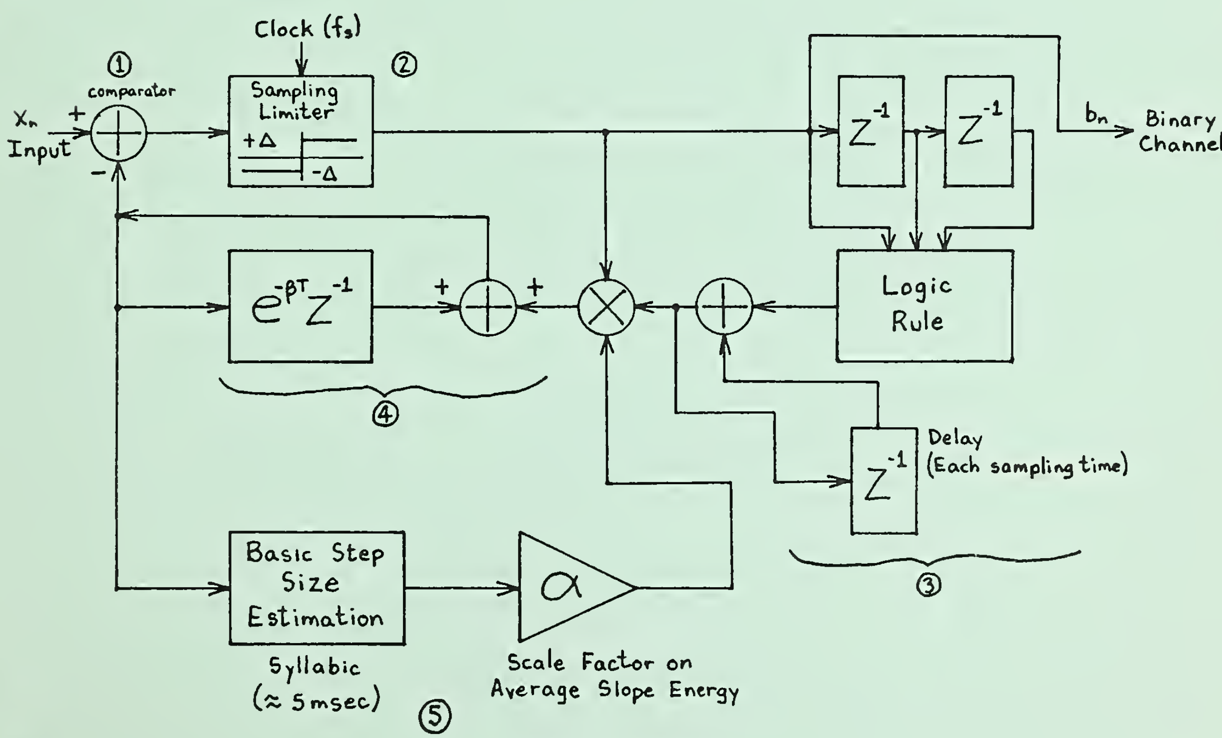
CVSD Quantizer Step Size

Figure 6A



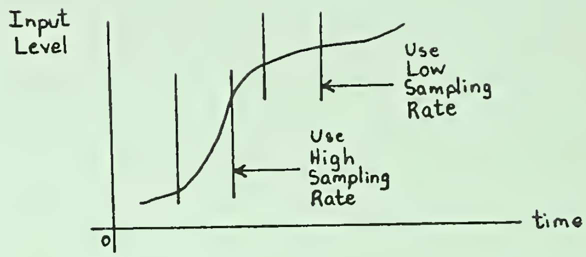
CVSD Encoder (top) and Decoder

Figure 6B



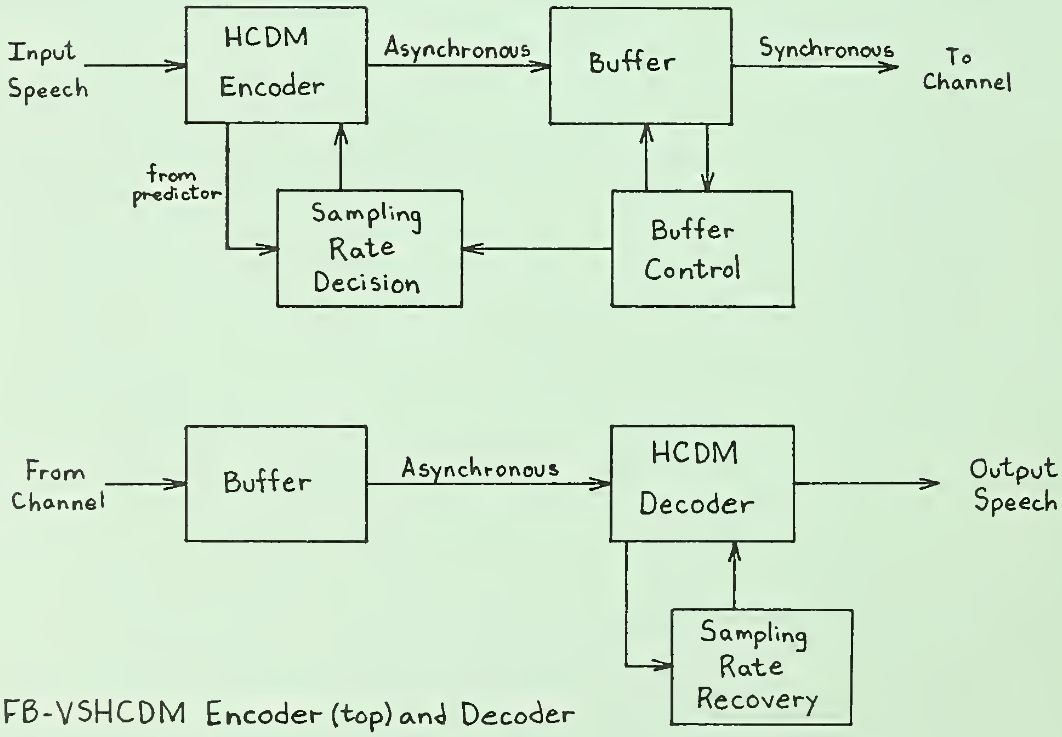
HCDM Encoder

Figure 7



VS Law

Figure 8A



FB-VSHCDM Encoder (top) and Decoder

Figure 8B

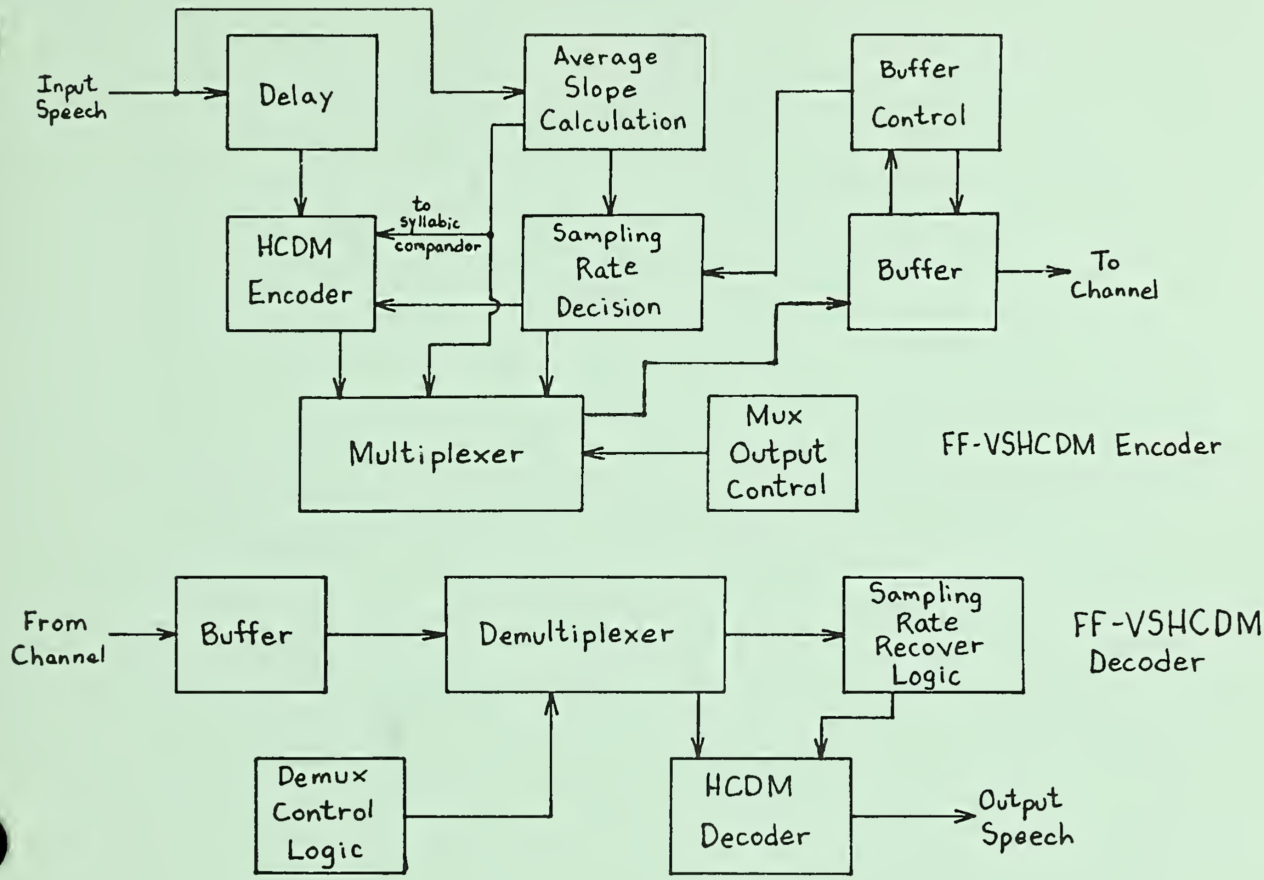
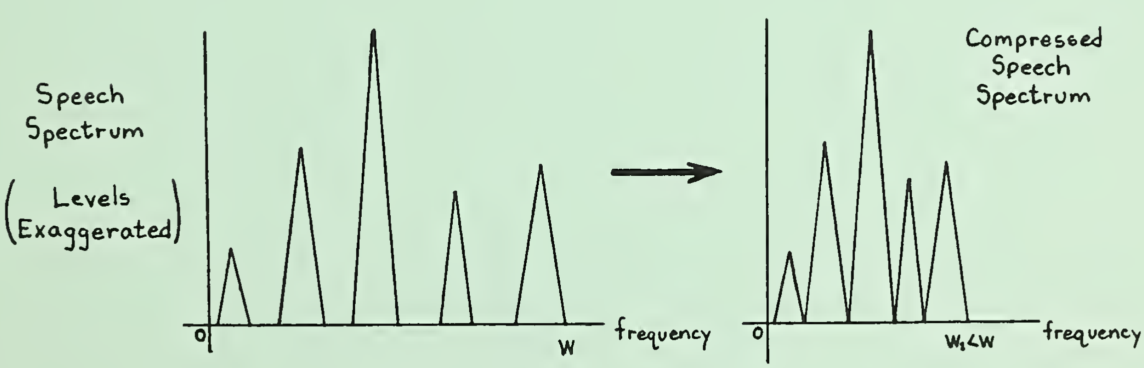


Figure 8C



TDHS in the Frequency Domain

Figure 9A

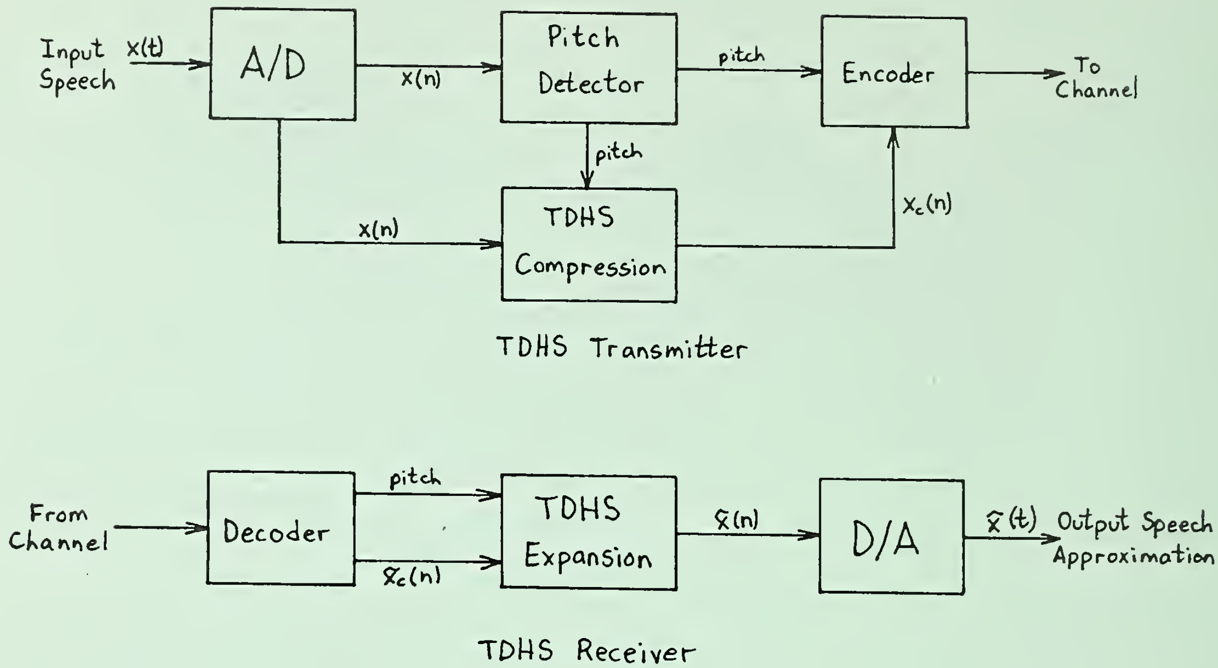
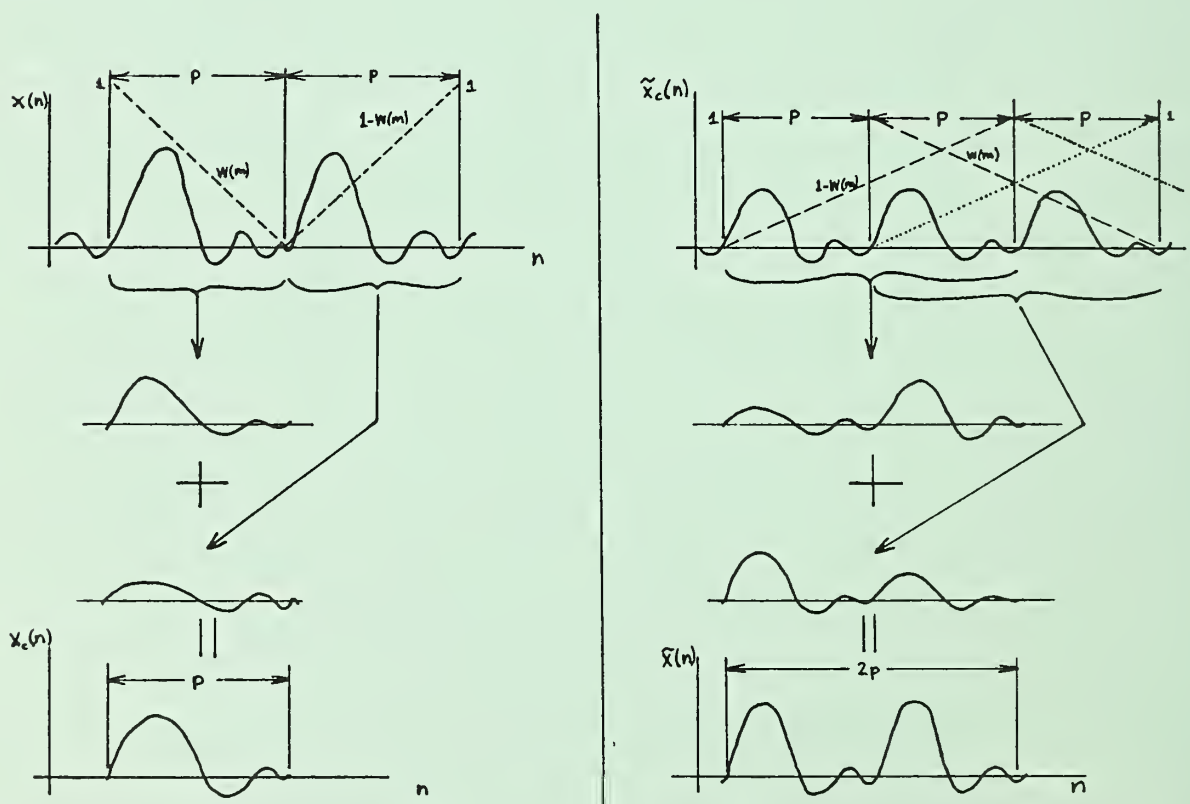


Figure 9B



A. 2:1 TDHS Compression (Time Domain)

B. 2:1 TDHS Expansion (Time Domain)

Figure 10

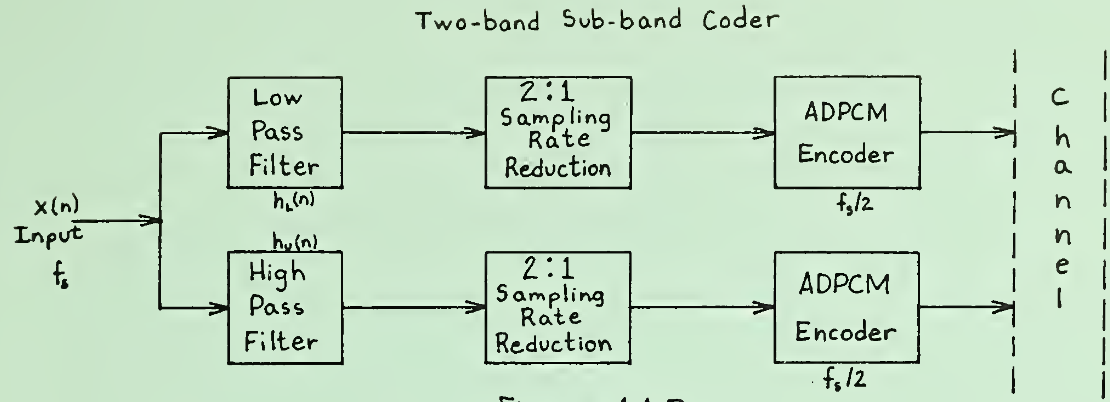


Figure 11B

Possible Bit Allocation Table	Band 1	Band 2	Band 3	Band 4	Band 5	Line Rate
Cutoff Frequency	0-500Hz	500-1kHz	1-2kHz	2-3kHz	3-4kHz	
bits/sample	4	4	2	2	0	16 kbits/s
bits/sample	5	5	4	3	0	24 kbits/s
bits/sample	5	5	4	4	3	32 kbits/s

Figure 11A

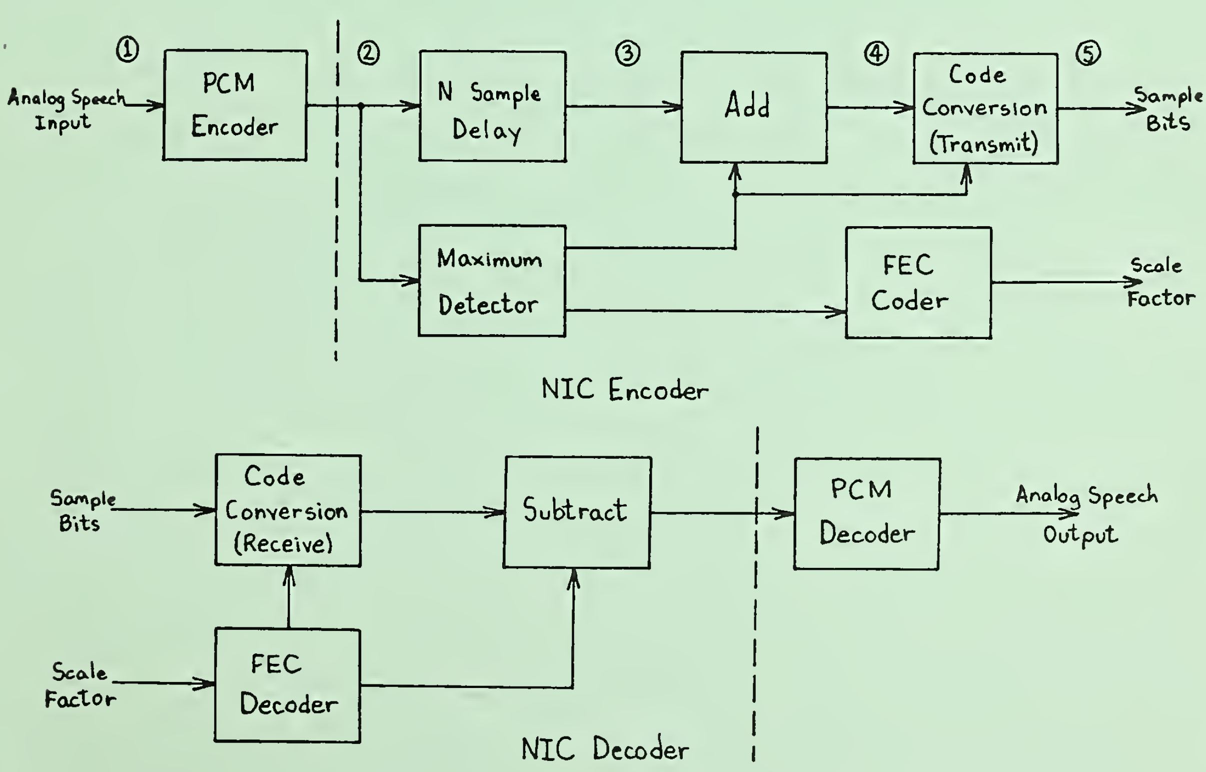
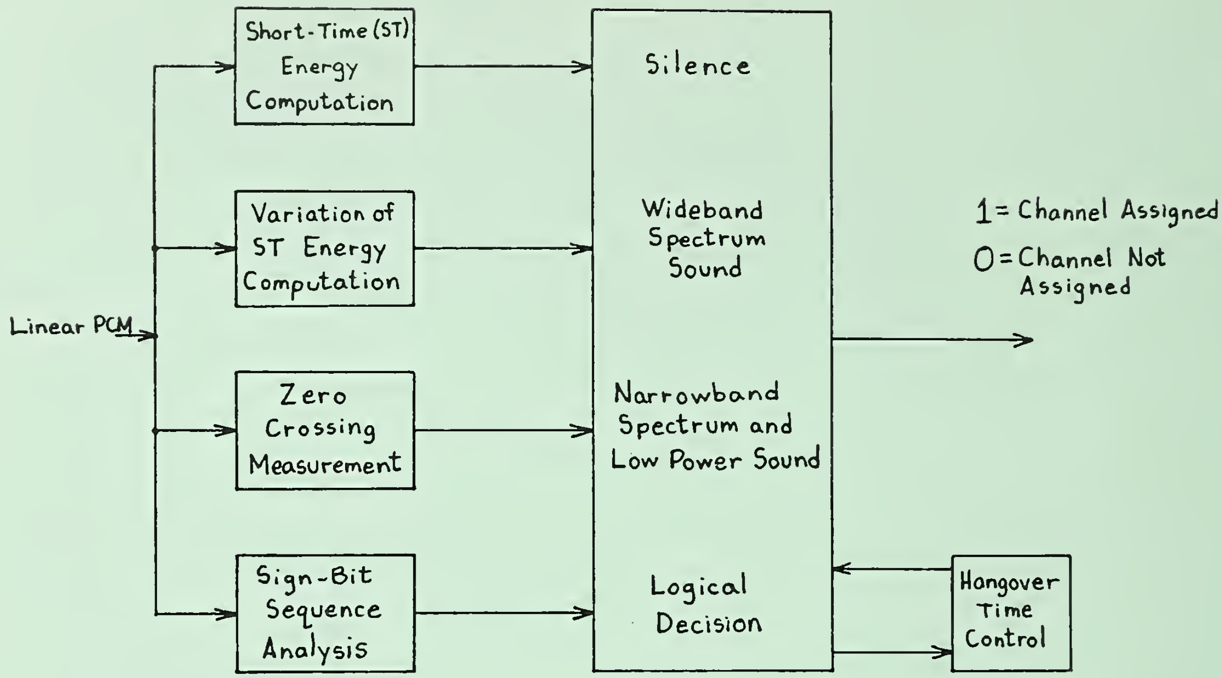
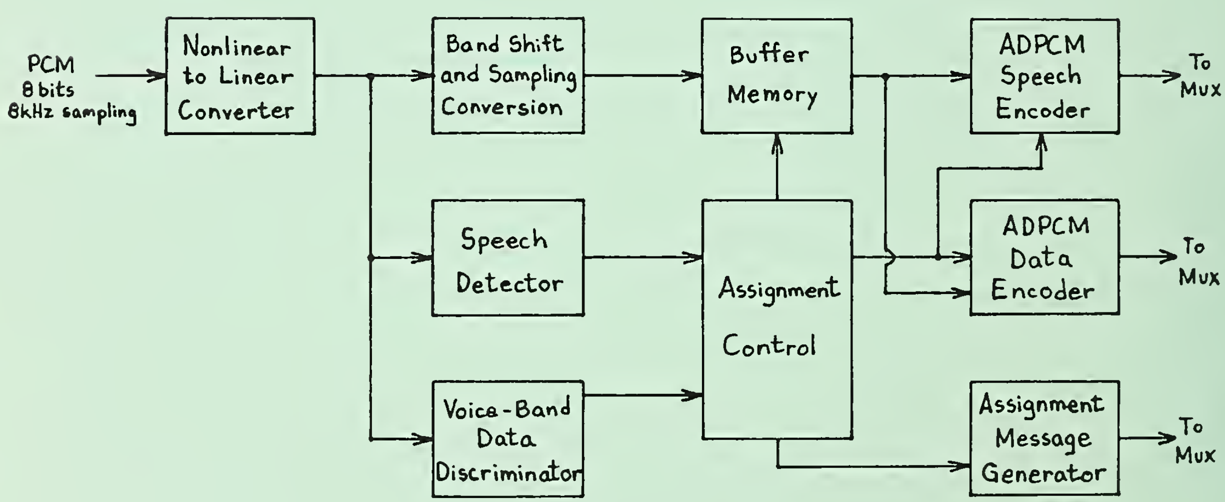


Figure 12



Speech Detector for DSI

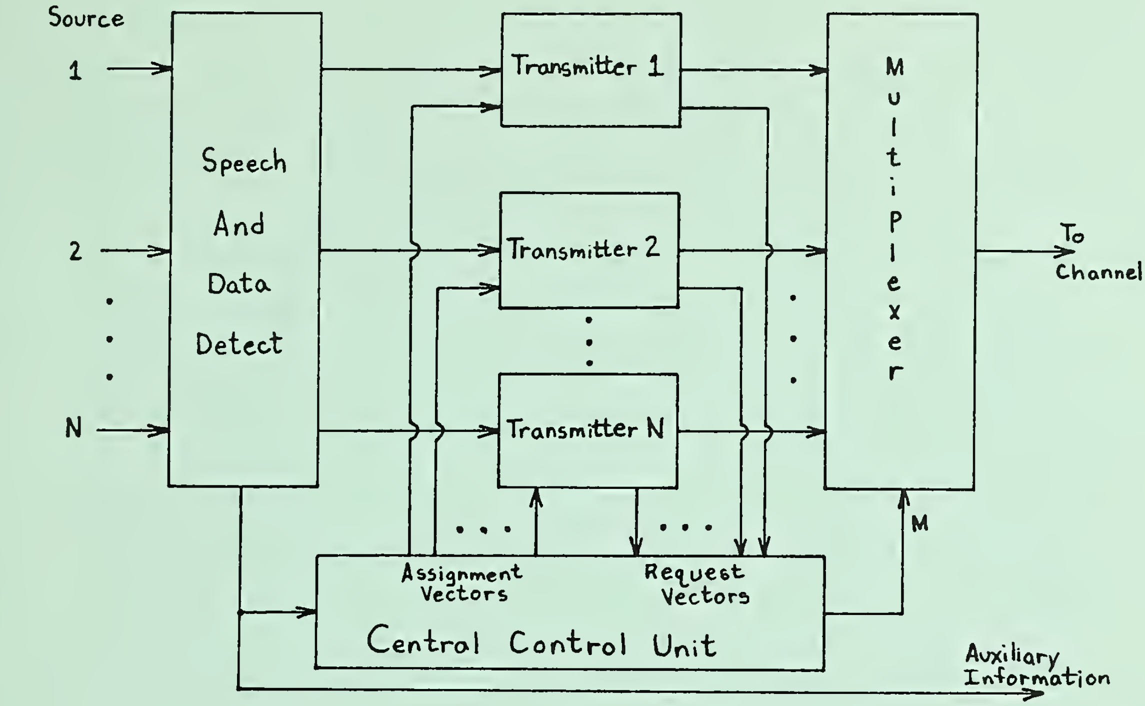
Figure 13A



(from multiplexer, bit stream is sent to line)

DSI-ADPCM Transmitter

Figure 13B



DSI/PWA Transmitter

Figure 14

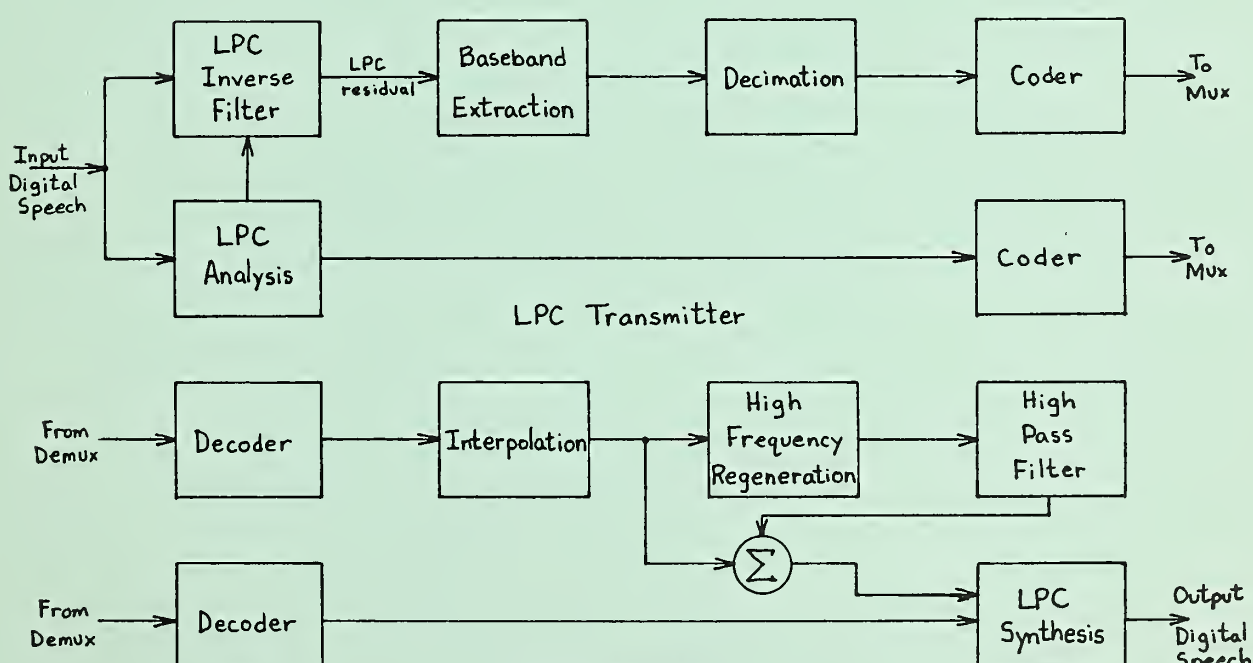


Figure 15

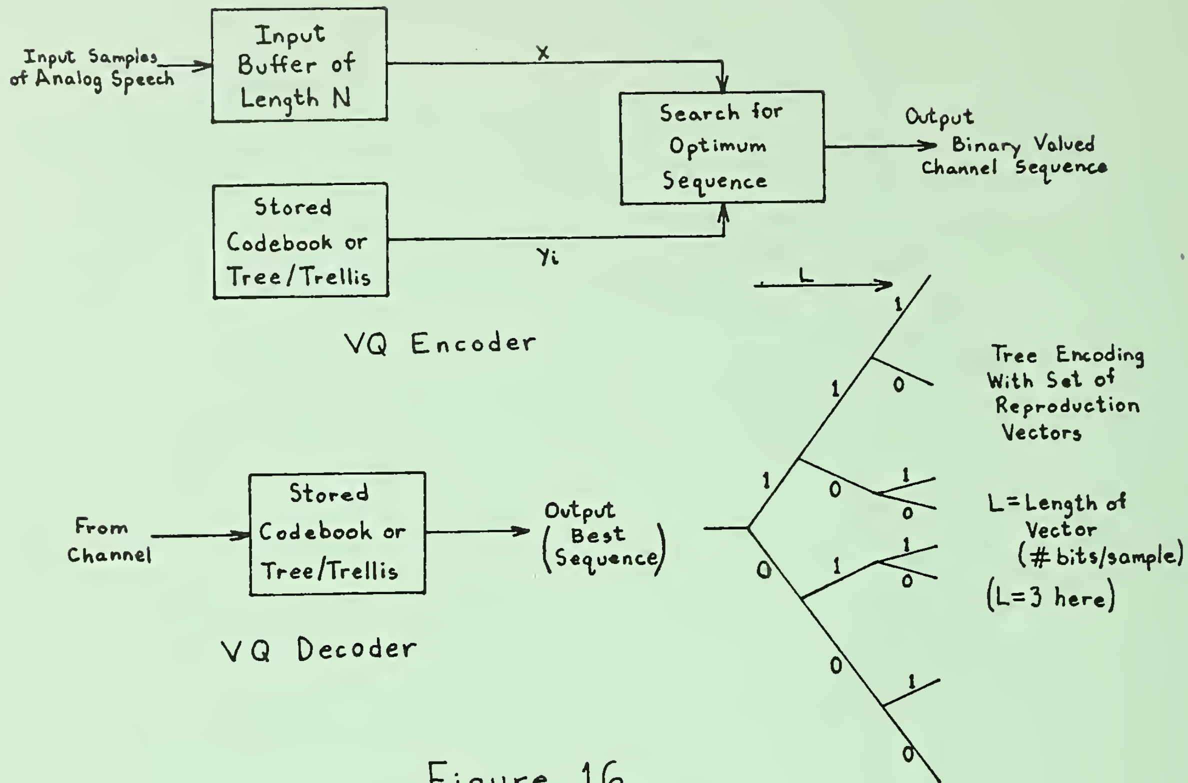
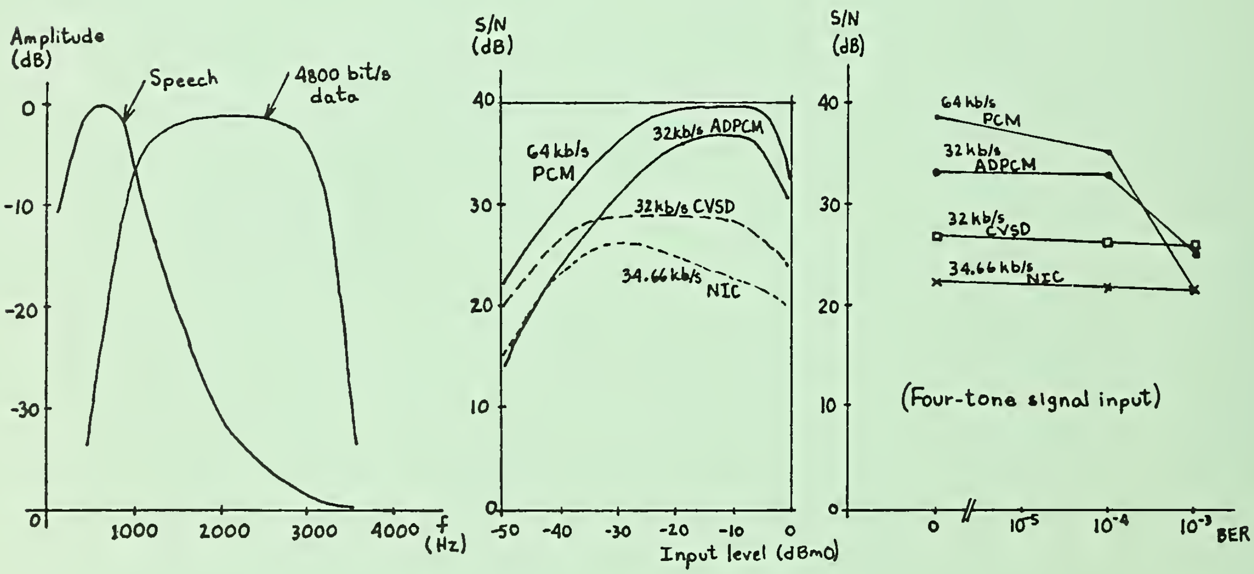


Figure 16

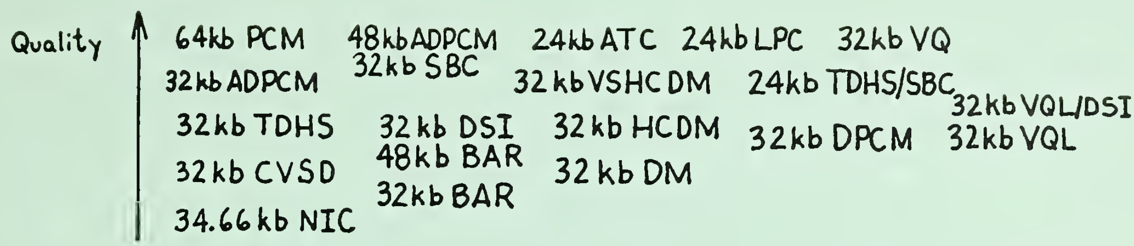


Amplitude spectrum of speech and 4.8 kbit/s data

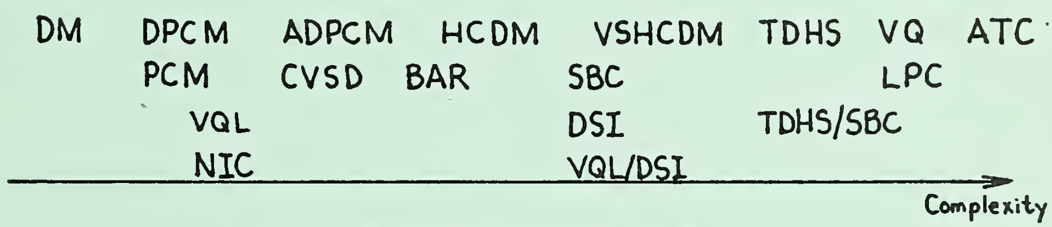
Graphical comparison of SNR between a few bit rate reduction techniques

Graphical comparison of SNR vs. bit error rate (BER) between a few bit rate reduction techniques

Figure 17



Relative Quality Comparison



Relative Complexity Comparison
(initial letter is reference)

Figure 18

CELLULAR MOBILE RADIO SYSTEM

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1. Introduction

The Cellular Mobile Radio System is a high capacity common carrier telephone system that was developed to serve densely populated metropolitan areas utilizing a minimum amount of radio frequency spectrum. Equipment has been designed for both moving vehicle and portable use. The major technological features that distinguish the cellular system are:

(1) Trunking of radio channels
(2) FCC assignment of a large frequency block
(3) Frequency synthesis
(4) Frequency reuse within a relatively small geographical area (low-power)
(5) Cell splitting
(6) Locating and self locating
(7) Master control implemented by digital messages and protocols
(8) Handoff of calls to adjacent base sites
(9) Stored program control and electronic switching
(10) Directional antennas for small cells
(11) Automatic roaming

2. Principles of the Cellular Mobile Radio System

Two independent cellular systems may be authorized to operate in a given geographical area, each being connected via land lines to the public telecommunications network. The entire radio frequency spectrum assigned to this service has been divided into two separate blocks each consisting of 333 frequency pairs with 30 kHz channel spacing. Cellular System A will use a band of frequencies between 825 MHz and 835 MHz for the mobile station transmitters and a band of frequencies between 870 MHz and 880 MHz for the base station transmitters. Cellular System B will use the band between 835 MHz and 845 MHz for mobile station transmitters and the band between 880 MHz and 890 MHz for base station transmitters. During the first two years that applications are filed all landline telephone companies will be assigned the System B frequency block.

The major subsystems of a Cellular Mobile Radio System are:

a. The Mobile (or Portable) Telephone Subscriber Station;
b. The Base Station or Cell Site;
c. The Mobile Telecommunications Switching System.

Figure 1 is a simplified diagram of one cellular system. Each cellular system is identified by a unique 15 bit digital code. The two most significant bits specify the country (00 for USA) and the least significant bit specifies either System A (1) or System B (0). The identification code of its home system is stored in the permanent memory of each mobile station.

The mobile station has both a mobile identification number and a serial number. The 34 bit binary mobile identification number is derived from the mobile station's 10 digit directory telephone number. The serial number is a 32 bit binary number that uniquely identifies a mobile station to any cellular system. It must be factory set and not readily alterable in the field. The circuitry that provides the serial number must be isolated from fraudulent contact and tampering. Attempts to change the serial number circuitry should render the mobile station inoperative. In addition to the above, a mobile station that is operating in a system other than its home system may be assigned a temporary 34 bit mobile identification number.

Each mobile station is capable of communicating on any of the 666 channels. It has the means to identify either System A or System B as the preferred system. The mobile station is intended to be used while in motion or during halts at unspecified points. It is assumed that mobile stations include portable units (e.g. hand-held personal units) as well as units installed in vehicles. Mobile stations may not communicate with each other on the same frequency pair. All transmissions must be with and through base stations only.

An important feature that is of great value in the mobile environment and not generally available on land-line telephones is "pre-origination dialing." This allows the subscriber to enter and store the called destination number

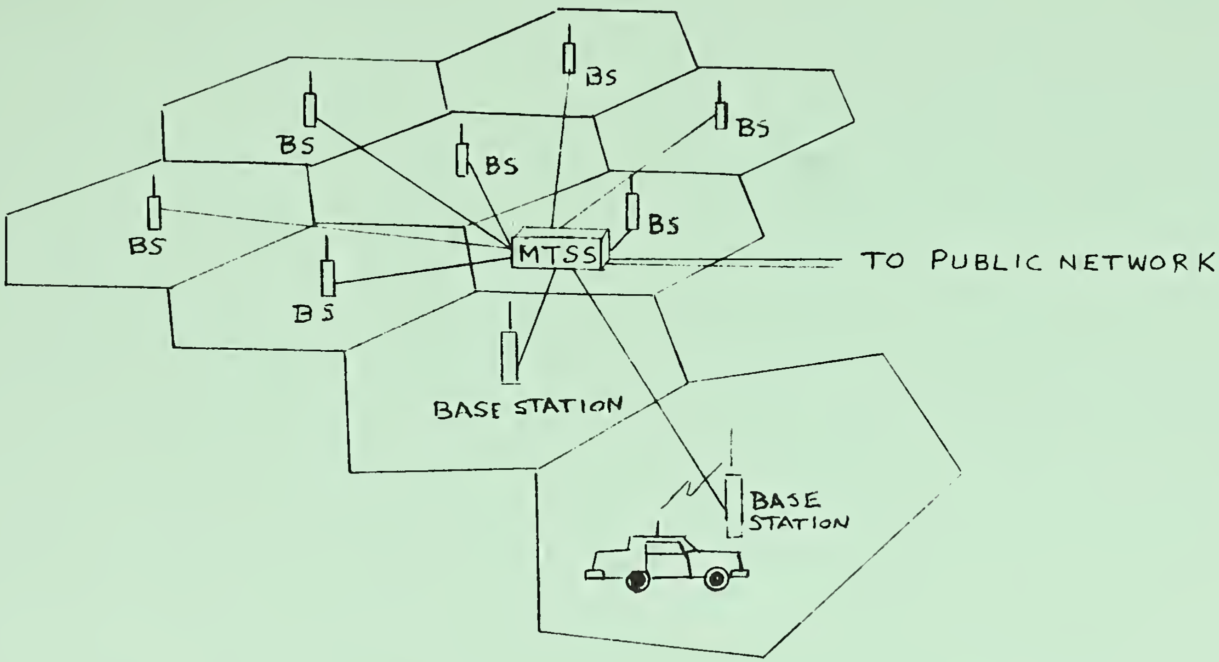


Figure 1 - A Cellular Mobile Radio System

before going off-hook. No dial tone is used. When the user wishes to place a call, he depresses the proper sequence of numbered pushbuttons. The keyed number will appear on a fluorescent display permitting him to check its validity. If a mistake has been made he can depress the "clear" button and make another attempt. When the subscriber is satisfied that the correct number has been entered into the display, call origination is started by depressing the "send" button. The system uses the stored number to establish the connection. If the called line is busy or doesn't answer the user may try again later without having to enter the same number again. This feature permits the utilization of multiple access techniques when the unit must gain access to a common control channel and substitutes automatic digital transmission of the information needed to establish the connection for time consuming manual methods. Channel usage time is not wasted by dialing errors or fumbling and hesitations during dialing.

2.1 The Cellular Concept

Frequency reuse and cell splitting are the two major aspects of the cellular concept.

2.1.1 Frequency Reuse

Frequency reuse has existed on a national scale since the early days of radio broadcasting. In order to permit the use of the same carrier frequency in a large number of different channels within a single geographic service area it is necessary to limit the power of the transmitters. The effective radiated power (ERP) of a cellular base station must not exceed 100 watts. If the transmitting antenna is more than 500 feet above the average terrain the power must be further reduced. The usual elevation, however, is from 100 to 200 feet above the ground.

The effective radiated power of a mobile station transmitter must not exceed 7 watts. The maximum power level can be reduced in steps of 4 dB on command from a base station to give a total of eight levels. The actual power will vary with the ambient temperature and the supply voltage.

Radio channels that use the same carrier frequency are said to be co-channels. If a geographical service area is subdivided into a very large number of small subareas or zones or "cells", a set of frequencies that are used in one cell may be reused in other cells that are separated from each other by sufficient distances so that co-channel interference is not objectionable. Adjacent cells will never use the same set of frequencies.

At least one land transmitter site is required for each cell. For service, the mobile station chooses the base station sending the strongest signal which is usually the nearest one. The entire allocation of 333 frequency pairs may be subdivided into distinct sets. A cell can be defined as the geographical subarea that uses one of these distinct sets. The total number of duplex channels provided by the cellular system or, in other words, the total number of simultaneous calls can, therefore, greatly exceed 333. There is no limit on the number of times the frequencies may be reused.

2.1.2 Cell Splitting

When a cellular system is initially placed in operation it will use the largest cell size possible in order to minimize the number of base stations. The maximum cell radius is a compromise between the objectives of low cost and good transmission quality. The chief transmission impairment to contend with is ambient noise; that is, receiver thermal noise and man-made environmental noise. Good quality is obtained if the radio frequency signal to ambient noise ratio, S/N, exceeds 18 dB in 90 percent of the area covered by the cell.

In most locations, this can be achieved with a cell radius of 8 miles.

The number of cells required initially is determined by the size and typography of the cellular geographic service area. Usually this does not require a reuse of frequencies since a sufficiently large number of channels will be available to handle the initial telephone traffic demand. As more and more subscribers enter the system the traffic demand in the various cells will grow. When the set of frequency pairs assigned to a given cell can no longer handle the traffic demand with a reasonable blocking rate and no additional pairs are available for assignment it will be necessary to reduce the size of the cell so as to reduce the channel loading. This is normally done by cutting the maximum cell radius in half and thereby, effectively replacing the original cell with four smaller cells. This process is called cell splitting.

It is not necessary to split all cells in the entire service area at the same time. Nor is it necessary to replace a given cell with four smaller cells. One or two small cells may be superimposed on one large cell so that the larger and the smaller cell jointly serve the area covered by the smaller cell. There can be as many as three stages of successive cell splitting. The value of three is arrived at by assuming an initial cell radius of 8 miles. Successive splitting results in radii of 4, 2 and 1 miles, respectively. All four sizes of cells may be present within a given geographic service area at the same time, thus permitting the cellular structure to adapt to the various traffic densities encountered in the region. It is not practical to consider the use of cell radii smaller than one mile because of cell-site position tolerance and the burden of frequent handoffs.

Cell splitting allows the system to adjust to a growing spatial traffic demand density without any increase in the spectrum allocation. However, as the cells decrease in size the co-channels move closer together, thus increasing possible interference. This problem will be discussed in more detail later. Each stage of cell splitting increases the number of cells fourfold. If the entire service area experiences three stages of cell splitting the number of original (maximum size) cells are multiplied by 64. The smallest size cell (one mile radius) permits each of the two systems to handle an average of approximately 17 simultaneous calls per square mile under the assumption of an equal number of channels per cell. Lower demand areas can be served by larger cells at the same time that higher demand areas are served by smaller cells.

2.1.3 The Cellular Structure

A cell is the area in which a particular set of channel carrier frequencies is the most likely set to be used by the mobile units that happen to be in the area at that time. The mobile stations may communicate with either an omnidirectional antenna base station located near the center of the cell or one of several directional antenna base stations located on the borders of the cell. Directional antennas provide superior coverage in the presence of nearby co-channels sites and border base stations can serve several cells simultaneously.

Although, in principle, cells could have any shape and base stations could be irregularly spaced such a configuration would be acceptable only if the initial layout could be frozen indefinitely. It is far more practical to utilize an orderly geometrical pattern that can be systematically revised in the future to maintain an efficient and economic operation that will be capable of adapting to spatial traffic growth. Even though propagation anomalies exist in the field a planned regular cellular pattern can be achieved by proper positioning of land transmitter sites, proper design of azimuthal gain antenna patterns and careful selection of frequency sets. The mobile station receiver periodically checks the signal levels on the control channels transmitted by all the base stations in the area and chooses the control channel that has the strongest signal. This procedure is called "self location". It is effective in the initiation of all calls (origination and completion). The locus of all points where the signal levels from two omnidirectional base stations are equal is the effective outline or boundary of a cell. A similar locus exists for two adjacent beams of a directional base station. The object of the plan for a cellular structure is that of satisfactorily achieving the above conditions.

The hexagon has been adopted as the ideal shape for a cell. Hexagonal cells can cover a plane with no gaps or overlaps. Actual propagation irregularities occasioned by "shadowing" and "multipath fading" result in an extremely rough approximation to any idealized shape. However for system design purposes and visualization, the hexagon offers many advantages.

A cell may be "center excited" or "corner excited". These terms refer to the location of the base station with respect to the hexagonal outline of an ideal cell. Center excitation is produced by an omnidirectional antenna that usually is sectored so that it can at a later stage produce directional beams. A base station at the center of a cell will control all the frequency pairs assigned to the cell. Corner excitation is produced by directional antennas located at every other corner of the hexagon. The 120° beamwidth follows the sides of the hexagon. The frequency set for a given cell is controlled by three base stations but each base station controls three cells. The radius of a hexagonal cell is defined as the distance from the center to a vertex and represents the greatest distance between a mobile station and a base station. The area of a hexagon is 2.598 times the square of the radius.

Figure 2 shows the location of the base stations for center and corner excitation. Center excitation is used when a system is initially placed in operation and employs maximum size cells. A change to corner excitation usually occurs at the first stage of cell splitting since the co-channels will move closer to each other. Figure 3 illustrates the orientation of the directional antennas. The use of corner excitation in the interior of a service area and 120° beam width requires no larger number of base stations than the use of center excitation. Cell splitting can be accomplished without relocating existing base stations. Figures 4, 5 and 6 show possible layouts for the frequency sets. The heavy border depicts the cluster of cells needed for one use of the 333 frequencies. The letters designate the frequency sets.

In order to repeat the frequency sets in a systematic way only certain cluster sizes are permissible. Possible cluster sizes are 3, 4, 7, 9, 12, 13, 16, 19 and 21. Other sizes will create overlaps or gaps. To limit adjacent channel interference adjacent channels must never be used in the same cell. Frequencies are normally assigned to each set in such a way that the maximum frequency separation in achieved. For example, if a 12 cell cluster is used for System A, set a (see Figure 6) would use channels 1, 13, 25, 37, etc.; set b would use channels 2, 14, 26, 38, etc.; and set c would use channels 3, 15, 27, 39, etc. By the utilization of a 12 cell cluster it is possible to avoid the use of adjacent frequencies in adjacent cells. For this reason the 12 cell cluster is usually used for initial operation with omni-directional antennas.

When directional antennas are used it is possible to achieve a satisfactory signal to co-channel interference ratio with the use of only 7 cells per cluster. Although it is now impossible to avoid having adjacent channels at adjacent cells there is an effective alternative. Each of the seven sets is subdivided into three subsets to give a total of 21 subsets. These subsets are deployed as illustrated in Figure 7 so that each 120° lobe from a cluster of seven base stations is associated with one of the subsets. The received adjacent channel interference, at both the mobile station and the base station, is usually attenuated by the front-to-back ratio of the base station directional antennas.

There are various ways of assigning frequencies to the antenna faces at the base stations. In Figure 7, the number within the circles indicate the lowest frequency of the subset. Adjacent numbers represent adjacent frequencies. There is a distance of 21 between each member of a subset, e.g. 2, 23, 44, 65, etc. The base station controls frequencies separated by 7, that is, 2, 9, 16, 23, 30, 37, 44, etc. For corner excitation it is more appropiate to consider the frequency set as a property of the base station rather than that of the cell.

Figure 8 demonstrates the transition from a system of 12 channel sets and omnidirectional antennas to a system of 21 channel subsets and directional antennas. Most of the 21 subsets will accommodate 15 voice channels, giving a total of 45 voice channels per base station. Since 21 channels are set aside for control channels the maximum number of voice channels for each cluster of 7 cells may not exceed 312.

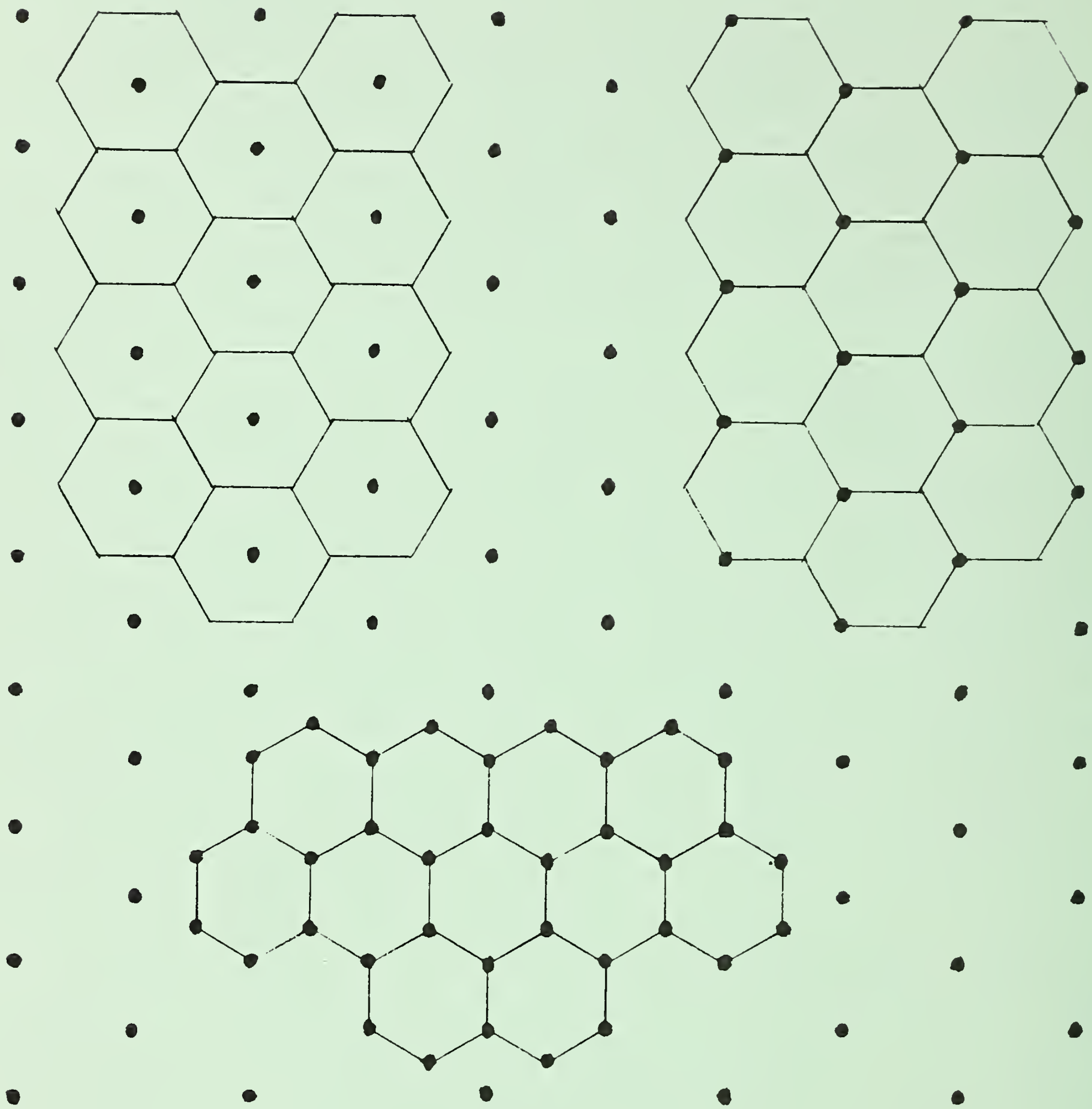
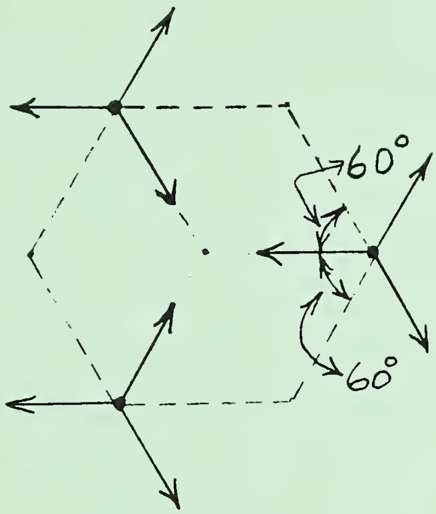


Figure 2 - "Center Excited" Cells vs. "Corner Excited" Cells

Note: Dots indicate location of antennas. These form a pattern of equidistant points (three adjacent points are vertices of equilateral triangle)

(a) Upper left shows center excitation (regular pattern)
(b) Upper right shows corner excitation with 120^{o} beams (regular pattern)
(c) Bottom shows corner excitation with 60^{o} beams (irregular pattern)



120° BEAMS

NOTE: ARROWS SHOW MAIN AXIS OF FRONT LOBES

60° BEAMS

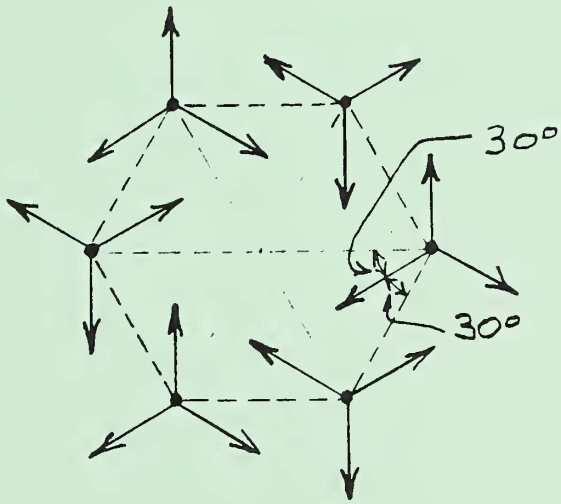


Figure 3 - Orientation of Directional Antennas

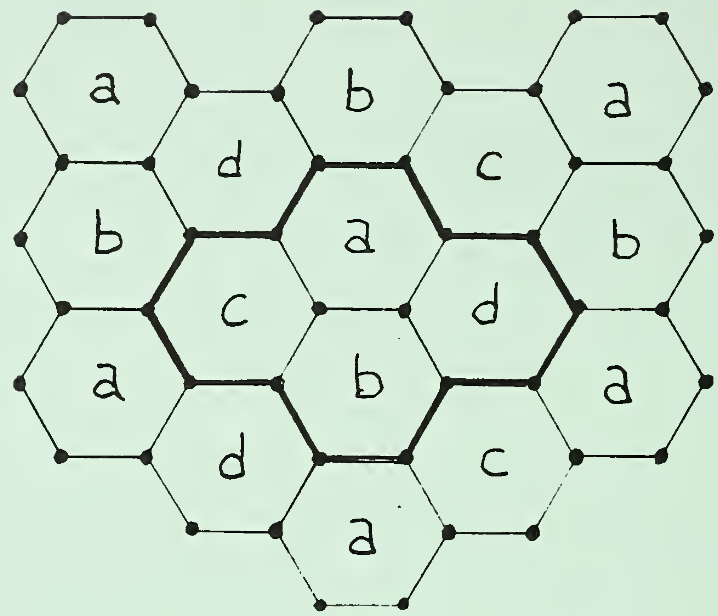


Figure 4 - Four Cell Cluster

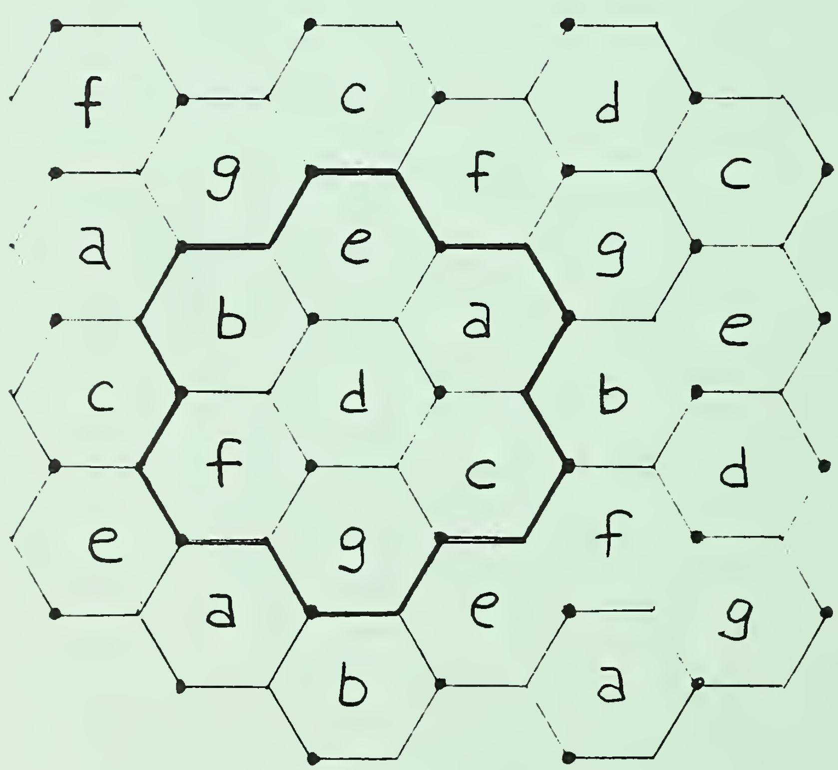


Figure 5 - Seven Cell Cluster

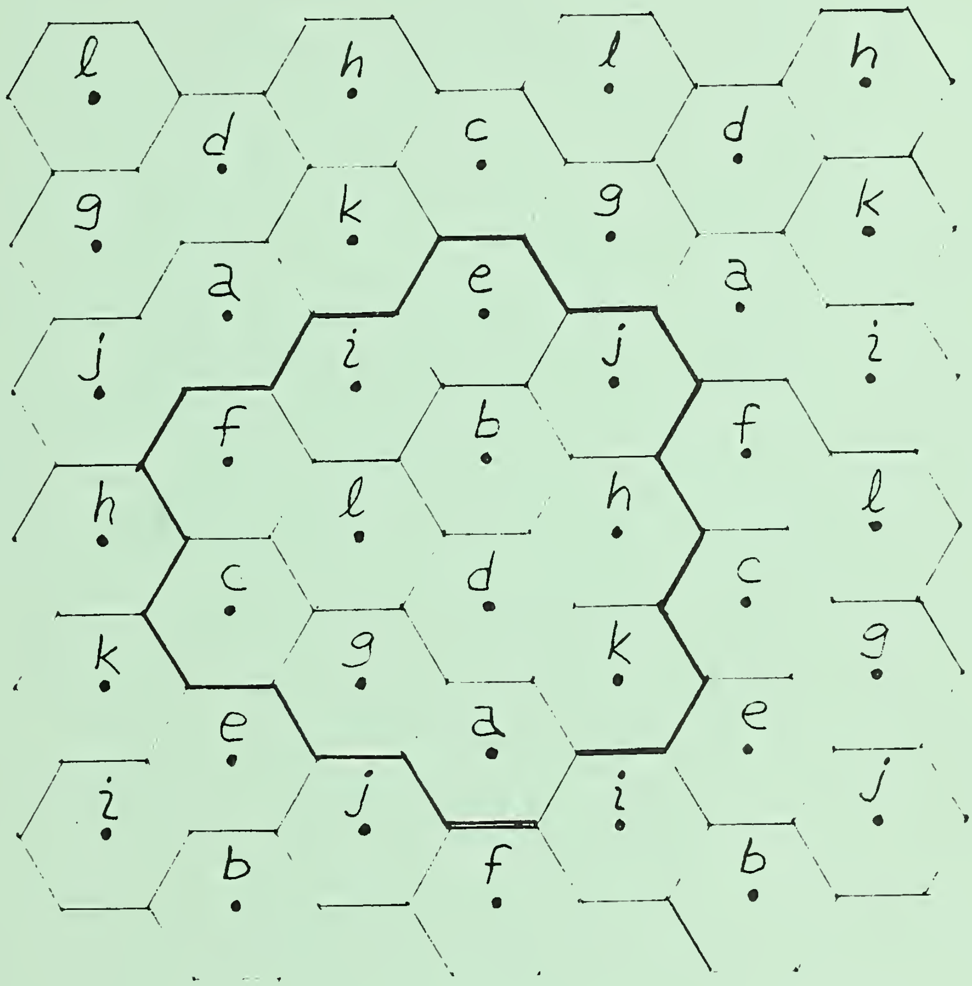


Figure 6 - Twelve Cell Cluster

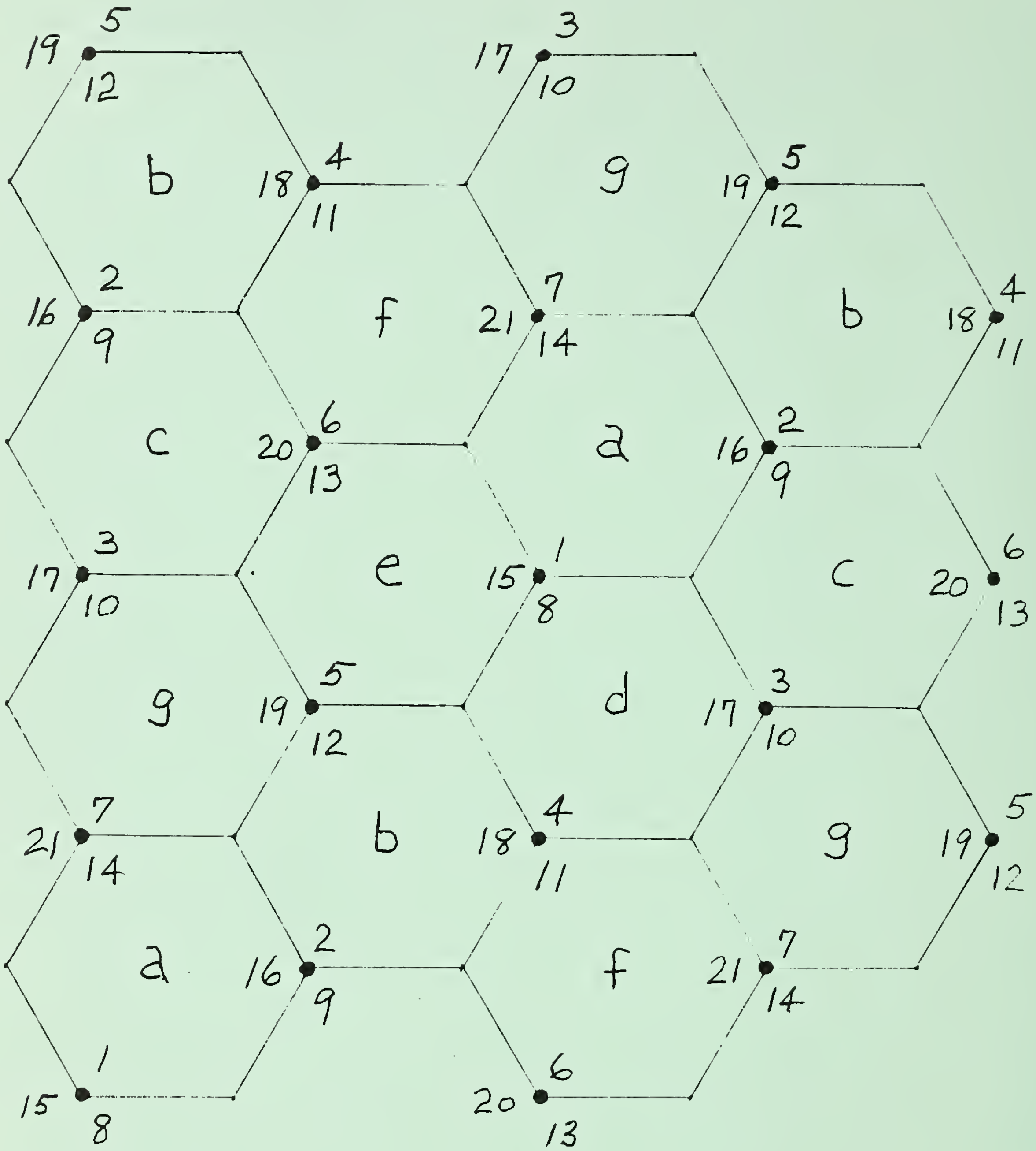


Figure 7 - Assignment of Frequencies to 120° Antenna Beams

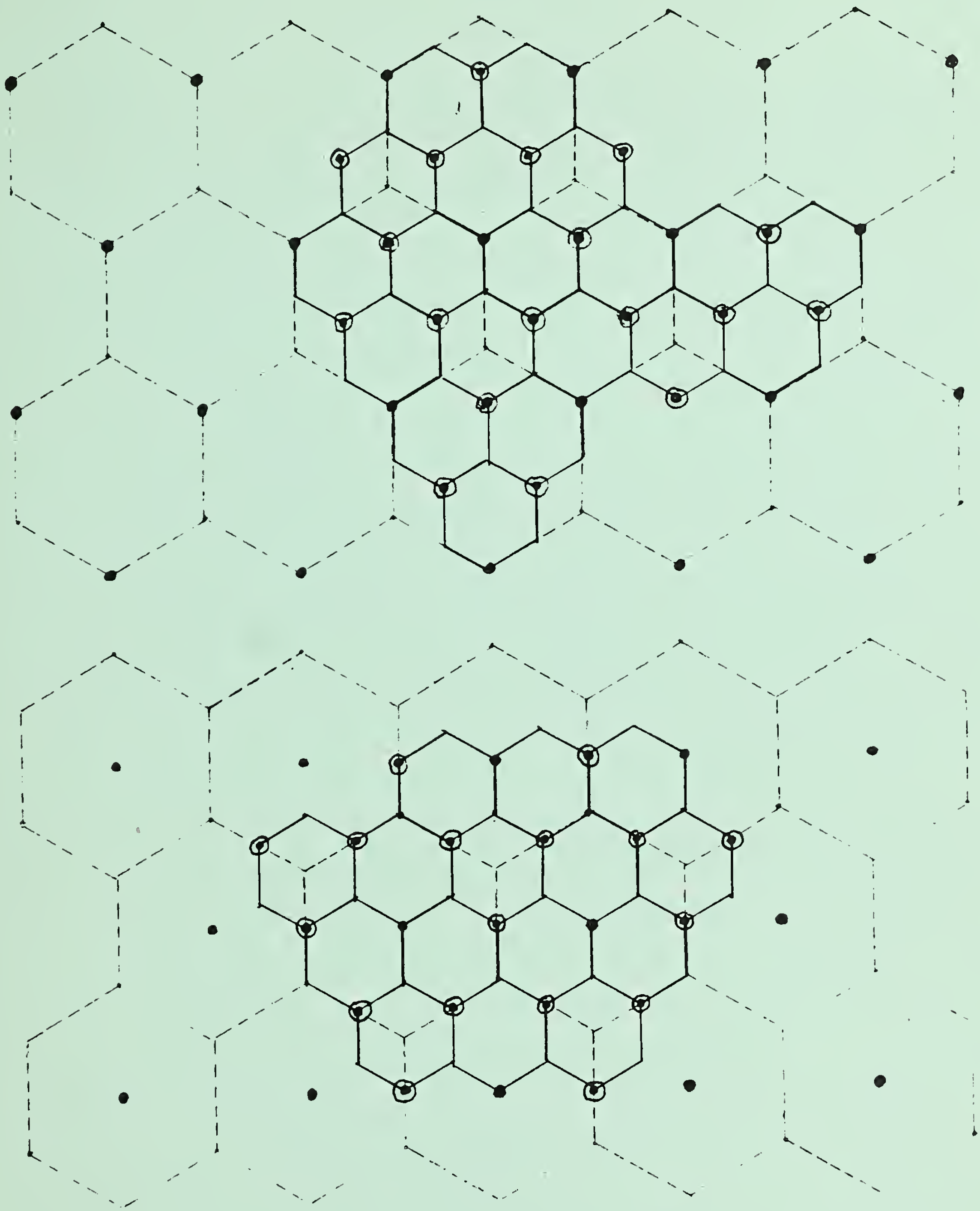


Figure 8 - Cell Splitting

Note: Circled dots show new base stations. Upper view shows splitting when both stages have corner excitation and 120° antennas. Lower view shows change from center excitation to corner excitation and 120° antennas.

For each stage of cell splitting, a new base station is located exactly halfway between each pair of existing base stations. This will result in the addition of three new base stations for every existing base station in the portion of the service area that is being split. New cell boundaries are chosen in such a way that the new cells will again form hexagons. Half of the old boundary is reused and half disappears. A change from center excitation to corner excitation does not affect this procedure. A careful study of Figure 8 together with the above procedure should show that it is possible to achieve a different configuration for the new hexagons that represents a rotation of 60^{0} from the configuration shown.

In the transition shown in Figure 8, that is, from omnidirectional to directional antennas, a gradual alteration may be necessary in the assignment of channel frequencies to base stations. Once directional operation is established, however, additional stages of splitting does not alter any existing assignments. Each new base station will find a location that is midway between two existing co-channel base stations. This same set of frequencies should be assigned to the new station.

Although ideally new base stations should be located precisely as described above, in practice the actual position may be anywhere within a tolerance of one quarter of the smaller cell radius without causing undue interference problems. All the channel equipments at the various base sites are identical. The changes in frequency assignments mentioned above are effected by software.

2.1.4 Cellular System Parameters

The choice of the number of cells per cluster is determined principally by co-channel interference and to a lesser extent by adjacent channel interference. The "co-channel reuse ratio" is defined as the ratio of the distance (D) between the base station sites using the same frequency set to the cell radius (R). This ratio is equal to the square root of three times the number of cells per cluster (N).

$$\frac{D}{R} = (3N)^{\frac{1}{2}} \qquad (1)$$

As the number of cells per cluster decreases, the relative separation between co-channel sites decreases and the probability of poor signal to interference conditions increases. For a 12 cell cluster, D/R is equal to 6.0; for a 7 cell cluster, D/R is equal to 4.58; for a 4 cell cluster, D/R is equal to 3.46.

The co-channel reuse ratio has an impact on (a) transmission quality, (b) total system cost and (c) ultimate system capacity.

A directional antenna can transmit the same signal level as an omnidirectional antenna in the region it serves while causing substantially less interference within co-channel cells that lie outside the illumination area of the front lobe. Similarly, a directional receiving antenna substantially attenuates interference from mobile stations at locations not covered by the front lobe. This permits the directional antenna base station to operate satisfactorily with a lower co-channel reuse ratio than that required for an omnidirectional antenna base station.

Tests have indicated that the transmission quality is usually judged to be good or excellent at a signal to interference ratio (S/I) of 17 dB over 90% of the coverage area. This condition can be met either with a D/R ratio of 4.58 for directional antennas or with a D/R ratio of 6.0 for omnidirectional antennas. Consequently, the choices of a 12 cell cluster with omnidirectional base stations and a 7 cell cluster with directional base stations give equivalent transmission quality.

For a given total number of channels in a system or for a given traffic load a 7 cell cluster requires only 7/12 as many base station sites as does a 12 cell cluster. Although a directional antenna is more expensive than an omnidirectional antenna, the smaller number of base sites reduces the total cost of the system. Additionally, for the smallest size cell (one mile radius) a 7 cell cluster will provide a greater traffic density since it may use 12/7 times as many channels. Therefore, the ultimate system capacity is greater.

The foregoing discussion obviously assumes that frequencies will be reused. If a system is so small that frequency reuse is not required and that never in the foreseeable future will there be a need for more than 312 channels then the only interference that needs be considered is from adjacent channels.

Table 1 is presented to illustrate the graceful way in which a cellular system can grow and adapt to an increasing spatial traffic density. It is assumed that this would represent the central part of a large metropolitian area. The channel groups specified indicate the maximum number of channels available. Fewer may be used. For a 7 cell cluster the number 312 is not exactly divisible by 7. Most of the subareas may, however, have 15 channels. The column entitled "Density Factor (Reuse Factor)" shows the increase in spatial density brought about by each stage of cell splitting as well as the number of additional times the frequency sets are reused. The column for "Base Station Factor" shows the increasing cost for the added number of base sites. This cost would include such things as the building, real estate, legal fees, heating, lighting, and antenna tower but not the base station equipment.

The bottom half of the table shows the possible use of 4 cell clusters either as a fourth step that would not encompass cell splitting or as a combination third step that also included cell splitting. This would be applicable only in the densest areas of large cities. It is assumed that the use of 60° beam directional antennas located at every corner of the hexagons would give equivalent transmission quality to that obtained in 7 cell clusters with 120° beam antennas located at every other corner. Doing this without changing the size of the cell would double the cost for base stations but achieve a 75% increase in ultimate system capacity.

The use of antennas at every corner creates an irregular pattern for base stations and therefore would not be recommended at an earlier stage. The use of omnidirectional antennas at the centers of hexagons or the use of directional antennas at every other corner creates a regular lattice of equidistant base stations spaced at a distance equal to the square root of three times the cell radius. If an additional antenna were placed at the center of the hexagon with one at every corner, a regular lattice of equidistant antennas spaced at a distance equal to the cell radius would result. However, such an antenna is not required and serves no useful purpose.

Table 1
Cost and Spatial Density Factors Resulting from Cell Splitting

Split	Cluster Size	Maximum Channels Per Group	Base Station Factor	Density Factor (Reuse Factor)
0	12	26	1	1
1 (120^o)	7	15 (45-42)	x4	x6.86
2 (120^o)	7	15 (45-42)	x4	x4
3 (120^o)	7	15 (45-42)	x4	x4
60^o	4	13 (39)	x2	x1.75
3 (60^o)	4	13 (39)	x8	x7
Products of Factors			128	192

(   ) = Maximum Channels Per Base Station

2.2 Trunking and Frequency Synthesis

The concept of trunking has been used for many years in the landline network to increase the traffic-carrying efficiency and to reduce the blocking probability for calls on inter-office trunks. The Cellular Radio System utilizes the concept of trunking for subscriber channels. This feature provides the ability to combine a number of channels into a single group so that a mobile unit can utilize any unused channel in the group. Former mobile radio systems have used this concept but only for a small number of channels. Each mobile unit is capable of operating on any of 666 channels.

The same is true for the radios at the base station sites. The master system control computer assigns the frequency pairs on a dynamic basis limited only by the sizes of the channel groups available in any given geographic sub-area.

The mobile units and the base site radios do not require circuit tuning. All carrier frequencies are synthesized as needed in each equipment unit. Frequency synthesis significantly reduces the cost of each unit and permits standardization. The number of channel equipment units (or radios) installed at a base station site must only be sufficient to handle the expected busy hour traffic with a stated grade of service. The grade of service is equal to the probability of blocking (finding all channels in use) at any time that a call is being originated or completed. There must be one radio available at the base site for each call in progress.

Trunking is an important feature of the Cellular System and can be used to advantage in all size systems including those so small that frequency reuse is not required. It enables the system design to adjust to different amounts of expected traffic within cells of constant size.

Mobile vehicle and portable traffic loads are very light. The assumption usually made is that the calling rate (origination and completion) will be one call per subscriber per busy-hour. In the AT&T developmental test in Chicago the mean (or average) call duration time was 100 seconds. Since the service was free this value was not affected by cost of service. The traffic intensity expressed in consistent time units is the product of the call arrival rate and the average holding time (call duration time). For mobile traffic, then, the traffic intensity is 100 call seconds = 1 CCS = 0.028 Erlang per subscriber. The TE&CM Section 322 Application Guide advises the use of 3.6 CCS per fixed business subscriber and 2.4 CCS per fixed residential subscriber for new digital offices. It would appear that a fixed service for business use would require 3.6 times as many channels as for mobile traffic if the same channel group sizes were used.

The estimate of the rate at which calls enter the system is derived from the following assumptions. Each subscriber is expected to average 0.6 origination per busy hour. The attempts made to complete calls to each subscriber is expected to average 0.8 call per busy hour, of which half are successful. The sum in these two directions will average 1 call per subscriber per busy hour.

Table 2 shows traffic intensity in both CCS and Erlangs per channel for various channel group sizes and blocking rates. Since mobile traffic is expected to average 1 CCS per subscriber the table values also give the number of subscribers that can be served per channel. Table 1 gives the maximum group size for different stages of a cellular system if the channels are distributed equally over all cells of the cell cluster.

The maximum average spatial density that can be obtained with the smallest size cell and a 2% grade of service is approximately 615 subscribers per square mile per system.

Table 2

Traffic Intensity in CCS/Channel (Erlang/Channel)

Channel Group Size	Blocking Rate		
	1%	2%	5%
13	18.0 (.50)	20.5 (.57)	24.5 (.68)
15	19.4 (.54)	21.6 (.60)	25.6 (.71)
26	23.8 (.66)	25.6 (.71)	29.2 (.81)
39	25.9 (.72)	28.1 (.78)	31.3 (.87)
45	26.6 (.74)	28.8 (.80)	31.7 (.88)
52	27.7 (.77)	29.5 (.82)	32.4 (.90)

Note: For a traffic intensity of 1 CCS per subscriber the CCS values in the table give the number of subscribers per channel.

2.3 The Control Concept and Implementation

Although the Cellular Mobile Radio System utilizes analogue transmission, control is effected for the most part by methods that are the same as those used with digital data transmission networks. Microprocessors and control computers are contained in both the mobile and fixed station equipment. Interfaces are maintained by digital messages using prescribed control words that are repeated 5 or 11 times. This is euphemistically called wideband data transmission although the effective information rate is rather low. Control channels are used exclusively for data transmission. Voice channels are utilized as required for control messages by means of a "blank and burst" technique. There is no provision in the Cellular system for any kind of user-to-user data transmission.

Master system control is implemented by the stored program Mobile Telecommunications Switching System (MTSS). However, control is distributed among all elements of the Cellular system. The major control functions are:

(a) Interfacing with the nationwide switched telephone network;
(b) Dialing from mobile units;
(c) Supervising calls from mobile subscribers in the presence of noise and co-channel interference;
(d) Performing call setup functions including paging and access;
(e) Locating and handing off mobiles between base stations;
(f) Handling roamers by interim methods initially, and later as a part of a nationwide automatic roaming system.

Basically, the cellular system requires a grid of base sites distributed throughout a mobile coverage area to serve as the interface between the large numbers of moving customers and the public switched telephone network. Figure 9 shows the connections required between the basic control elements. The mobile stations communicate with nearby base stations by means of radio voice channels and control channels. The base stations are connected to the MTSS by land-line facilities consisting of voice trunks and a common channel for control. The land-line voice trunks are provided on a one-to-one basis with the base station radios. In most cases, one common control channel per base station is sufficient although this is duplicated for use in case of failure. The MTSS is connected to the public switched network as a standard interoffice connection.

The radio channels are numbered in consecutive order beginning with the lowest frequency pair. Channel #1 is the designation applied to the mobile station transmit channel at 825.030 MHz and the corresponding land station transmit channel at 870.030 MHz. Each succeeding channel is spaced at a 30 kHz higher value. Channels #1 through #312 are designated as voice channels for System A while channels #355 through #666 are designated as voice channels for System B. Twenty-one control channels are reserved for each system. System A uses channels #313 through #333 for control and System B uses channels #334 through #354 for control. Channel #666 operates at 844.980 MHz and 889.980 MHz, respectively. Transmit and receive are always separated by 45 MHz.

2.3.1 Analog Supervisory Tones

During periods of voice transmission it is necessary to use two out-of-band tones for supervision. One of these is known as the "supervisory audio tone" or SAT and consists of a continuous modulation that originates at a base station transmitter and is transponded back by the mobile station transmitter when received by the mobile unit. The supervisory audio tone (SAT) is one of three frequencies, 5970 Hz, 6000 Hz, or 6030 Hz. Only one of these is employed at a given base site. The base station looks for the specific SAT it sent to be returned; if some other SAT is returned the incoming RF power is interpreted as being corrupted by interference either in the land-to-mobile or in the mobile-to-land direction. The phrase "transponded back" means that the mobile station receiver must detect and filter the transmission from the base station and then modulate its transmitted voice channel with this same tone. If the base station does not receive a returned SAT, it assumes that either the mobile is in fade or that the mobile transmitter is off. All base stations associated with a given cell cluster will use the same SAT frequency. Three adjacent cell clusters will use different SAT frequencies. This effectively multiplies D/R, the co-channel reuse ratio (defined in paragraph 2.1.4 and equation 1) for supervision by the square root of 3. For example, if a 7 cell cluster is being used, a base site that has both the same frequency set and the same SAT is as far away as if the cluster had 21 cells. The second out-of-band tone is known as the signaling tone (ST) and consists of a burst of 10,000 Hz that originates at a mobile station transmitter and is used only in the mobile-to-land direction. When the base station receiver detects a returned SAT but no signaling tone, the mobile is said to be

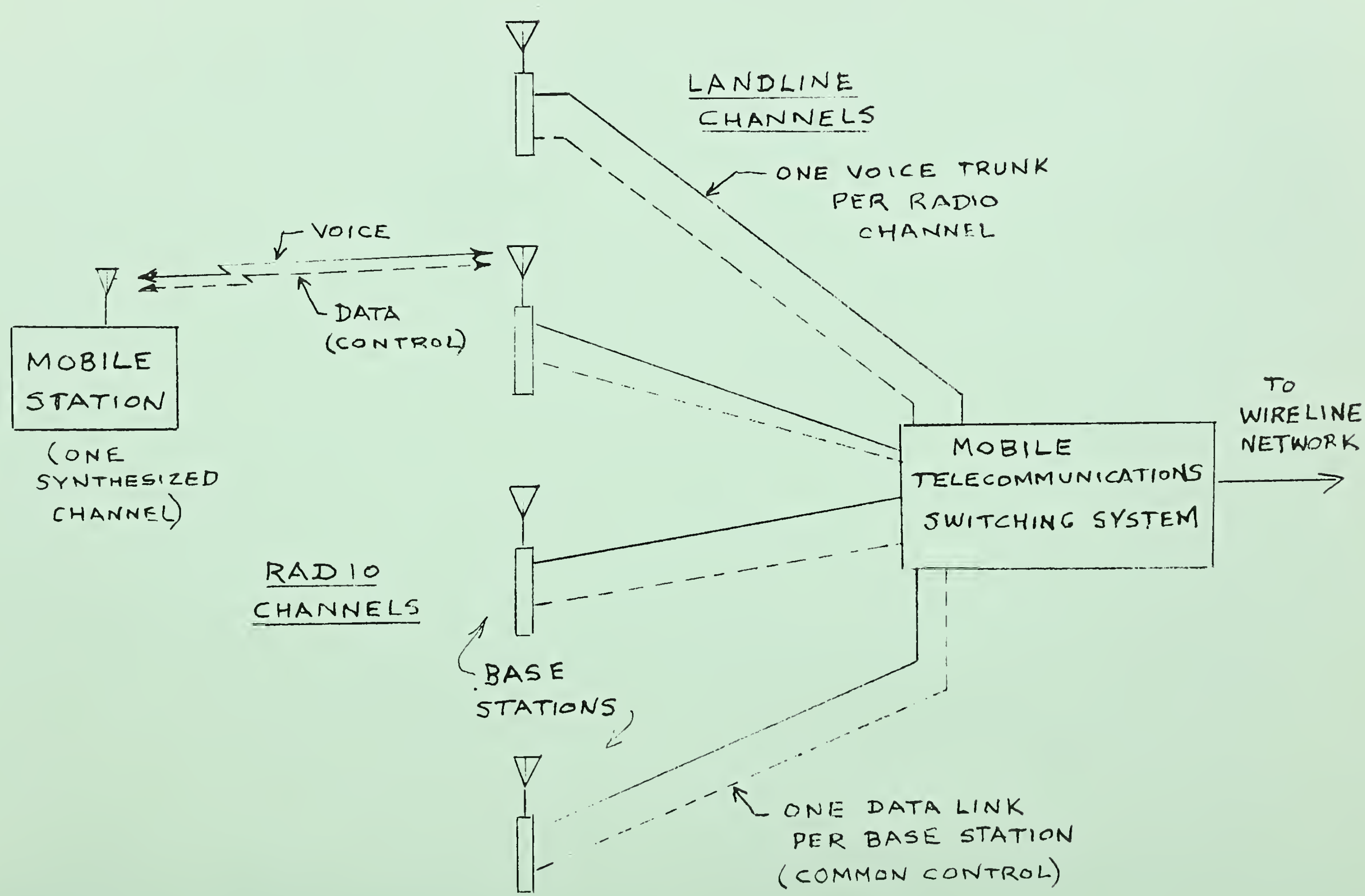


Figure 9 - Major System Connections

"off-hook". When both a returned SAT and an ST burst are received, the mobile is said to be "on-hook". Signaling tone is present when the user is

(a) being alerted
(b) being handed off
(c) disconnecting
(d) flashing for mid-call service such as, "hold".

These two tones are used only on voice channels when data is not being transmitted. The supervisory audio tone is also called an analog color code which may be represented by a two bit digital number that is transmitted over the forward control channel as part of a message sent by the base station to the mobile unit. The mobile station stores this number in its temporary memory and calls it the SAT color code. In addition to the above, the EIA compatibility specification provides for a two bit digital color code (DCC) that is also transmitted over the forward control channel. The mobile unit will then transmit a 7 bit version of the DCC back over the reverse control channel.

Whenever the mobile station is transmitting on a voice channel, it may signal the occurrence of certain events during the progress of a call by changing the status of the SAT and the ST, abbreviated (SAT, ST) in a prescribed manner. These status changes are interpreted by the base station as a message, wherein the presence of a tone is represented by 1 and the absence by 0. In addition to the analog signaling to and from the mobile station, digital messages can be sent to and from the mobile station. The response to a digital message sent to the mobile station will be either a digital message or a status change of (SAT, ST). The burst of signaling tone (ST) has different prescribed durations depending on the context in which it is being sent.

2.3.2 Digital Message Formats

The digital message bits are generated at a 10 kilobit/second rate, converted to a 20 kilobaud Manchester code that contains a clock signal and used to modulate the transmitter carrier with direct binary frequency shift keying. A continuous wideband data stream is transmitted on the forward control channel from the land station to the mobile station. On the reverse control channel, the mobiles act in a random and competitive way to initiate calls, the signals and the interferences being turned on and off in an uncorrelated fashion. Each action represents a burst of a wideband data stream transmitted from a mobile station to the land station. The forward control (or setup) channel with the reverse control (or setup) channel constitute one duplex control channel using one pair of carrier frequencies. Although the voice channels are primarily used for conversation, it is necessary to transmit messages over them while a call is in progress. The technique used for this is "blank-and-burst"; that is, the voice signal is blanked and a wideband data stream is transmitted in a burst. This occurs in both directions.

2.3.2.1 Forward Control Channel Format

The continuous data stream on the forward control channel actually consists of three discrete information streams, called message stream A, message stream B, and the busy-idle stream, that are time-multiplexed together. A given mobile unit is not required to decode both of the message streams. Messages to mobile stations having the least significant bit of their mobile identification number equal to "0" are sent on stream A, and those having the least significant bit of their mobile identification number equal to "1" are sent on stream B. Details of the data format are shown in figure 10. The format is periodic to provide synchronization to the idle mobile units. The basic periodicity is 463 bits, (46.3 milliseconds) summed as follows:

200 bits -- Word A (40 bits, repeated 5 times)
200 bits -- Word B (40 bits, repeated 5 times)
10 bits -- Bit sync (dotting 1010101010)
11 bits -- Word sync (11100010010)
42 bits -- Busy-idle bits
463 bits

The interleaving of the five repeats of words A and B ensures partial decorrelation of bit errors between repeats of the same word. The busy-idle bits (0 = busy, 1 = idle) indicate the current status of the reverse control channel. A busy-idle bit is located at the end of each dotting sequence, at the end of each word sync and after each 10 message bits. The effective busy-idle status information rate is approximately 907 bits/second. Each message word contains 28 information bits and 12 parity bits giving an effective information rate of approximately 605 bits per second. Each message may consist of one, two or four words. The information content of these messages relate to pages, channel designations, overhead words and filler text. The forward control channel is a broadcast channel whereby a given base station broadcasts continuously to all idle mobile stations in its general area. The dotting sequence consisting of alternate ones and zeros provide bit synchronization while the special 11 bit code, 11100010010, provides word synchronization. These codes precede each word block. The Manchester code used on the transmitted 10 kilobit/second data stream enables each idle mobile station to derive a stable clock waveform from the received signal.

2.3.2.2 Reverse Control Channel Format

Details on the data format for a single burst of data sent by a mobile station on the reverse control channel is shown in Figure 11. A 48 bit seizure precursor precedes each message. The message consists of from 1 to 5 words repeated 5 times. Each message word contains 36 information bits and 12 parity bits. The information rate varies from 1250 bits/second to 1442 bits/second depending on the number of words in the message. The duration of a burst varies from 28.8 milliseconds to 124.8 milliseconds. The precursor consists of a 30 bit dotting sequence, a word sync (11100010010) and a 7 bit sequence known as the coded digital color code (coded DCC). The coded DCC is one of four sequences used to identify the cell site at which the message is

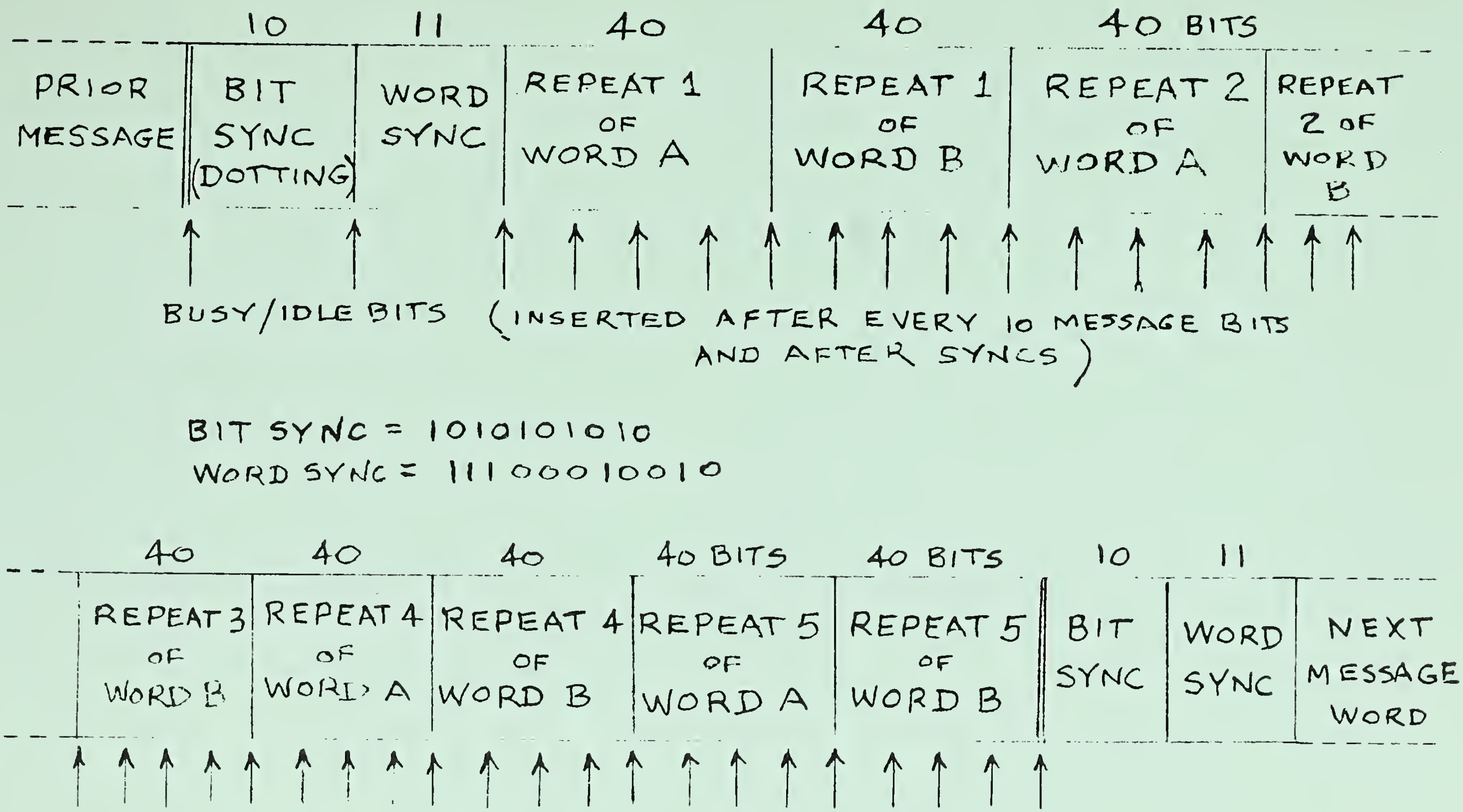


Figure 10 - Forward Control Channel Message Format (Land to Mobile)

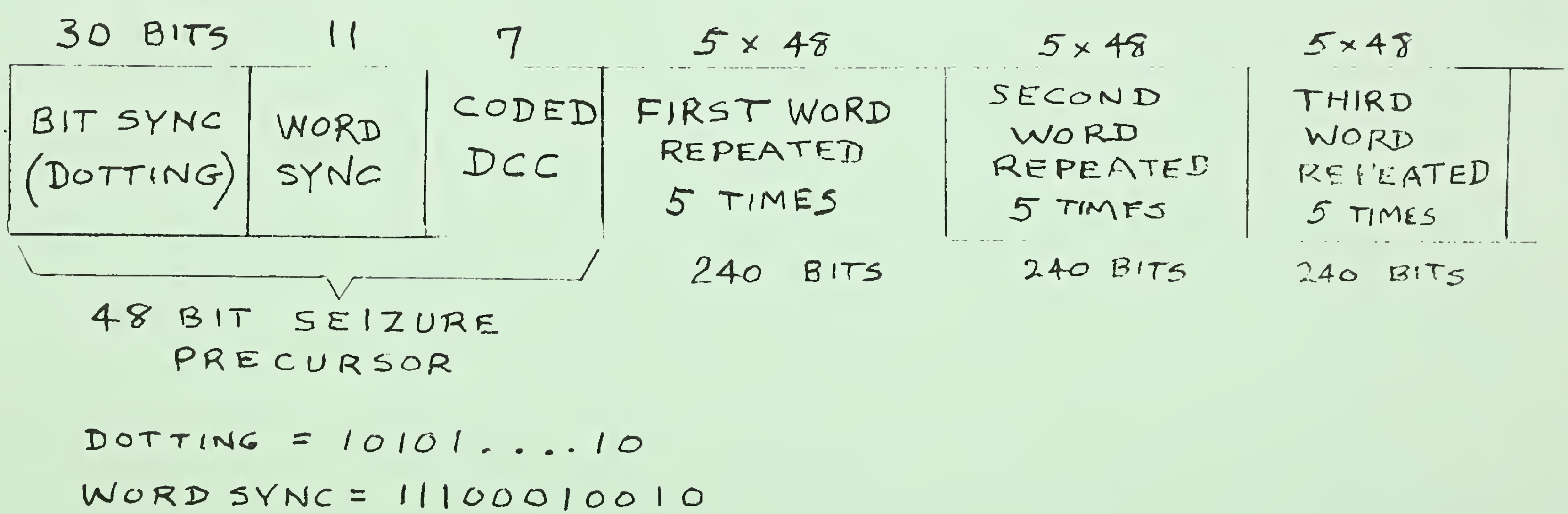


Figure 11 - Reverse Control Channel Message Format (Mobile to Land)

aimed. The mobile station will use the channel to respond to a page, to originate a call, to register with the system or to request a disconnect. The reverse control channel provides the path whereby many mobile stations can send messages to the base station that appears to be nearest to them at any given time.

2.3.2.3 Voice Channel Formats

During the progress of a call there are certain times when it is necessary to send data messages on the voice channels, the primary reason being handoff. The voice signal is blanked for a fraction of a second during which time a burst of data is transmitted as if this were a control channel. The data formats used (forward and reverse) are shown in Figures 12 and 13. In the forward direction (land station to mobile station) the message is a single word that it repeated 11 times. The primary reason for that many repeats is that the handoff message is usually sent under atypically low signal to interference conditions. The word has 28 information bits and 12 parity bits. Each repeat is preceded by a bit sync (or dotting code) and a word sync (11100010010). The initial bit sync contains 101 bits while the others have 37 bits. The information rate is approximately 271 bits per second with a message duration of 103.2 milliseconds.

In the reverse direction, the message has either one or two words each being repeated 5 times. A word has 36 information bits and 12 parity bits and is preceded by bit and word syncs as described above. The information rates are approximately 662 and 703 bits/second with message durations equal to 54.4 and 102.4 milliseconds, respectively.

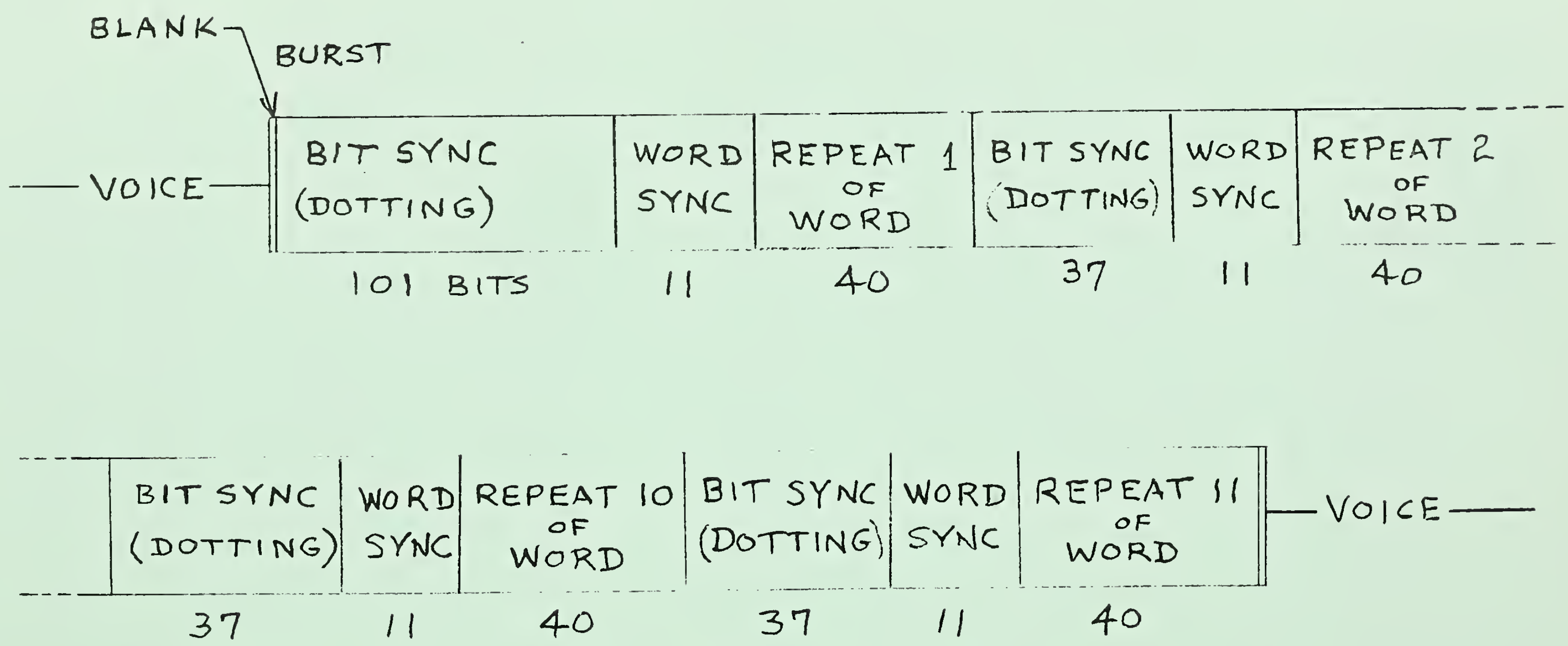
2.3.2.4 Land-line Data Channel Format

Voice and control utilize completely separate landline facilities between a base station and the Mobile Telecommunications Switching System. Control of all connections is effected by digital messages sent over one or two common duplex data channels. The capacity of the common channels must be great enough to handle all traffic expected at a mature base station. Since these channels operate totally within a given cellular radio system all installations are not required to use the same format. One such format is shown in Figure 14. The channel data rate is 2400 bits/second or 75 words per second. Synchronization is via a 3 bit preamble embedded at the start of each message word. The 32 bit word includes the 3 bit sync, a 6 bit parity check and 23 bits for information. The true information rate is 1725 bits/second.

2.3.3 Error Detection and Correction

The most serious transmission impairment encountered on the radio channels is the rapid fading experienced by signals as mobiles move through the complex radio frequency interference pattern.

To combat the burst errors caused by this fading, all data words are encoded and repeated either 5 or 11 times at the source, and a bit-by-bit, 3-out-of-5



DOTTING = 10101....101

WORD SYNC = 11100010010

Figure 12 - Forward Voice Channel Message Format (Land to Mobile)

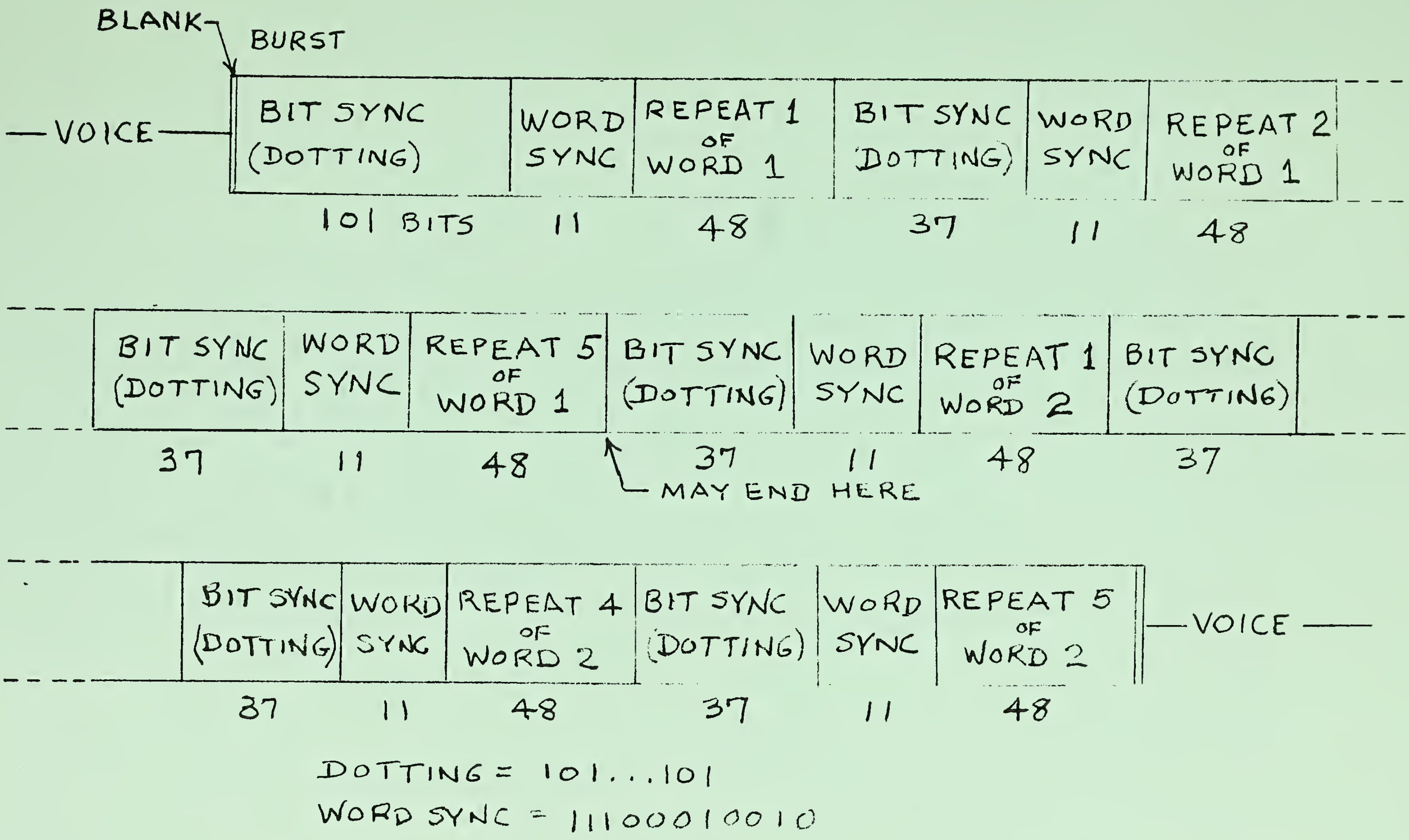


Figure 13 - Reverse Voice Channel Message Format (Mobile to Land)

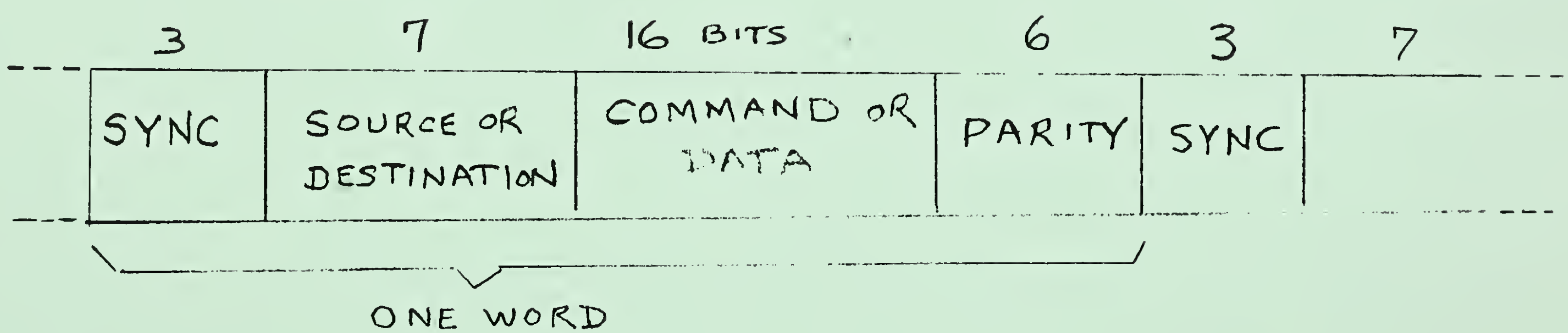


Figure 14 - Typical Message Format for Common Data Link (MTSS/Base Station)

majority vote is taken at the receiver to determine the best-guess detected word to send to the decoder. Only 5 of the 11 repeats are loaded, the extra redundancy assuring reception of at least 5. The coding used on the radio channels is a systematic linear block code originated by Bose, Chaudhuri and Hocquenghem. These codes are particularly effective in the detection and correction of randomly occurring multiple errors. The (40, 28; 5) BCH code used in the forward direction and the (48, 36; 5) BCH code used in the reverse direction are each a shortened version of the primitive (63, 51; 5) BCH code. These numbers indicate that 63 bits are transmitted of which 51 are information and 12 are parity-check bits; the distance between valid codes is 5. This code has the capability of correcting one error while detecting at least two more. The above scheme provides a good balance between a low miss rate (probability of not detecting a message when one is sent) and a low falsing rate (probability of detecting the wrong message). The coding scheme chosen for the landline data channel is a (32, 26) BCH code shortened from a basic (63, 57) BCH code.

2.4 Paging, Access, Handoff and Roaming

2.4.1 Supervision

Supervision has a broader meaning in a cellular radio system than in classical landline telephony. In addition to the detection of changes in the switch-hook state of the mobile station it also has the task of ensuring that adequate radio frequency signal strength is maintained during a call. Unlike other mobile telephone systems this system must function satisfactorily in the presence of nearby co-channel interference. Due to the limited range of the low power transmitters, the mobile station may be required to change land stations and/or radio voice channels during the process of a single call. This change is called handoff. During handoff, the connection to the public landline telecommunication network must be rapidly switched from one base station to another. An established telephone connection will come to a premature end only when the mobile vehicle reaches the outside boundary of the cellular geographic service area.

No attempt is made or contemplated to maintain a connection if the mobile crosses the boundary between two adjacent service areas or systems. In the same sense, calls are not switched between two competing systems in the same general geographic service area even though one system may cover a larger area than the other. If two or more independent system operators desire to maintain continuous coverage throughout a large geographical region they must join in a common enterprise to establish a single system in the region. Even the latter can not be accomplished under existing FCC rules if it would encompass a crossing of the boundary of an established Metropolitan Statistical Area. (An exception was made in the Baltimore/Washington region.)

2.4.2 Locating and Self-locating

When power is applied to the mobile station, the unit will scan the appropiate set of control channels to find the two channels that have the greatest signal strength. After storing the channel numbers, it will continue to listen to the messages on the forward control channel (used for paging) that has the greatest strength. This process will be repeated at least once a minute thereafter and again immediately prior to any access attempt. (A different set of control channels may be used for access). This process is called self-locating. This represents the way in which a mobile station becomes associated with a particular land station at the initiation of a call.

During the progress of a call, the cellular system will maintain the signal strength from the mobile unit at a high level so that (a) the mobile's average signal to interference ratio is adequate for its own high quality communication, and (b) other active mobiles do not experience high co-channel or adjacent channel interference. One possible command is to change the mobile station's power level. This supervisory function is known as locating.

Locating requires two measurements. One is a measurement of gross range made on each active channel using the voice channel radios at the base sites and is based on the round-trip delay of the supervisory audio tone (SAT). The other is a measurement of the RF signal strength on appropiate channels, made using a tunable logarithmic receiver located at each base site. The MTSS analyzes this information to determine whether a change of voice channels and/or a change of base stations should be made. This determination may require the measurement of the mobile station's signal from two or more base stations.

2.4.3 Paging

Paging is the process of determining a mobile station's availability to receive a given incoming call. The assumption made for traffic analysis is that at any given time during the busy hour only 50% of the mobile stations are idle and ready to respond to a page. The remainder are either busy or have the power turned off (don't answer). Paging is performed throughout the entire mobile service area for each incoming call since the position of the mobile station is unknown. The transmission of a paging command from each land station on the forward control channel is called "illuminating an area".

The information capacity requirements for paging will grow in proportion to the number of customers. Splitting cells will not help to increase the capacity since the paging information is needed at all land stations. A complete paging identification consists of the 34 bit mobile identification number corresponding to a 10 digit telephone number and requires a two word control message. A one word message is sufficient for 7 digit numbers if separate paging channels are used. The system must have the capacity to handle 0.8 page per user per busy hour and be capable of serving some unknown future demand. It is normally assumed that if paging is separated from access, the capacity of each time-multiplexed paging stream is 25 pages per second (or 90,000 per hour).

2.4.4 Access

Access is the process of initiating a call and is performed by the mobile station for either of two reasons, namely (a) to originate a call or (b) to respond to a page. Access is a two way process in contrast to paging which is a one way process. When a system is first placed in operation, the paging and access functions are combined on the same set of control channels. They are usually separated after the first cell splitting occurs. In this case, the mobile unit is required to scan a different set of control channels for access. The overhead word which is part of the paging stream will inform the mobile station as to the number of channels to be scanned for either function as well as the first channel for access.

The information capacity needed to handle access attempts will grow with the number of customers but cell splitting will increase this capacity since mobile units only access one base station. The system must be able to handle 0.6 origination or 1.0 access per user per busy hour. In areas saturated with access traffic, it is expected that calls will arrive at a rate of one per second (3600 per hour) in each cell regardless of size.

2.4.5 Collision Avoidance

Since all mobiles within a cell compete for the same reverse control channel during access attempts the cellular system utilizes several techniques to minimize collisions and to prevent temporary system disruption when collisions do occur. These consist of:

(a) the busy-idle status stream on the forward control channel;
(b) the coded DCC in the seizure precursor of the mobile's access message (see 2.3.2.2) that gives the base station with which the mobile is attempting to communicate;
(c) the random amount of time that the mobile waits at various stages in the attempt procedure;
(d) the window in time during which the mobile expects to see the channel become busy (after 56 bits and before 104 bits of the message being transmitted);
(e) automatic retry at random intervals up to the limit permitted in the overhead word.

2.4.6 Handoff

During the time a call is in progress, the mobile station may cross a cell boundary or move out of the beam lobe from a directional antenna. When the cells are small this may occur several times. To maintain call continuity it is necessary to change frequency pairs and, in most cases, to handoff the call to a different base station. The MTSS must rapidly switch the connection from one base station to another. The cellular system performs this task without interrupting the perceived conversation. Location information gathered by the base station serving the mobile and by base stations surrounding it is transmitted to the MTSS where it is analyzed and a decision is made. The MTSS chooses a new base station and a new frequency pair. During a blank-and-burst on the voice channel, the mobile station is informed by a digital message to change to a new channel.

Land station antenna beams overlap to a certain extent such that when a mobile finds itself in the position described above it will usually be able to operate satisfactorily in either of two frequency sets. If the mobile station follows a zig zag path along one of these borders, the MTSS software is sufficiently sophisticated so that it will not require that the connection be switched back and forth between two base stations at short time intervals.

2.4.7 Roaming

Each mobile station is a subscriber in a particular cellular radio system that it considers to be its home. If it operates in a cellular system other than its home system it is said to be a roamer. Nationwide compatibility means: (a) that any mobile station is able to place and receive calls in any cellular system and (b) that all systems are able to place and receive calls for any mobile station. This feature has its greatest value in neighboring systems.

The permanent memory of a mobile station contains the unique system identification number (SID) of its home system. Its semi-permanent memory may contain several other numbers of systems with which it has recently registered. The base stations transmit the first 14 bits of the system identification number as part of the system parameter overhead message on the forward control channel. If the received number is different from the number stored in the permanent memory, the mobile unit knows that it is in "Roam Status".

Automatic roaming throughout the country requires the establishment of a complex system for validation and charging. This does not yet exist for the American system (the Nordic system has complete automatic roaming). A nationwide information system for the transfer of customer data from the home system to any system into which a mobile station has roamed as well as a set of agreements among operators is essential. Such a system could provide call forwarding.

DEREGULATION OF CUSTOMER PREMISES EQUIPMENT AND WIRING

T. Lamar Moore
Transmission Branch
Telecommunications Engineering and Standards Division

A memorandum from John H. Arnesen on deregulation of customer premises equipment and wiring was forwarded to REA telephone borrowers in June 1983. A copy of that memorandum is included in this material for reference.

The contents of the June 1983 memorandum are still valid. Only minor changes have occurred to date. The status of three items are briefly highlighted.

Hearing Aid Compatibility: Prompted by Congress, the FCC approved hearing aid compatibility standards on December 23, 1983. Applications for FCC registration of telephone sets must address hearing aid compatibility after March 1, 1984.

A copy of the FCC News Release covering its new rules on access to telecommunications equipment by hearing impaired and other disabled persons is included with this material.

Pay Telephones: Public ownership of pay telephones has not been addressed by the FCC. Regulation of pay telephones is now handled by state commissions. One state allows toll carriers to provide pay telephones for toll service, but not for local service.

Customer Wiring: Customer premises wiring has not yet been addressed by the FCC. The FCC plans to review the issue of one and two line customer wiring and the wiring demarcation point in the Spring of 1984.

United States
Department
of Agriculture

Rural
Electrification
Administration

Washington
D.C.
20250

June 27, 1983

SUBJECT: Deregulation of Customer Premises Equipment
and Wiring -- Technical Considerations

TO: REA Telephone Borrowers

Issues associated with the recent deregulation of customer premises equipment and the proposed changes in customer premises wiring have raised a number of questions within the telephone industry and on the part of customers. The purpose of the enclosed paper is to assist you in dealing with these issues and some problems that may result from customer provided terminal equipment.

With deregulation, the Federal Communications Commission (FCC) has outlined certain responsibilities for customers and for telephone companies and cooperatives. It is important to maintain good customer relationships during these early phases of deregulation. Telephone systems should inform customers of the deregulation issues and impact through bill inserts and by other means. While some areas of regulated telephone service will be lost to deregulation, service is still the primary function of telephone systems. It is recommended that you help your customers -- and keep your customers. Through good public relations and service, rural telephone systems can remain "The Phone Company" to their customers.

Potential and real interface problems have existed in various parts of telephone systems since the invention of the telephone. Many interface areas are not clearly defined, especially for subscriber services. In the past, satisfactory operation and service to the customer was the total responsibility of the telephone company. With deregulation, this responsibility is now divided among the telephone company, the customer, and others. However, this division of technical and financial responsibility is not always clearly defined. While real and potential problems have surfaced as a result of deregulation, these problems exist because there is a lack of clearly defined standards in some areas.

This paper attempts to provide information on the causes of some problems that may arise, and offers some possible solutions. In many cases, there may be no simple solution. The paper deals with Part 68 of the FCC Rules and Regulations as it relates to (a) connection of terminal equipment, (b) customer premises wiring, and (c) customer premises equipment. Descriptions of subscriber loop plant and historical factors that have shaped its evolution are included.

We hope that this information will be of value to you in maintaining good relationships with your customers, and save your organization unnecessary costs while continuing to provide excellent telephone service. If you have questions, please contact your REA Public Utilities Specialist.

John H. Arnesen

JOHN H. ARNESEN
Assistant Administrator - Telephone

Enclosure

Deregulation of Customer Premises Equipment
and Wiring -- Technical Considerations
Prepared by the
REA Telecommunications Engineering and Standards Division
June 1983

PURPOSE: The purpose of this discussion is to assist REA Telephone Borrowers in handling technical and administrative problems that may result from customer provided terminal equipment.

CONTENTS

INTRODUCTION

Potential and real interface problems have existed in various parts of telephone systems since the invention of the telephone. In the past, satisfactory operation and service to the customer was totally the responsibility of the telephone company. With deregulation, this responsibility is now divided among the telephone company, the customer, and others. However, this division of responsibility is not always clearly defined. Customer premises equipment (CPE) is now deregulated, and deregulated rules are evolving. This paper describes some aspects of Part 68 of the FCC Rules and Regulations, "Connection of Terminal Equipment to the Telephone Network." It also describes some aspects of telephone system subscriber plant and equipment charactertics; some problems that may arise as a result of deregulation; divided responsibility; and suggestions for handling these problems.

It is difficult to provide conclusive recommendations for implementing Part 68 and for handling the problems that arise because Part 68 is evolving and many telephone system parameters are not defined on a universal basis. In order to provide useful information as deregulation evolves, telephone system characteristics are illustrated on a generalized basis, and FCC Part 68 rules are discussed as they now exist. Interim recommendations are provided. Adjustments must be made to consider evolutionary changes in Part 68, and for deviations from the generalized telephone system parameters illustrated.

CONNECTION OF TERMINAL EQUIPMENT

PART 68 of the FCC Rules and Regulations: All new customer premises equipment (CPE) was deregulated on January 1, 1983. After that date, customers may purchase CPE from any available source. Part 68 of the FCC Rules and Regulations outlines conditions on use, registration, complaint procedures and other issues on the "Connection of Terminal Equipment to the Telephone Network." Selected sections of Part 68 are cited for reference.

> 68.1 Purpose.
> The purpose of the rules and regulations in this Part is to provide for uniform standards for the protection of the telephone network from harms caused by the connection of terminal equipment thereto.
>
> 68.100 General.
> In accordance with the rules and regulations in Subpart B of this Part, terminal equipment may be directly connected to the public switched telephone network and to those private line services included in 68.2 (a)(2). In addition, PBX (or similar) systems may be directly connected to those private line services included in 68.2 (a)(3).
>
> 68.102 Registration Requirement.
> Terminal equipment must be registered in accordance with the rules and regulations in Subpart C of this Part, or connected through registered protective circuitry, which is registered in accordance with the rules and regulations in Subpart C of this Part.

68.108 Incidence of Harm.
Should terminal equipment or protective circuitry cause harm to the telephone network, the telephone company shall, where practicable, notify the customer that temporary discontinuance of service may be required; however, where prior notice is not practicable, the telephone company may temporarily discontinue service forthwith, if such action is reasonable in the circumstances. In case of such temporary discontinuance, the telephone company shall (1) promptly notify the customer of such temporary discontinuance, (2) afford the customer the opportunity to correct the situation which gave rise to the temporary discontinuance, and (3) inform the customer of the right to bring a complaint to the Commission pursuant to the procedures set forth in Subpart E of this Part.

68.110 Compatibility of the Telephone Network and Terminal Equipment.
(a) Availability of interface information. Technical information concerning interface parameters not specified in this Part, including the number of ringers which may be connected to a particular telephone line, which is needed to permit terminal equipment to operate in a manner compatible with telephone company communications facilities, shall be provided by the telephone company upon request.

In summary, Part 68 establishes rules under which the telephone system customer may connect terminal equipment to the telephone network. It provides a mechanism for the registration program under which terminal equipment must meet certain minimum environmental and electrical requirements designed to protect the network from harm to equipment and personnel. It provides for notification of customer and temporary discontinuance of service where equipment causes harm to the network.

Part 68 is still being amended and updated as new equipment and technologies are developed. Dockets are released for public comment. Currently, Part 68 includes some 35 devices or systems from alarm dialing systems to protective voice couplers. Among the largest number of filings for registration in 1982 were telephones, cordless telephones and data modems for use with personal computers.

Registration and Notification: To register terminal equipment, manufacturers must perform or have a laboratory perform the necessary tests to show compliance with Part 68. A manufacturer may register protective circuitry for a group of equipment rather than register each item separately. Terminal equipment registration provides a degree of control to minimize "harm to the network." However, compliance with registration requirements does not guarantee that the terminal equipment will provide satisfactory service when connected to the network. Cooperation with customers is recommended in dealing with problems that result from customer provided terminal equipment.

This is especially important where harm to the network and possible temporary discontinuance of service is considered.

Part 68, Section 68.106 (not shown) requires that the customer notify the telephone system of connected terminal equipment, and to supply information such as the equipment registration numbers and ringer equivalence. In turn, Part 68, Section 68.110 requires the telephone system to make available technical information concerning interface parameters, including the number of ringers that may be connected to a line. Except for the specific areas covered by Part 68, these interface parameters may be determined at this time on a broad general basis, or on an individual subscriber line basis.

REA borrowers should inform their customers of the deregulation issues and the impact on rates and services. Through bill inserts and by other means, customers should be reminded of the FCC requirement to furnish the telephone system with the Part 68 equipment registration number and ringer equivalence. When the customer notifies the telephone system of connected equipment, the telephone system should compare the information furnished by the customer to that of the assigned subscriber loop for compatibility and satisfactory operation.

CUSTOMER PREMISES WIRING

Deregulation rules on customer premises wiring are evolving at this time. There is a degree of uncertainty in this area until final rules are issued by the FCC.

Demarcation Point: The FCC proposed that the telephone system/customer demarcation point shall be located on the customer side of the telephone system's protector. The protector shall remain the sole responsibility of the telephone system. Subsequent relocation of the demarcation point may be arranged either at the subscriber's request or at the telephone system's own initiative. When the customer purchases existing wiring, no physical device at the demarcation point is required. However, for new customer owned premises wiring the telephone system would be required to install a standard modular jack (Part 68, Subpart F) as a part of bringing service to the premises. Such a jack would constitute the telephone system side of the demarcation point. If the customer hardwires new wiring to existing wiring, both new and existing wiring would be treated as new customer owned premises wiring; a modular jack/plug arrangement would then be required at the demarcation point.

The telephone industry and state commissions are in substantial agreement with the FCC proposals concerning the demarcation point. The exact location and physical characteristics are not precisely defined at this time. Several demarcation point devices, often called "Network Interface Devices" (NID), are currently available for inside or outside installation. The NID should not be confused with the remote isolation device (RID). If the NID is installed outside the premises, it must be weatherproof or housed in a weatherproof enclosure. It is recommended that telephone companies approach the demarcation issue slowly and selectively until the Part 68 Rules are finalized and network interface devices are known to be reliable. REA is monitoring this situation from the standpoint of regulation and hardware with the expectation of writing a NID specification in the future. Based on current trends in Part 68 Rules and for the ease of administration and records, it is recommended that telephone systems follow a policy of installing modular jacks for all new installations and for additions or significant modifications to existing installations.

Inside Wiring: Part 68 currently contains rules for installation of other than "fully-protected" premises wiring. These rules apply to multiple line services such as PBX and key telephone systems. They include requirements for workmanship, materials, documentation, and acceptance testing.

The FCC proposed to use a modified version of the existing Part 68 Rules for one and two-line premises wiring. To assure that adequate wire is used, the FCC proposed an abbreviated registration procedure for cables of less than 25 pairs. It added a requirement for ringback to the acceptance testing procedure. Ringback is a procedure whereby a customer may call a telephone system specified number, hang up, and automatically receive a ringing signal. Most of the telephone industry seems to support some form of the FCC proposals for wiring standards. However, the final form of the wiring standards is not clear at this time.

Several years ago, REA recommended that borrowers begin a program of converting terminal equipment and inside wiring from "hard wire" to modular. While many installations were converted to modular, many hardwire connections remain. Hardwire connections present a problem for both the telephone system and customers when customers wish to install their own equipment.

Many telephone systems make available modular conversion kits with adequate installation instructions. This enables customers to convert from hardwire and to install their equipment. It is recommended that REA borrowers make these modular kits available. This practice should minimize problems, reduce costly premise visits, and improve customer relations.

Wiring Polarity: Telephone sets with dual tone multifrequency signaling (DTMF or tone dialing) may be polarity sensitive. When a customer elects to install and own the premises wiring, telephone systems should advise the customer of the importance of maintaining proper polarity. DTMF sets may be inhibited from dialing outgoing calls unless proper polarity is maintained. Some types of central office equipment use battery reversal for answer supervision to the called party. With battery reversal supervision, the DTMF dial cannot be used to access a computer unless the DTMF set contains a polarity guard. The REA telephone set specification requires polarity guards in DTMF sets. The DTMF polarity guard would be required for the customer to directly complete calls beyond central office equipment with battery reversal. An alternative is to program the central office equipment to register and retransmit tones for all DTMF and rotary dials.

Remote Isolation Devices: Remote isolation devices (RID) are designed to be placed near the customer's protector for maintenance and test of the subscriber loop. The purpose of the RID is to remove the customer's wiring and assist in testing the telephone system's outside plant (and protector) from the central office or a centralized test location. Some RID's may be incompatible with pair gain equipment such as carrier and line concentrators. After experience with a wide variety of these devices, some users and state regulatory agencies are de-emphasizing their importance. Also, the FCC is considering proposals for Part 68 to safeguard the system from wholesale wiring problems through standards for inside wiring and telephone system/customer demarcation, rather than address this issue through the use of RID's to separate telephone system and customer facilities. RID use should be selective and limited to loops with a demonstrated need for special maintenance procedures.

CUSTOMER PREMISES EQUIPMENT

Customer premises equipment is now deregulated. The following paragraphs outline some of the technical and administrative considerations involved in this deregulation.

Ringing Systems: Ringing frequencies for single party and multiparty service can range from 16.7 to 67 hertz. A 20 hertz ringing signal and straight-line ringers are most often used for single party service. Straight-line ringers respond to a range of 16 to 34 hertz, and are sometimes used with 30 hertz ringing signals for one party service rather than the standard 20 hertz. Because of the higher ringing sensitivity, tuned ringers are used on long single party loops as well as multiparty loops.

In the past, when multiparty service was converted to single party service, multifrequency ringing generators and tuned ringers at frequencies less than 60 hertz were often retained. With deregulation of CPE, ringers are no longer under the complete control of telephone systems. With the telephone set mobility allowed under deregulation, some incompatibilities may occur. Currently, Part 68 does not require modifications to existing ringing systems for CPE compatibility.

The following are REA recommendations on ringing systems to minimize incompatibilities and to provide adequate ringing on long subscriber loops. Where it is feasible and practical, telephone systems should develop a phase-in policy to implement changes to existing ringing systems as changes are made elsewhere in the telephone system. It is recognized that a variety of ringing systems are in use for both single party and multiparty service, and that customer provided equipment may furthur complicate efforts by the telephone system to standardize ringing frequencies and systems. Changes to standardize ringing systems may obsolete existing customer provided ringers.

Single Party Service: REA recommends using a 20 hertz ringing signal for single party service. Straight line ringers are recommended for loops with a dc resistance of less than 2000 ohms (outside plant). For increased sensitivity, 20 hertz tuned ringers are recommended for loops with a dc resistance of 2000 ohms or more.

Multiparty Service: REA recommends the use of only 20, 30, 40 and 50 hertz ringing signals and tuned ringers for multiparty service. Electronic ringers generally respond to a wide range of frequencies, and should not be used on party lines. As a result of the technical aspects of providing party line service and its declining use, the FCC has ruled as follows. CPE for party line service is deregulated, but is not included in the Part 68 registration program. Premises wiring for party line service is not included in Part 68. To avoid compatibility problems, the FCC recommends that the customer coordinate the installation of party line CPE with the telephone system.

A state commission responded to the FCC that because party line CPE is deregulated but not included in the registration program, party line customers may be required to pay unreasonably high prices for CPE. The state commission proposed that telephone systems should be required to provide proposals for modifying the FCC registered CPE for compatibility with their party line services. The FCC has not addressed this issue, but has recently ruled that states can require local rural telephone systems to provide telephones and repair service for the next two years. Telephone systems will be permitted to charge customers the full cost of repair and maintenance for these services.

Cordless Telephone Sets: These devices are currently in widespread use throughout the nation. An industry survey estimates ten million will be in service by 1987. Some types of cordless telephone sets do not have a security feature. Such units may allow an unauthorized cordless handset near the premises to access the base unit, thereby obtaining unauthorized use of telephone system services. These units may also be susceptible to Radio Frequency Interference (RFI) from home appliances. The RFI can cause these units to go off-hook and seize the central office. The office is released when the source of the RFI is turned off. Other types have a security system built into the base unit which minimizes unauthorized use and RFI problems.

Some cordless telephone sets use the telephone wires or power line as an antenna. When RF energy is applied directly to the telephone line, these sets may interfere with the proper operation of subscriber carrier equipment and when located close to the central office they may interfere with switching equipment operation. The FCC has proposed new rules to overcome these problems and to provide additional radio frequency channels. Where cordless telephones or any CPE cause undue interference with the network the telephone system may take action in accordance with Part 68 Section 68.108.

SUBSCRIBER PLANT AND EQUIPMENT CHARACTERISTICS

The following paragraphs illustrate traditional characteristics of telephone system subscriber loop plant and terminal equipment at customer locations. This is followed by a discussion of some incompatibilities that may surface and some possible solutions to these incompatibilities. Solutions may be costly in some cases.

Overview: Various parts of the telephone system can be characterized in broad general terms. There are few interface criteria defined in specific quantities to ensure subscriber loop plant and equipment compatibility. Compatibility existed because of a general knowledge of plant and equipment characteristics, a conservative design that provided some margin for error, and undivided responsibility (telephone system) to correct incompatibilities that did occasionally occur. While many potential areas of incompatibility exist, only the one most probable area is addressed. This is the dc interface between the telephone system's loop facility and the customer's termination (telephone set).

Because customer premise equipment (CPE) is now deregulated, the customer may purchase CPE from any source. Registered CPE must not "cause harm to the network," but functional characterestics of CPE are defined in a very limited manner. Section 68.3 of Part 68 describes loop simulator circuits intended to be representative of telephone system and customer equipment and facilities. By combining telephone system and customer loop simulator circuits, there may be implication that the customer interface requires 20 mA minimum into a 400 ohm termination under worst case conditions. However, there are no known operational requirements imposed on telephone systems or customers at this time except those dealing with "network harm." It is known that existing telephone system subscriber loops will not always provide 20 mA into 400 ohm customer terminations; and, there is a possibility that registered CPE will not meet the criteria. Telephone system and customer responsibilities are not clearly defined when one or both parties fail to meet the loop simulator circuit criteria. This does represent the first stage in establishing interface criteria and responsibilities. However, a requirement for immediate implementation by the telephone system to provide 20 mA into 400 ohm terminations at all customer locations could be very costly for some rural telephone systems.

Subscriber Loop Characteristics: Figure 1 illustrates a basic physical subscriber loop (dc functions). While the parameters of this loop are not precisely defined, traditional nominal characteristics can be cited for illustrative purposes.

Vo = 50 to 52 volts (CO battery voltage)
Rb = 400 ohms (Battery feed resistance)
Rp = 0 to 1700 ohms (Outside plant resistance)
Rt = 100 to 200 ohms (Termination resistance - telephone set)
Ohms Law: $I = E \div R = Vo \div (Rb + Rp + Rt)$
$I\ max = 50 \div (400 + 0 + 100) = 100$ mA maximum current
$I\ min = 50 \div (400 + 1700 + 200) = 22$ mA minimum current

Occasionally, other devices are added to the line, increasing the loop resistance. For example, adding 200 ohms to the maximum loop reduces the minimum loop current by less than 10 percent. At this point, the loop current becomes marginal for central office operation, but some margin is available to operate the subscriber's telephone set. It should be noted that central office voltages are often cited as nominal 48, 50 or 52 volts; and minimum current requirements are often cited as nominal 20, 21 or 23 mA for central office equipment and telephone sets. REA specifications cite a nominal 21 mA minimum for central office equipment and 20 mA minimum for telephone sets.

Loop Treatment: To reduce outside plant costs, fine gauge cables and various types of loop treatment are employed. The most popular forms of loop treatment are voice frequency repeater - loop extender combinations, subscriber carrier, and concentrators. With loop extenders (boosted voltage) applied to longer loops, the outside plant resistance becomes an even larger percentage of the total loop resistance. A 200 ohm change in loop resistance has less effect on the loop current with loop extenders. Subscriber carrier uses a different principle of providing loop extension. Thus, resistance changes affect subscriber carrier loops in a different way as noted below.

Subscriber Carrier: Figure 2 illustrates a subscriber carrier loop. Outside plant is separated into the carrier section (Rc) and the drop section (Rd). Rc has little or no effect on subscriber loop current within application limits. Battery for the subscriber terminal has been moved from the central office to the subscriber terminal, at a location near the subscriber. Loop current is a function of Vo, Rb, Rd and Rt.

Higher density subscriber carrier systems such as PCM types generally use ac power, a 50 volt battery supply and a conventional 400 ohm battery feed relay at the subscriber terminal. Application rules for loops beyond the subscriber terminal are similar to conventional subscriber loops. A 200 ohm change in loop resistance (Rd + Rt) will generally affect loop current slightly more than on a conventional loop.

Low density subscriber carrier (station carrier) generally provides power for the subscriber terminal from the central office over the carrier line. This includes the subscriber battery supply. To accomplish this task requires that efficient power techniques be used. The battery supply voltage may be in the range of 6 to 20 volts at the subscriber terminal and the battery feed resistance may be 150 ohms or less. To conserve power, these systems are designed to deliver approximately 20 mA into the subscriber loop that includes a telephone set of 200 ohms or less. The telephone set represents a large percentage of the subscriber loop resistance, and the addition of 200 ohms can affect loop current drastically. The worst case situation is for the one channel station carrier where a 200 ohm telephone set may represent about 70 percent of the total loop resistance. A 400 ohm telephone set could cause the loop current to decrease from 20 mA to about 12 mA.

Telephone Sets: In the mid 1960's, extensive tests were made on rotary dial telephone sets by Bell Telephone Laboratories, REA and manufacturers. Telephone set characteristics were determined, but no formal industry specification was adopted. Rotary dial telephone sets generally provide a loop termination resistance that ranges from 100 ohms (at 100 mA) to 175 ohms (at 20 mA). Thus, the telephone set was characterized as having a resistance up to 175 ohms at 20 mA or greater. Early tone dial or DTMF telephones exhibited a slightly higher resistance (up to 250 ohms) without a polarity guard and with a tone button depressed. When these DTMF telephones were used on station carrier loops, current into the telephone set could be significantly less than 20 mA. There is a compounding effect; lower current causes higher set resistance; and higher set resistance causes lower current. While a large potential problem existed, no real problem existed. These rotary dial and DTMF telephones functioned well with only a slight degradation at loop currents of 12 to 14 mA.

A new generation of DTMF circuit was introduced around 1979. It replaced the discrete analog circuit with state-of-the-art integrated circuit (IC) technology which digitally synthesized the DTMF signal. The IC technology changed the set characteristics, requiring a minimum voltage level for satisfactory operation. Even though an industry accepted telephone set specification did not exist, the 20 mA minimum loop design criteria was adopted as the minimum telephone set current. Below this 20 mA minimum current level, the DTMF circuitry lacked sufficient voltage to output the DTMF signal. The termination resistance of these sets is approximately 350 to 400 ohms in the dialing mode at 20 mA.

All telephone sets are designed to function properly in both the talking and dialing mode at 20 mA or greater. The termination resistance of the set can vary (generally from 100 to 400 ohms) depending on the set design and loop current. In the dialing mode, only one telephone set must be considered. In the talking mode, multiple telephone sets must be considered because of extension sets and party lines. There may be an unequal division of current between a main and extension set when used simultaneously. This becomes more apparent when a rotary dial set and a DTMF set are used. If both sets contain carbon transmitters, transmission from one or both sets may be poorer -- but it is likely that both will be usable. An electronic telephone set may not operate in the talking mode when used simultaneously with one having a carbon transmitter.

<ins>Summary</ins>: There are several areas of real and potential incompatibility that may surface as a result of deregulation. Some are totally the customer's responsibility, but may result in telephone system trouble reports. There are no standards that require satisfactory operation of customer premises equipment (CPE). Even if telephone sets demonstrate satisfactory operation individually, no standards exist for simultaneous operation of two or more telephone sets (extensions and party lines). There is limited power available for ringing and for telephone set current in rural areas. A requirement for 20 mA into customers' 400 ohm telephone sets is in conflict with the 21 mA minimum current requirement for central office equipment. A review and engineering to new criteria would be required for a small percentage of physical subscriber loops to provide 20 mA (or 21 mA) into 400 ohm CPE. A large percentage of carrier loops will fail to provide 20 mA into 400 ohm CPE. The most acute situation is the interface of analog station carrier and 400 ohm CPE.

In late 1981, the Electronics Industries Association (EIA) sponsored a meeting to resolve the carrier and telephone set interface problem. The meeting was attended by major telephone systems, carrier equipment manufacturers, telephone set manufacturers, REA and others. As a result, carrier equipment manufacturers agreed to develop new equipment which would deliver 20 mA into a 400 ohm telephone set. This is a step in the right direction, but is not a final solution for operating telephone companies. Telephone systems still face the situation of having existing carrier in place that will not deliver 20 mA into 400 ohms. A mandatory universal requirement to provide 20 mA into 400 ohm CPE would result in the retirement of a large quantity of station carrier.

Most existing telephone sets provide a termination of much less than 400 ohms. Thus, interface problems are expected to evolve as new customer provided sets containing electronics are introduced. (Note: The problem results from the lack of interface standards and not from the use of electronics.)

LOOP ENGINEERING: 400 OHM CUSTOMER PREMISES EQUIPMENT

Some interim recommendations to assist telephone systems in handling problems that may arise as a result of customer provided CPE are addressed. Specifically, methods for providing at least 20 mA (or 21 mA) into 400 ohm CPE. The recommendations apply to new and existing subscriber loops. In the past, devices such as line filters, neutralizing transformers and longitudinal chokes have been added to loops with limited concern about the added loop resistance. In the future, it may be necessary to account for the resistance of each added device.

Physical Loops: Physical loops should present few problems. Central office signaling limits are generally 21 mA and 1900 ohms total resistance without loop treatment. (CO battery voltage is maintained at 50 volts.) This has generally been allocated as 1700 ohms for outside plant and 200 ohms for the telephone set (CPE). Occasionally, loop extenders (or other long loop technique) may be required for loops in the 1500 to 1700 ohm range (outside plant resistance). If 400 ohm CPE becomes a mandatory standard, loop design practices may require loop extenders at 1500 ohms rather than 1700 ohms. It is unlikely that longer loops containing loop treatment will present any problems related to 400 ohm CPE.

Line Concentrators: Line concentrators may use physical or carrier derived trunks between the central office and remote terminal. Concentrator loop problems will primarily be a function of the physical trunk plus loop resistance, or the carrier battery feed plus loop resistance. If the concentrator equipment adds resistance to the overall loop, it must be considered in providing 20 mA (or 21 mA) into 400 ohms.

PCM Subscriber Carrier: Digital subscriber systems generally use ac power and batteries at the subscriber terminal with no provision for maintaining the 50 volts during an ac power failure. Thus, minimum loop current is calculated at 44 volts dc which represents the lowest operating battery voltage. These systems are generally set at 2 dB loss, leaving 6 dB for the subscriber loop beyond the carrier. The above considerations have generally established PCM carrier subscriber loops at 1300 ohms for outside plant and 200 ohms for the CPE (1500 ohms total). Under this design criteria, it is unlikely that 400 ohm CPE would cause any problems. The 20 mA requirement would generally be met under worst case conditions. If problems do occur, the outside plant limits could be reduced to offset the higher CPE resistance.

Station Carrier: Station carrier that is powered over the cable pair presents the largest interface problem with 400 ohm CPE. Because of the necessity to be power efficient, these systems were initially designed on the basis of 200 ohm CPE. Recently designed equipment provides 20 mA into 400 ohm CPE. However, there is a large amount of station carrier in service that will not provide 20 mA into 400 ohm CPE. Solutions to providing 20 mA range from abandonment of existing equipment to modification of equipment or changing the application guidelines. The most acute problem is with the one-channel station carrier. The following is a generalized summary of solutions. The final solution will depend on the specific equipment, including specific models of each basic type (age, etc.).

One-Channel Station Carrier will likely require some change to provide 20 mA into 400 ohm CPE. There is a factory modification for some types. Others will require replacement of the subscriber terminal. There are no other known solutions at this time. Outboard devices to boost voltage and current may damage the carrier equipment and should not be used unless recommended by the carrier manufacturer.

Multichannel Station Carrier solutions may vary widely with different models of the same equipment. Alternatives that should be considered include choices of equipment and application. Outboard devices powered from the carrier line are available from some manufacturers to boost the subscriber loop voltage and current. The additional power required from the carrier line must be considered, especially on longer systems. There are two areas of application that may be considered. The outside plant loop resistance limits beyond the subscriber terminal can be reduced as necessary to provide 20 mA into 400 ohm CPE. (This may not be practical with some equipment and applications.) Some models of equipment provide for longer than normal drop resistance limits if the carrier line voltage at the subscriber terminal can be maintained above certain minimum levels. This will sometimes require costly intermediate power additions along the carrier line. Some equipment cannot provide 20 mA into 400 ohm CPE on any practical basis and must be relocated or retired from plant.

FIGURE 1
PHYSICAL SUBSCRIBER LOOP

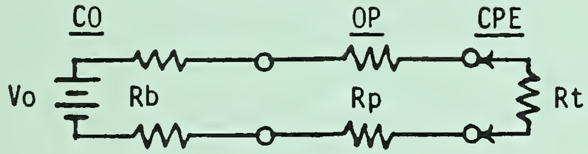
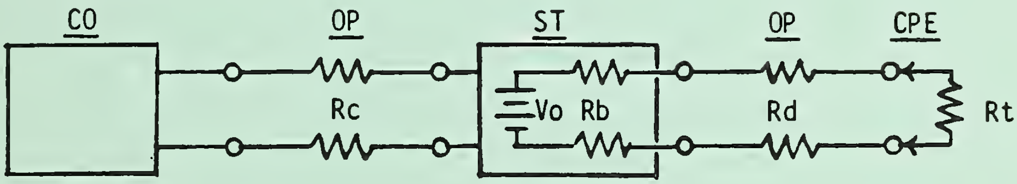


FIGURE 2
SUBSCRIBER CARRIER LOOP



NOTES

CO = Central Office
OP = Outside Plant
CPE = Customer Premises Equipment
ST = Carrier Subscriber Terminal
Vo = Battery Feed Voltage
Rb = Battery Feed Resistance
Rp = Outside Plant Resistance
Rt = Termination Resistance (telephone set)
Rc = Carrier Line: Outside Plant Resistance
Rd = Carrier Drop: Outside Plant Resistance

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Report No. 17780 ACTION IN DOCKET CASE December 2, 1983

FCC ADOPTS RULES ON ACCESS TO TELECOMMUNICATIONS EQUIPMENT BY HEARING IMPAIRED AND OTHER DISABLED PERSONS (CC DOCKET 83-427)

To comply with the Telecommunications for the Disabled Act of 1982 (Act), signed into law January 3, 1983, the Commission has adopted rules to ensure access to telephone service by the hearing impaired, and to facilitate access to telecommunications equipment by persons whose speech, vision, hearing or mobility is impaired.

Specifically, the Commission has adopted the following rules to implement the Act:

—Exchange carriers will be required to make available a hearing aid-compatible telephone, on request to each user who cannot otherwise obtain such a telephone;

—Carriers will be required to notify regulatory authorities six months in advance of the proposed termination of specialized operator and directory assistance for users of telecommunications devices for the deaf;

—Those carriers which supply Telecommunications Devices for the Deaf (TDDs) will be required to supply information on the use of TDDs;

—After January 1, 1985, all telephones which are installed in "essential" locations must be hearing aid-compatible;

—All coin-operated and "emergency use" telephones, which were installed prior to January 1, 1985, must be converted to hearing aid-compatibility by that date;

—Adoption of a uniform, nationwide technical standard which will allow confirmation of whether telephones are actually hearing aid-compatible;

—All telephones offered for sale after June 1, 1984, will be required to be accompanied by package labelling or written statements notifying the prospective purchaser whether or not the telephone is hearing aid-compatible, and if not, disclosing that the instrument may not be used as "essential"; and

—Carriers may offer specialized Customer Premises Equipment (CPE), either on a tariffed or untariffed basis as each state may direct.

Noting that American Telephone and Telegraph Company provides TDD operator and directory assistance to customers of any carrier, and General Telephone and Electric's provision of similar services in certain of its territories, the Commission will require that carriers providing such services notify the Commission and affected states six months prior to terminating such service. However, it will not require that carriers make available more sophisticated or costly services, such as call waiting, call forwarding, and relay services using intermediaries to allow conversation between persons without hearing impairments who do not have TDDs, and TDD users.

As mandated by the Act, the Commission is requiring that as of January 1, 1985, all newly installed "essential" telephones -- generally defined as coin-operated, "emergency" use, and other phones frequently needed by people with hearing aids -- be hearing aid-compatible, and all incompatible coin-operated and emergency telephones be retrofitted by that date.

The requirement that coin-operated telephones be hearing aid-compatible applies to any coin-operated telephone regardless of location.

Telephones provided for emergency use are telephones provided for use in isolated areas, telephones needed to signal life-threatening situations in confined institutional settings, and telephones specifically installed to contact public authorities or providers of medical assistance (including telephones in elevators, police call boxes, telephones in hospital rooms). The Commission is not requiring placement of an "emergency" telephone where none existed.

The category of "frequently needed" telephones includes: credit card telephones; workplace telephones; telephones made available at places of business or in public buildings; telephones in hotel and motel rooms; and non-emergency telephones in locations where the hearing impaired may be confined, e.g., hospitals.

As recommended by Congress, the Commission will require that a newly-installed credit-card telephone be hearing aid-compatible unless no coin-operated telephone is readily accessible which is capable of performing the same functions as the credit card telephone.

The Commission is requiring that when an employer installs a new telephone at the work station of a hearing impaired employee, that telephone must be compatible if that employee will use it in the course of work duties.

Newly installed telephones in public buildings and places of business, which are made available to the public, will be required to be hearing aid-compatible. However, a newly-installed credit card telephone will not be required to be hearing aid-compatible if it is in proximity to a hearing aid-compatible coin-operated telephone.

Consistent with the House Committee Report, the Commission found it unnecessary to require that all telephones in hotel and motel rooms be compatible. If at least 10 percent of the rooms in a hotel or motel are equipped to accommodate a hearing impaired customer, the hotel or motel need not purchase or install a compatible telephone when it replaces a telephone. If less than 10 percent of the rooms are hearing aid-compatible, when replacing a telephone the hotel or motel must, until the 10 percent mimimum is reached: replace it with a hearing aid-compatible telephone, or maintain a plug-in hearing aid-compatible telephone handset which it will provide to a hearing impaired customer upon request.

The Commission will not require existing telephones in hospital rooms, convalescent homes, residential health care facilities for senior citizens, and prisons to be retrofitted, but telephones installed after January 1, 1985, must be hearing aid-compatible.

The Commission will not require the placement of TDDs, or coin telephone booths which can accommodate them, in public locations. Instead, it will leave this matter for resolution between states, carriers and suppliers of TDDs.

Concerning labelling and packaging for hearing aid-compatible CPE, the Commission is requiring labelling of external packaging and directed manufacturers to include written disclosure statements with new telephones delivered unpackaged, because equipment used in workplaces, hospitals, places of business, etc., is often delivered unpackaged. Any new telephones which are incompatible with hearing aids must be accompanied by written information concerning limitations on use as "essential."

These amendments are effective 30 days after publication of the Report and Order in the Federal Register.

Action by the Commission December 1, 1983, by Report and Order (FCC 83-565). Commissioners Fowler (Chairman), Quello, Dawson and Rivera, with Chairman Fowler issuing a separate statement.

-FCC-

For further information contact Carl Gold at (202) 632-4890.

Seperate Statement of Mark S. Fowler, Chairman

RE: Access to Telecommunications Equipment by the Hearing Impaired and Other Disabled Persons

This decision completes an important link of our implementation of Computer II. Congress recognized in passing the 1982 Telecommunications for the Disabled Act that the new competitive communications environment must ensure continued service for those with hearing, sight, speech and mobility impairments. Today's decision takes account of these needs, balancing them against the dictates of a robust telecommunications marketplace.

I want to complement the staff in drawing up procedures and regulations that strike that balance extremely well. And I hope that state regulators will use today's decision as their guide in formulating policies and reviewing tariffs that affect the rights of consumers that need special services. Under this decision, the hearing impaired and others will find that they are merely different, not disabled, consumers when it comes to using their telephones.

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CONTENTS

Management (Salmon Sheets)

REVENUES, REVENUES & REVENUES
(Choosing the Right New Services)

Henry I. Buchanan, III
Loans and Management Branch
Telecommunications Management Division

It's an old adage in real estate that the key factors are location, location, and location. Revenues, revenues, and revenues are the key factors in selecting new telecommunication services. I am challenging management and engineering to change the way you evaluate and plan for business opportunities. Examine in detail those opportunities that are best suited to the telephone system you are involved with. Be selective!

Until recently the key considerations in the independent telephone industry have been:

1. Service to the customer.

2. Quality of service.

3. Level and condition of plant investment.

In today's market these priorities must change. The amount of revenues generated by new product and service offerings are the key factor. To meet the challenges presented by deregulation and competition, management and engineers must break away from traditional thinking, which is geared to rate base regulation.

Let's look at the typical investment decision sequence:

1. The area into which new service is to be extended is identified.

2. If it meets the criteria for REA financing, an area coverage survey is performed.

3. The system or addition is engineered.

4. The REA loan is obtained.

5. Additional toll revenues are calculated (under the Ozark Plan these are automatic.)

6. Any remaining revenue requirement comes from increased local rates; you go to the commission for rates.

The rules of the game have changed, however. The days of planning and engineering for toll settlements are over! You must engineer for an environment of risk. The competitive environment demands that goals must be to:

1. Generate more revenues from your existing plant; and

2. Minimize the capital investment required to offer additional services.

Many of you have gone after new revenue sources. You've sold PBX's, offered custom calling features, tone dialing and possibly even alarms and CATV. But because of rate base regulation there was no urgency associated with these offerings. They were "icing on the cake;" not essential to your company's survival. Your major emphasis has been on expanding service, engineering for toll and quality of service.

We are constantly bombarded with news about the changes through which the industry is going:

1. The breakup of the Bell system.

2. Deregulation and competition in traditionally regulated areas.

3. The potential for further deregulation.

4. The potential for bypass and local service competition.

The example of firms in other common carrier industries is telling. Eastern Airlines was extremely successful under regulation. With lucrative routes, Eastern could carry its heavy capital investment and high labor costs. Under deregulation, discount carriers cut into the profitability of Easterns' best routes. As a result, the company went to the brink of bankruptcy before it could cut costs and compete profitably. Braniff was a successful airline that expanded rapidly in the regulated environment. When the airline industry was deregulated, Braniff was proven to have over extended itself and was driven under by the competition. Delta did not tailor their business practices to regulation to the extent which Eastern and Braniff did. When the industry was deregulated, they were better positioned to compete.

Deregulation and competition also resulted in a shakeout in the railroad industry. A poorly managed giant like Penn Cental went bankrupt even before actual railroad deregulation. Other common carriers such as trucking and airlines combined with interstate highways drove them under. At the same time well managed, efficient carriers such as Southern and Norfolk and Western have prospered.

The changes occurring in telecommunications are profound. In order to survive and prosper you must redefine the business you're in. Communications today can include computers, telephones, even entertainment. When considering new areas to move into you must look first at the revenue potential. You must heavily promote new products and services, a practice new to the industry. In order to protect what you have, you must increase the telephone company's public relations efforts.

When evaluating new businesses, you must:

1. Review your organization's strong points.

2. Analyze your potential markets.

3. Study feasibility.

4. Choose one or more of the most promising upon which to concentrate your efforts.

The first area to emphasize when choosing new services is how to get more use out of your in place telephone plant. Your existing subscriber loop plant in most instances is an excellent transmission system capable of supporting many types of data, alarm services and other offerings. It is really available to reach virtually all locations in your service area. The following list of regulated services can maximize the use of your plant and personnel, and minimize additional capital investment:

1. Consider providing directory assistance. How much are you paying the BOC? You may be able to justify hiring operators. In addition, services such as alarms and answering services can piggy back, allowing you to spread the costs to unregulated services.

2. If you have a digital switch, make sure you're exploiting its potential fully.

   a. We've seen that custom calling features generally have not sold well. While repricing may stimulate sales, you may want to provide these at no charge, since the cost of the capability was insignificant. Call Forwarding and Conference Calling may increase toll billings. Call Waiting improves the efficiency of the local network by decreasing the number of incomplete calls made to busy numbers. The addition of these services at no charge can be a major public relations coup.

   b. In most cases, the additional investment necessary to add LAMA and equip a digital switch for local measured service is nominal. This will enable you to offer recoprding and billing services to other interexchange carriers at the earliest possible time and move to LMS when appropriate.

   c. Once providing interconnection to more than one interexchange carrier, you can offer least cost routing to your customers.

3. You should maximize the use of your in house computer by providing billing serivces for other businesses in the area. When other interexchange carriers connect with your switch, you will be able to do the billing for them.

4. Investigate your potential for providing long distance circuits. Alone or as a joint venture, this can mean a significant investment. However, in a competitive environment, the greater efficiency of new facilities on selected routes can mean keeping a significantly greater portion of toll billings. Your criteria for these opportunities should be whether it will make you money. With intrastate toll networks you are competing directly with the Bell Operating Company. Be prepared!

5. Cellular radio is the major new technology in which many are interested today. Cellular involves a significant investment and offers little opportunity to utilize your existing plant. With the annoucement by most digital switching equipment manufacturers that cellular radio capability is being developed this may change. Other switch manufacturers are sure to follow. There is an excellent article in the Fall, 1983 issue of Rural Telecommunications, on figuring the financial feasibility of cellular radio. I recommend that anyone thinking about a cellular investment read this aritcle.

6. The conversion of urban IMTS to cellular should mean that more frequencies will become available for rural areas. This could provide a cheap way for many of you to expand your mobile and paging services. Paging especially, seems to be a service whose time has come.

7. Institute new charges for existing services, such as time and weather.

I believe that only after exploring additional regulated services using existing plant and personnel, should you look at new unregulated service possibilities. Here again, your objective should be to gain the maximum return on the minimum capital investment. The following areas are among those which you may want to evaluate:

1. Terminal equipment sales and service is an obvious business opportunity. Business system installation and maintenance, computers, even a Radio Shack outlet are naturals. The key points I would like to emphasize are to keep inventory, floorspace and personnel to a minimum and promote your business heavily. You will be competing with low cost mail order houses and large discount retail stores. This is a retail operation and you need a broad product base.

2. Communications consulting is a service which is coming into great demand. It requires no capital investment in equipment and plays to your strengths: knowledge of your customer's needs, knowledge of the equipment available and technical know-how. Of course you have to

have a thorough and up to date knowledge of business communications and the evolving industry.

3. The resale of long distance service is a risky business requiring a significant up-front investment. The profit margins the reseller operates on are narrow, and in order for the operation to be profitable, it must be in urban markets. That means competition! In the post divestiture, competitive environment we can expect MTS and WATS prices to move toward cost. The result will be that the reseller's already narrow margins will shrink.

4. Direct Broadcast Satellite (DBS) service should present a significant business opportunity in rural areas. Dish sales and leasing, installation, maintenance and billing are all possibilities for you. DBS is in an embryonic state, with several competitors starting up. Now is the time to investigate this opportunity. The operation could dovetail nicely with a retail CPE operation.

5. Cable television is the unregulated business (other than CPE) into which the greatest number of REA borrowers have entered. In many instances the motivation has been to provide service. In some it has been a defensive strategy to foreclose future broadband competition. In very few has the stated motivation been to make profits. There are certainly numerous negatives associated with CATV, including:

    a. finding financing for a significant capital investment.

    b. possibly having to apply for an FCC cross-ownership waiver.

    c. a long payback period with capital at significant risk.

    d. the potential for competition by DBS.

In conclusion, let me re-emphasize that you must shed complacent attitudes fostered by rate base regulation. Recognize that in the competitive environment you must engineer for risk. Finally, when evaluating opportunities remember the key factors, revenues, revenues, and revenues!

A LOOK AT BUILDING AN INDEPENDENT OWNED TOLL NETWORK

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The first question that needs to be asked is, "why build an independent company owned toll network?" If it duplicates the Bell operating company routes or interLATA routes, then significant competition can be expected between the two. The risk will be greater than under regulation. Therefore, a greater return on investment and a shorter capital recovery period than those received on regulated enterprises should be your goal. If you take greater risks, then the potential rewards should be greater. On the other hand, if you don't build your own, what will the BOC do? There is a real possibility that rural telephone systems will receive lower toll settlements and rural subscribers will have higher toll rates. Consequently, other reasons for building your own network exist, such as control, flexibility, and the possibility to directly connect to intercity carriers.

In order to clearly think through the feasibility of building an independent company owned network, one must go through an analysis which the independent telephone industry has not had to do before. This analysis or approach is as follows:

1. Identify basic rural toll problems.
2. Recognize how the regulated telephone industry was structured to solve these problems.
3. Study industry changes and their potential effects on toll investment decisions.
4. Analyze the feasibility of hypothetical networks.
5. Draw conclusions.

Identifying Basic Rural Toll Problems

It obviously costs more to provide toll service to rural areas than to urban areas. In the 1980 REA Study on Subscriber Rates, the costs of toll connecting links between the class 5 local office and the class 4 toll center were eight times greater in rural areas than in urban areas. The major reasons for these huge cost differences are listed below:

1. The average toll trunk route in rural areas is much longer.

2. Cable costs and microwave costs are relatively greater for the smaller number of circuits required in rural areas.

3. Installation costs are relatively greater in rural areas when allocated to a smaller number of revenue producing circuits.

4. Smaller trunk groups are less efficient and carry less revenue producing traffic.

In addition to the toll routes themselves, costs for originating, switching, and terminating rural toll traffic are higher in rural areas.

Rural exchanges are by definition not the centers of economic or government activity. Figure 1 shows various rural local offices (A, B, C, etc.) and centers (X, Y) where the class 4 toll offices are located. A call from office A to office B must be routed by toll center X and back again out to office B. The route miles are significantly greater than the airline miles. Incidentally, at present, toll rates are based on airline miles. A similar analysis can be made for local offices B and M where the toll call must be routed through two toll centers. This could be an interLATA toll call. In Figure 1, the route miles of calls from X to the surrounding local offices (A, B, C and D) generally approaches airline miles. Calls from center X to center Y also approach airline miles. Calls from center X to exchanges M, N, O and P have greater route miles than airline miles, but the greatest difference is for calls from rural exchanges A, B, C and D to exchanges M, N, O and P. The conclusion that can be made is that the more rural a system is the greater the difference between route miles and airline miles for a toll call. Pricing on a route by route basis, if it happens, will be be a severe rural problem.

Figure 2 demonstrates that this difference between airline miles and route miles narrows with the length of haul for a toll call. Figure 3 graphs the volume of rural toll traffic with the airline mile distances of toll calls and shows that most rural toll calling is short haul in nature. Looking at Figure 2 again, short haul traffic has the greatest difference between route miles and airline miles.

For rural traffic, costs are greater, efficiencies are less, and traffic route miles compared to airline miles are greater for rural areas than urban. The short haul nature of rural toll calls compounds all of the cost problems since it is less profitable than long haul toll calling. Again, the high cost of rural toll routes is obvious; however, the independent telephone industry during the last 13 years with the Ozark Plan in effect, has not had to deal directly with these problems. The future will probably change this.

How the Regulated Telephone Industry was Structured to Solve the Problems

Regulation of toll rates and the Ozark Plan accomplished the following for rural areas:

	State	Interstate	Result
Toll Rates (averaging)	Averaged statewide by airline miles. Set by Bell.	Averaged U.S. wide by airline miles. Set by AT&T.	Eliminates the problems of pricing on route miles. Helps rural more than urban.
Toll Rates (distance)	Long haul generally supports short haul	Long haul generally supports short haul.	Price break for short haul toll users. Majority of rural toll traffic is short haul.
Settlements (Revenue sharing and pooling)	All toll revenues go into pool and settlements come out based on cost or schedules.	All toll revenues go into pool and settlements come out based on cost on schedules.	Rural system toll costs (however high) paid through pool.
Settlements (Rate of Return)	BOC State Rate of Return.	AT&T U.S. Rate of Return.	REA borrowers realize benefits because of low cost of debt vs higher BOC or AT&T rate of return.

The concept of toll rate averaging and pooling has had major benefits for rural areas. It has allowed rural telephone companies as well as the Bell Operating Companies (BOC's) to provide rural toll service at the same quality levels and rates as intercity toll traffic. When consulting engineers or telephone companies engineered toll routes, then rates, grades of service, and repayment of all costs were a given. Generally, toll investment decisions were made as follows:

1. Establish a need for more trunks or better quality.

2. Obtain Bell Operating Company concurrence.

3. Engineer.

4. Obtain REA loan.

5. Build the system.

6. Receive automatic toll settlements.

Industry Changes and Their Potential Effects on Toll Investment Decisions

Although the Ozark Plan was extremely good for rural areas, there were problems even before the breakup of AT&T and the Bell System. The Ozark Plan loaded significant amounts of exchange costs on toll rates. For large business users, this meant rates significantly higher than costs and high communication expenses. As a result, the first step for large businesses was changing from usage priced message toll to flat priced WATS, foreign exchange and private line. Large companies have continued looking for cheaper toll communication costs by building their own networks and subscribing to services of the new toll communication carriers. The problems presented by the growing toll competition with AT&T, and the Court ordered breakup of AT&T and the Bell Operating Companies (BOC's) have outdated the Ozark Plan. The new LATA concept mandated by the Courts in the AT&T divestiture also requires settlement contracts and that state toll be broken into two separate pieces; intraLATA and interLATA. The FCC's access charge system is the current replacement for the existing system and requires much of the new settlements between carriers to be on a contract basis. The continuation of toll rate averaging is tenuous in the face of competition. Toll rates and settlements in the new era may be on the following basis:

	State (IntraLATA)	State (InterLATA)	Interstate	Result
Toll Rates (averaging)	Cannot be averaged with interLATA; must stand on its own.	The potential for deaveraging is great in some states.	The potential for deaveraging is great. Probable volume discounts to large users.	Higher rural toll rates.
Toll Rates (distance)	Long haul is interLATA. Therefore, less support for short haul intra-LATA toll.	Possible route by route pricing with volume discounts to large users.	Possible route by route pricing with volume discounts to large users.	Possible higher rates.

	State (IntraLATA)	State (InterLATA)	Interstate	Result
Settlements (Revenue sharing & pooling)	States seem to be moving toward intra-LATA averaging & pooling	No pooling; only by contract.	No pooling; only by contract.	Real possibility for lower toll settlements.
Settlements (Rate of Return)	Probably BOC intraLATA return.	By contract; may be industry return.	By contract; may be industry return.	Differential advantage for REA systems may disappear.

With the new industry changes, current toll investment decisions need to be significantly revised even if one is building a traditional toll connecting facility. Toll rate averaging by airline mile and recovery of costs by pooling is in jeopardy. Costs of a toll connecting route may have to be recovered directly from the subscribers who use it. This may mean that the same grade of service may not be possible.

The decision to build a toll network in competition with the Bell Operating Company complicates matters even more. The State PUC may not even authorize construction of a competing network for intraLATA traffic. It is also worth noting that there seems to be a trend toward interLATA intrastate competition. If a competing toll network is built and the State PUC orders intraLATA pooling and rate averaging (many states are doing this), then will the new network be outside the averaging and pooling partnership? This is a critical question that has to be answered in the early stages of planning.

One point needs to be reemphasized. Because of industry changes, <u>the decision making process for toll investments has to change</u>. A new process should be something like the following:

1. What is the demand at various price levels? If facilities are not adequate, can pricing (time of day, etc.) be used to redistribute traffic and reduce the need for additional trunks? Is a lesser grade of service acceptable?

2. Will there be competition, or averaging and pooling with the BOC in the provision of toll service? The State PUC will have a lot to say in this.

3. If toll is to continue to be provided in partnership with the BOC, are the costs low enough in case of deaveraging and route by route pricing? High costs may encourage deaveraging and higher rates to rural customers.

4. If toll service is competitive for intraLATA, what is your projected market share of existing and future traffic? What will happen to rates? Can you survive a price war for both rates and settlements?

5. Assuming that Steps 1-4 indicated that your own toll network is the way to go, you must determine if it is financially feasible. Profits must be commensurate with risks.

6. The system must be engineered to keep costs low and meet the competition.

7. Explore all financing alternatives, including leasing. REA money may not be available for this purpose.

Given the potential for competition, the increase in variables and the decreased certainty of forecasts, investment decisions need to be examined for specific competitive advantages.

Specifically, there are several criteria that may make building your toll network feasible:

1. The presence of significant traffic that would originate and terminate within the proposed system.

2. There exists a high volume of traffic which is concentrated across LATA boundaries. The opportunity here is that the toll traffic can go directly to its destination, rather than over AT&T and through an extra BOC access charge. Route miles can more closely approximate airline miles.

3. There is one or more large toll customers that would go a long way toward making your network feasible.

4. The independent telephone company is strategically located along a large toll route or between major metropolitan areas. The advantage here may be the ability to provide toll service at lower cost. Economies of scale may be available.

5. The opportunity to interconnect to other State networks, other intercity terrestrial carriers or to a satellite carrier may offer some price advantages or a way to receive revenues from traffic not originating or terminating in your service area.

<u>Three Examples of Independent Company Owned Toll Connecting Facilities or Networks</u>

Working some hypothetical examples should help focus in on the potential problems and opportunities. Figures 4, 5 and 6 represent possiblities of building independent company owned networks. The costs and traffic assumptions shown are illustrative and probably will be inappropriate when applied to particular instances. The National Exchange Carrier Association (NECA) Tariff was used to project settlements on a very broad basis. The examples do represent approximations that possibly could be used in preliminary planning and feasiblity.

Figure 4 illustrates building a microwave connection for one central office to the BOC toll center or LATA Tandem. The annual charges for building this route more than double the projected settlement revenues. It seems unlikely in ordinary circumstances that connecting one exchange using your own company owned route will prove feasible. Upgrading or replacing this type of route will have to be accomplished in cooperation with the BOC. Pricing alternatives to shift busy hour traffic may have to be used instead of building wholly new facilities.

Figure 5 illustrates building a network connecting five exchanges (5 central offices) to the BOC toll center or LATA Tandem. This is a trunking network only with no provision for switching or dropping off intra network traffic. It looks feasible only if the network carries all the existing traffic. Therefore, in this example, cooperation with the BOC is imperative. Otherwise there will be competition for the current toll traffic which is only sufficient to support one network. With two connecting networks, there will be competition for the traffic to and from intercity carriers. This will result in price cutting for settlements from intercity carriers to the connecting network carriers. The only question would be who would lose the least. This a situation that intercity toll carriers would love to see happen.

Figure 6 is essentially the same as Figure 5 with a lot of "goodies" (including another LATA connection) added. There is a switch with operators and other services added at one location. The purpose is (1) to switch intra independent system traffic; (2) switch traffic directly to intercity carriers thus bypassing the BOC LATA Tandem; (3) switch concentrated traffic to another nearby LATA; and (4) provide other functions such as centralized maintenance, operators, alarm service bureau, directory assistance, and an answering service. In this particular illustration, adding the other services seems to make the network stronger and able to withstand competition. It must be recognized that significant BOC competition still has the potential to make this network a loser. A significant growth in traffic could possibly permit the existence of two competing connecting networks and enhance the possibilities. It is interesting to note that this network could significantly reduce rates to subscribers by reducing route miles closer to airline miles.

The question of who carries the traffic cannot be underestimated. It is of utmost importance. One seemingly easy solution would be to direct all originating traffic to your own network or even disconnect the BOC connecting route. It is almost certain that this will not be the local telephone system's decision to make. Even if it was, the BOC could counter with the same strategy. The State Public Service Commission will eventually decide. In addition, the intercity carrier will probably be able to choose which connecting toll facilities it wants to originate or terminate its traffic over. The decision will be based primarily on price, with consideration for quality of service. So the question remains do you cooperate with BOC or is there enough traffic for you to compete with the BOC.

In the past, REA has only financed telephone systems which offer complete telephone services to subscribers. A separate toll network, if it is a separate corporate entity, does not provide complete telephone service (basically only toll). Financing these networks is a question that REA has not addressed. But it is the author's opinion that there will be limited REA financing available for these separate networks. To date, REA has never financed a toll only company. Of equal importance is the fact that a finding of non duplication of service is required by the RE Act may prohibit financing in many cases. In the planning stages, financing from non-REA sources must be considered.

Conclusions

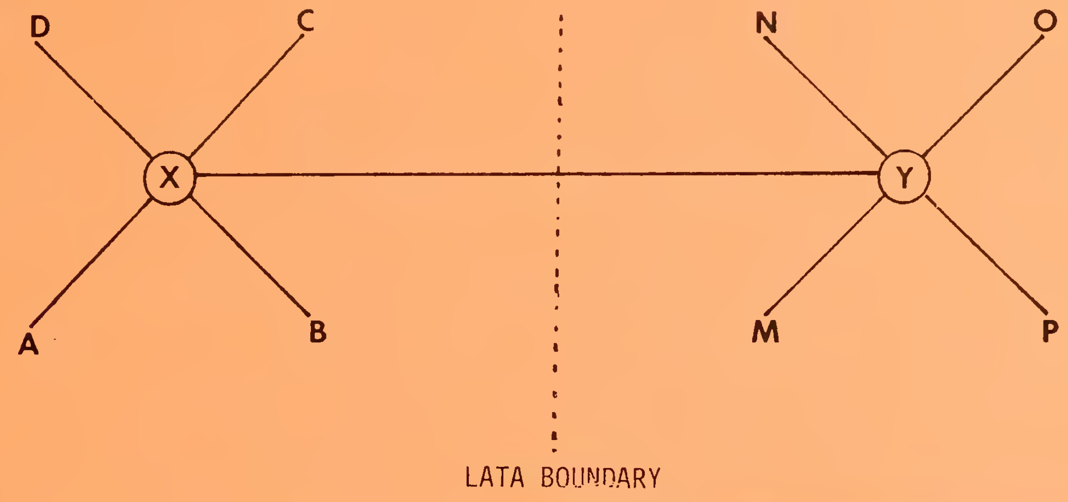
Building an independent company owned toll network is a complex decision with considerable risk. The investment decision process has many more variables and unknowns and therefore requires totally new criteria and thinking. Risks are higher and therefore the potential rewards should be greater. Rate structures and route mileage compared to airline mileage, must now be considered.

The State Public Service Commission will play a dominant role in the regulation of intrastate toll and thus the feasibility of an independent owned toll network. The possible continuance of averaging and pooling with a rural area high cost fund for intraLATA intrastate toll services will have a significant impact on the decision to build an independent network. If competition does occur for intraLATA intrastate toll, can the independent network compete with the BOC? Is there enough traffic for both? Can the independent toll network offer a cheaper rate to subscribers and cheaper cost to connecting carriers?

Building an independent owned toll network may be the most important decision many of you will make. It will require extensive research and analysis. Ultimately, it may require a willingness to take a significant risk.

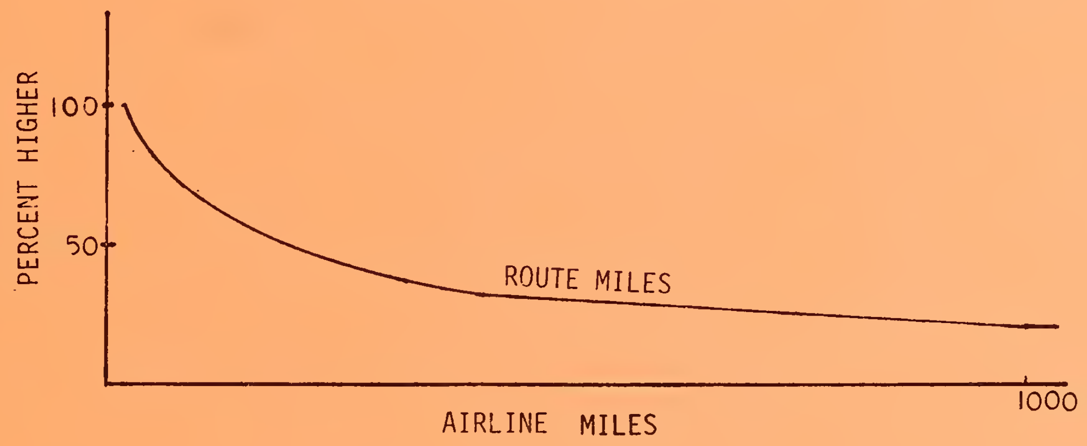
LOCATION AWAY FROM CENTERS

FIGURE 1



DIFFERENCE BETWEEN AIRLINE AND ROUTE MILES

FIGURE 2



SHORT HAUL NATURE OF RURAL TOLL CALLS

FIGURE 3

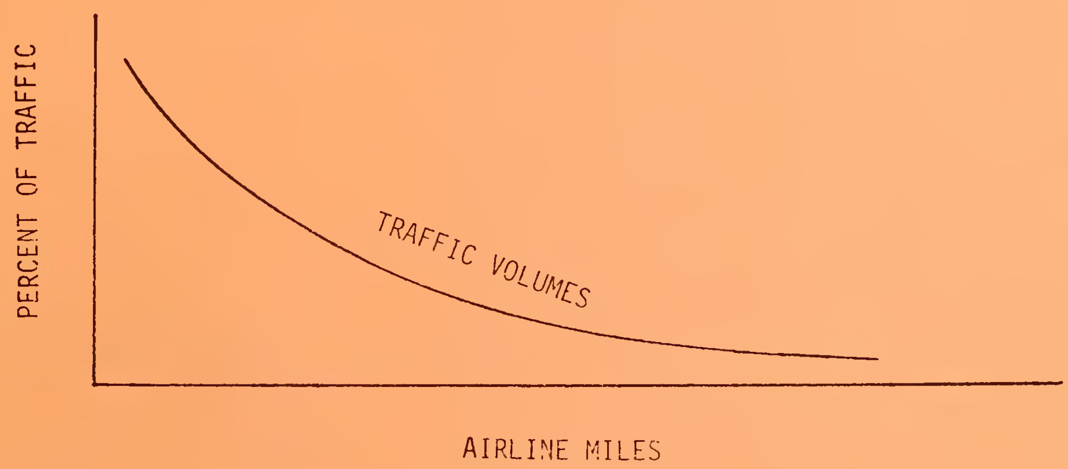


FIGURE 4

INDEPENDENT OWNED MICROWAVE ROUTE

INDEPENDENT AREAS | BELL AREAS

OFFICE HAS ENOUGH TRAFFIC FOR 24 TRUNKS

20 MILES BETWEEN OFFICES

ANNUAL CHARGES $67,000

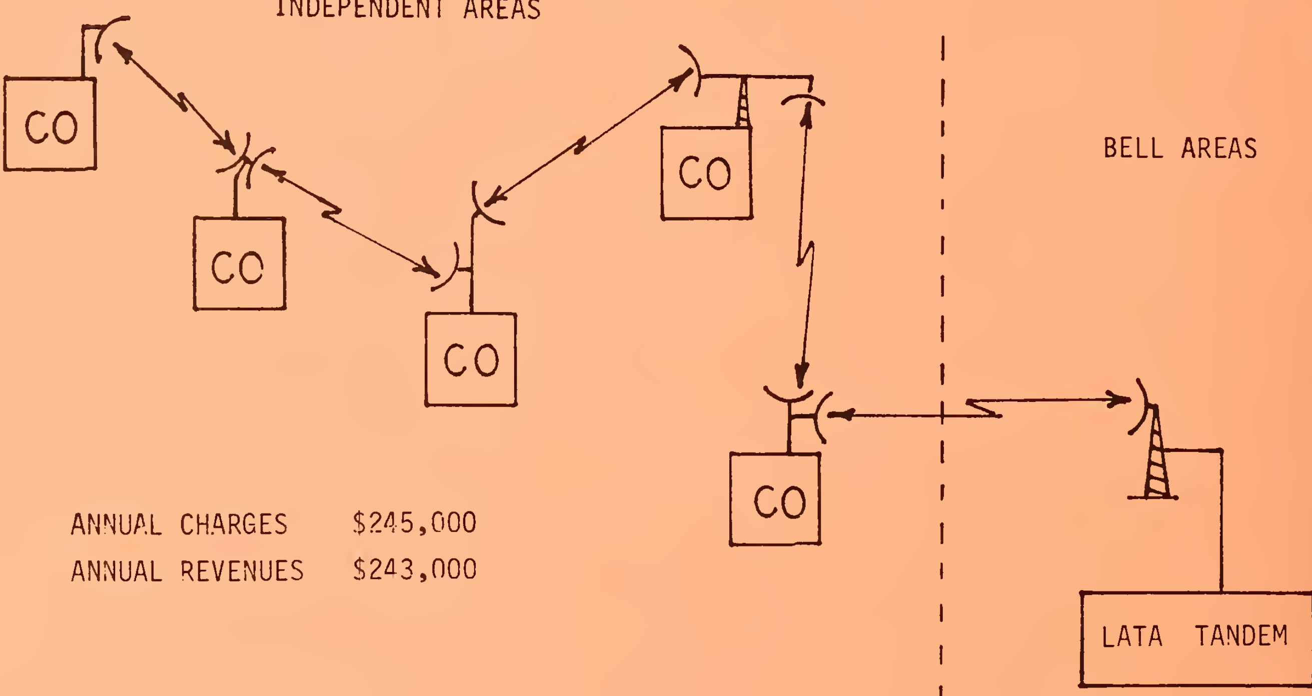
ANNUAL REVENUES $25,000

BOUNDARY

FIGURE 5

INDEPENDENT OWNED MICROWAVE ROUTE

INDEPENDENT AREAS



ANNUAL CHARGES $245,000

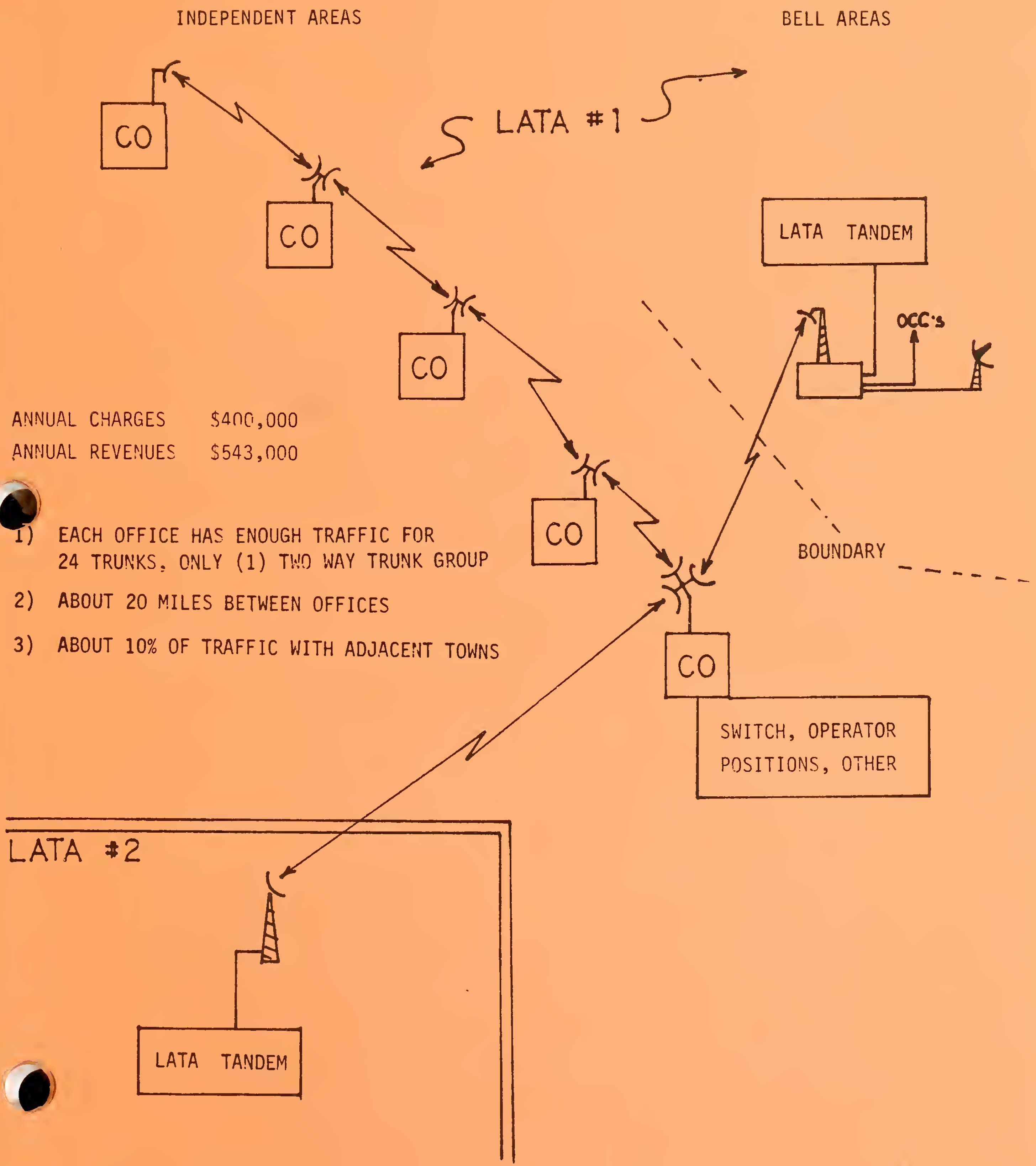
ANNUAL REVENUES $243,000

BOUNDARY

1) EACH OFFICE HAS ENOUGH TRAFFIC FOR 24 TRUNKS, ONLY (1) TWO WAY TRUNK GROUP

2) ABOUT 20 MILES BETWEEN OFFICES

FIGURE 6 INDEPENDENT OWNED MICROWAVE NETWORK



ANNUAL CHARGES $400,000
ANNUAL REVENUES $543,000

1) EACH OFFICE HAS ENOUGH TRAFFIC FOR 24 TRUNKS, ONLY (1) TWO WAY TRUNK GROUP

2) ABOUT 20 MILES BETWEEN OFFICES

3) ABOUT 10% OF TRAFFIC WITH ADJACENT TOWNS

BYPASS

Loans and Management Branch
Telecommunications Management Division

INTRODUCTION

The transformation of the U.S. telecommunications industry, from a total monopoly to a regulated/competitive environment with local service the last of the sole-supplier vestiges, has produced a phenomenon you may or may not have heard of: "bypass." The term "bypass" connotes different things to different persons because no official definition exists, or is universally accepted.

The American Telephone and Telegraph Company has defined bypass as "alternatives to local telephone company-provided distribution such as cellular radio, two-way cable TV, short-haul microwave and direct satellite-to-roof top antennas used by the OCCs and cable TV companies to circumvent the use of the local telephone network."

Although the FCC has not formally defined bypass, in the Access Charge Docket 78-72, the Commission referred to bypass as "the use of communications facilities or services (video, voice, or data) which go around the local telephone exchanges of the public-switched network."

New York Telephone (NYT) has defined bypass as any arrangement a customer uses to avoid or reduce local operating company provided access services. Bypass services can be voice or data, analog or digital, switched or dedicated, and intralata or interlata.

NYT has also made a distinction between "economic" bypass and "uneconomic" bypass whereas economic bypass occurs when bypass costs are less than a telephone company's costs for local-switched carrier access. Uneconomic bypass, on the other hand, occurs when a bypass supplier can provide selected customers access at a higher cost than a telephone company, but at a lower price because regulation causes the company's charges to be held at an artificial level above the costs.

Before proceeding any further, it is necessary to further distinguish between bypass in the contemporary sense and bypass in the form of alternative services. For example, private-line services (PLS) while technically a form of bypass, have been available for many years but are not generally considered bypass because PLS is made available through traditional telephone companies, and thus facilities are not constructed to avoid paying the costs of the local loop. However, construction of end-to-end private-line facilities by a non-telco organization for the purpose of replacing leased lines provided by the telephone company would be considered bypass.

A technology such as cellular radio also is not technically considered bypass of the local network because in every jurisdiction, one of the two cellular licensee awards will be enfranchised to the local telephone company. It is very possible that cellular radio in the future will be used to bypass or compete with the hardline telephone network. However, today's discussion of bypass will be confined to those services that are intended to avoid the use of a telephone company' local loop.

TYPES OF BYPASS

The bypass concept can be divided into three categories: local bypass, long-distance bypass and total bypass. Local, or "exchange" bypass is when a user communicates within an exchange area by way of a medium other than through the local exchange network (see Figure 1). Examples of local bypass are digital termination service (DTS) and cable TV networks.

Long-distance, or "toll" bypass occurs when a user attempts to duplicate the services provided by interexchange carriers by constructing private networks (see Figure 1). Long-distance bypass is usually provided by fiber optic routes, point-to-point microwave and satellite technology.

Total bypass is when the public network is totally circumvented at both the local and toll end. A total bypasser only uses common carrier facilities as a backup.

EMOTIONAL ASPECTS OF BYPASS

Some analysts assert that threat of bypass has been overstated. AT&T, some of the Bell Operating Companies and OCCs maintain that without cost-based rates, "uneconomic" bypass will be inevitable. On the other hand, carriers with a high percentage of rural subscribers stress the need for an adequate high cost fund to provide assistance to high-cost exchanges so service is affordable, or risk a significant number of "drop-offs" from the network. Fortunately, a majority of federal lawmakers fully support the universal service principle, and it is highly unlikely that rates will rise to a point of unaffordability, or permit bypass carriers to put traditional carriers out of business.

WHY BYPASS IS RELEVANT?

The concept of bypass has concerned a great many telephone company officials, primarily because of its economic impact. A small percentage of network users constitute a large portion of the revenue requirement for local service. If a large telecommunications user determines that it is more cost-effective to leave the public-switched network, that users' contribution to the revenue base (which is typically a much higher amount than a residential subscriber) will have to be absorbed by the remaining users; consequently, the monthly cost of telephone service will rise.

Government policymakers have become alarmed at the thought of bypass because it is believed to threaten the viability of universal and affordable service, as promulgated in the Communications Act of 1934. The effects have been numerous legislative proposals ranging from a bypass "tax" and "surcharge" to "lifelines" and "universal service funds" designed to soften the blow of bypass technologies on residential users.

Implications of Bypass for Urban Users

The implications of bypass technologies for users in metropolitan areas with high population density are different than the effects for rural Americans. Large businesses which often utilize vast amounts of telecommunications services are generally located in metropolitan areas.

Businesses needs are usually far more sophisticated than a residential user's. A high concentration of organizations with similar telecommunications needs in a condensed geographical area creates a market for new, distance-sensitive technologies such as fiber optic routes, DTS and point-to-point microwave that effectively compete with the costs of telephone company-provided services. Examples of this are the several fiber optic bypass systems used by the financial community in New York City.

Many times, communications managers find that building a network in an area where a company has several installations in a geographical area, or where several companies in an area form a joint venture for construction of communications facilities can save a lot of money.

At the same time, specialized carriers believing that local telephone company rates are not cost-based, continually search for alternatives to the local loop--and with some success. For example, MCI in 1983 tested a cable TV systems in Omaha, and Atlanta for two-way voice communications. The experiments proved the concept is feasible.

Implications for Rural Users

As in urban areas, it is possible rural communities may be adversely affected by bypass. As bypass technologies become more attractive and cheaper, users will be tempted to leave the network leaving the remaining subscribers to absorb the total revenue requirements.

In many rural areas, several businesses have already switched from message toll services to private-line or WATS services in order to lower their communications costs. This has resulted in lower toll revenues to the local telephone company. While this may not consititute bypass as I have described it, it is an attempt by business to reduce their cost by avoiding paying high message toll rates which are a result of today's level of support of local service by message toll. These same businesses may go even further and bypass the local exchange via satellite or other means where feasible.

Although bypass is less of a threat in rural areas than it is in urban areas, it is still a serious future problem. If a significant number of large businesses elected to bypass urban exchanges and carry traffic strictly over their own networks, the resulting terminating toll traffic to your exchanges may be reduced, or at least not grow. The cost of toll service over the present nationwide network could go up because it is underutilized because large businesses have left.

The problem is particularly pronounced in high high cost exchanges. This problem is particularly pronounced in high-cost rural communities where the differential between local telephone service and bypass technologies is marginal.

HOW LARGE IS THE THREAT OF BYPASS?

Although there is little information available to quantify the impact of bypass for rural carriers, obviously the effects of a large drop in any company's customer base can be detrimental. Divestiture and the postponement of the Access Charge Order and its accompanying "Universal Service Fund" creates an additional element of uncertainty. As a practical matter, the way to avoid a massive exodus from the local network is to minimize local exchange rate increases.

For the most part, it is only the large, sophisticated users that are familiar with alternatives in state-of-the-art telecommunications. In fact, the typical subscriber usually has some loyalty to their present carrier unless they have experienced difficulties in the past.

Most users shy away from intricate dealings with the telephone company unless they have a large monthly bill and wish to reduce it. The media has highlighted consumer frustration during the first few weeks of the Bell System breakup. It seems a majority of people were perplexed as to why Ma Bell was being broken up, lamenting that the old system worked very well It will be interesting to see how many subscribers migrate from AT&T to the OCCs in the absence of a compelling reason.

In addition to customer loyalty, the local loop has many advantages over other alternatives. First, the present infrastructure offers comprehensive service including equipment, repair, wiring, installation, etc. New companies usually do not offer all these services which tends to frustrate customers. Many people just do not care to deal with numerous vendors.

USERS' PERSPECTIVE

Both large users of telecommunications services and interexchange carriers by virtue of economics may be driven to bypass the public network if the price of access proves too high for equivalent service. It appears that telephone company provided services are highly price-elastic with the increasing number of alternatives becoming available.

A recent study conducted by Touche Ross & Co., a "big eight" accounting and consulting firm, indicated that in the State of Wisconsin, approximately three out of four companies indicated that price was a major factor to would-be bypassers. Company officials cite the ability to manage one's costs without worrying about rate increases as a primary incentive to engage in bypass.

On the other hand, bypass is an extremely capital-intensive proposition that requires a large technical staff to manage. Moreover, even the most sophisticated bypassers have large annual bills from their local telephone company.

Money, however, is not the only reason for bypass. Many users require data transmission capabilities that the telephone company cannot provide, but the Touche Ross study points out that present bypass systems are predominantly voice traffic.

It is not known how many users are anticipating the use of bypass technologies. The Touche Ross survey indicated that one in six large users are already engaging in bypass, and as new technologies become available, more traffic will be diverted from the public network.

CONCLUSION AND SUMMARY

The technological revolution in communications has created a host of alternative services to traditional wire-line telephony. Bypass is often -- perhaps too often -- thought of in the context of a threat.

Bypass technologies themselves should not be perceived of as a threat because improved, more efficient technologies can only enhance our ability to communicate. Many telephone companies are already incorporating new technologies into their present networks to meet customer needs.

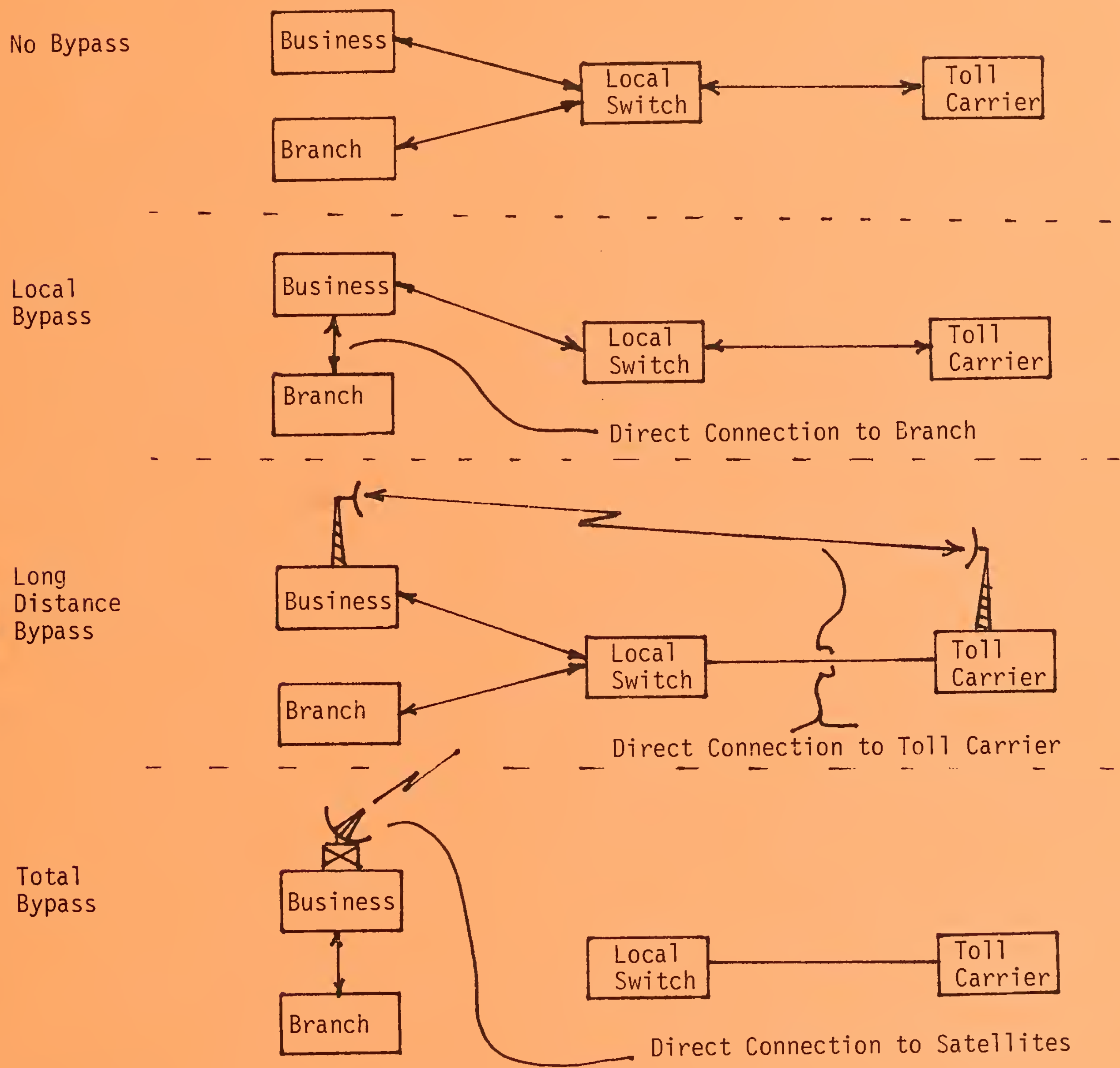
The challenge we must face is how to strike a balance between offering services at competitive prices while upholding the principles of universality and affordability to all Americans.

At this time, quantifiable information on the extent to which consumers are employing bypass techniques is scant and inconclusive. Presently, the FCC and the Joint Board are undertaking cost surveys in connection with implementing the Universal Service Fund. Additionally, the Commission plans to initiate a detailed study of the extent and dangers of bypass.

One thing, however, is certain: bypass technologies are here to stay. An attempt to stop or curtail their development would be akin to trying to halt innovation. Accordingly, it is in all of our interests to adapt as best we can in the changing world of telecommunications as the concept as bypass emerges.

FIGURE 1

THREE TYPES OF LOAN EXCHANGE BYPASS



Cellular Mobile Radiotelephone Systems
An REA Management Perspective

David B. Cohen
Revenue Requirement and Valuation Branch
Telecommunications Management Division

Cellular mobile radiotelephone systems are just now beginning to come on line in some of our nation's largest cities. They are expected to perform well, from both a technical and an economic perspective. Does this mean that cellular technology will enjoy equal success in rural America? Only time will tell. However, as you know, most new telephone technology has required some additional developments to be adapted economically to the rural environment on a broad scale.

Let's look at cellular radio from a purely functional viewpoint. Its frequency reuse and computer handoff abilities allow for numerous subscribers in a relatively small geographic area. It can be used for mobile service (in a car or truck), portable service (carried on one's person) or fixed service (in the home or office). You will notice that some of these services overlap with service provided by both landline systems and the currently used IMTS technology (Improved Mobile Telephone Service). The question then becomes - why use cellular technology if present technology can bring us the same services? The answer to that question may not be as simple as it may seem at first glance. On the positive side for cellular as opposed to IMTS, for example, are the following traits:

1. Cellular can furnish greater capacity in areas where such capacity is required. The problem of blocking will be greatly reduced.

2. Cellular will probably be the standard mobile technology for the next 10 to 20 years. The ability to interface with other mobile systems is important. This is especially true in relation to transient (roamer) traffic.

3. Cellular can accommodate portable units. IMTS generally cannot.

4. Since cellular is functionally similar to IMTS, it will receive similar treatment from REA in terms of financing and general funds policies.

On the other hand, IMTS has some functional advantages over cellular for rural telephone systems:

1. IMTS has a greater range than cellular.

2. Since IMTS is in a different frequency band than cellular, it is less vulnerable to propagation problems caused by vegetation or terrain.

3. As urban systems shift from IMTS to cellular, frequency space may become available which could mitigate the problem of channel crowding in rural areas.

Cellular radio can be compared with landline service on a functional basis:

1. Cellular technology can be used for portable, mobile or fixed service while landline is only for fixed. At present, the regulatory schemes set up by the FCC expressly allows use of the cellular frequencies for mobile service.

2. Through additions to plant, landline has an infinite capacity, cellular does not, since there are natural limitations on cell splitting.

3. Landline can partially mimic the portability of cellular in very very limited way by use of cordless phones.

4. REA views landline and cellular as merely two different technologies to achieve the same goal of providing telephone service within the meaning of the Rural Electrification Act.

So far, we have compared cellular radio on a functional basis with both IMTS and landline service. However there are many other telecommunications services available now or being proposed, against which cellular can be compared. For example, SMR (Special Mobile Radio), Two-way Radio Dispatch, and radio paging services are current radio technologies as is cellular. In the future, mobile service using satellites may be introduced, or the analog cellular system may go digital. So from a functional viewpoint, cellular mobile radiotelephone is not a unique service. There are many possible present and future competitors. Therefore, as usual, the answer to the question of whether cellular is the right service to provide to subscribers at this time boils down to a question of economics. From both a cost and a revenue standpoint, how does cellular stack up to these other technologies?

As a partial answer to this question, and to clarify other frequently misunderstood aspects of cellular, let's cover three main points. First, cellular is not a brand new technology. As a matter of fact, the idea of using many lower powered transmitters was proposed decades ago. The problem was in handing off the call from one transmitter to another as the vehicle crosses the cell boundary. This was solved in the early 1970's when computerized electronic switching technology allowed handoff without interrupting the call. The significance of noting the length of time cellular radio has been around is the fact that in the time interval between its development and its introduction, technology has been moving ahead rapidly. Cellular may not really be the state of the art system it appears to be.

A second frequently asked question about cellular is whether it is appropriate for fixed service at this time. From a functional viewpoint, it is not appropriate for fixed service under its present design for mobile. However, there is nothing inherent in the cellular technology itself which would prevent it from being engineered differently to accomodate fixed service.. From an economic viewpoint, it has not yet proved in. Although many people that have written about cellular have contended it may be viable for fixed service at this time, so far we have seen no situations where this is true. Even a small cellular system for fixed service, with a certain amount of unserved customers in a relatively dense arrangement, as far as we know is not now feasible, and probably only a handful of these situations exist, if that many. Using cellular to replace or complement existing plant capacity suffers from a similar problem of feasiblity. However, costs are constantly changing, so one must keep a careful eye on competing technologies to see which one is most cost effective.

The third point about cellular which is frequently misunderstood is its regulatory status. Cellular radio is not a deregulated service. It will be under tariff just like IMTS and plain old telephone service. Also like those services, cellular terminal equipment will be deregulated.

This last point brings us to the question of, "What has the Federal Communications Commission (FCC) done about cellular radio, and what is it doing now?" Well, as discussed earlier, the technology was basically ready in 1971. Yet here we are in 1984 and the first cellular systems are just beginning to come on line. What happended at the FCC in those intervening years?

1971 - AT&T files proposal for development of a cellular mobile system.

1974 - FCC allocates 40 MHz of 800-900 MHz spectrum for cellular systems and opens filing to all those interested in developing cellular systems.

1975 - FCC modifies 1974 ruling to include radio common carriers (RCC's).

1975 - Illinois Bell files application with FCC to begin developmental test of high-capacity cellular system in Chicago area.

1977 - Licenses granted for cellular systems in Chicago and in Washington, D.C./Baltimore areas.

1978 - Experimental service begins in Chicago, serving 2,000 customers.

1980 - FCC issues inquiry and proposed rulemaking for cellular service, emphasizing need for speed in the process to bring service to the public as quickly as possible.

1981 - FCC issues report and order outlining rules for cellular industry.

1982 - FCC decision on reconsideration creates competition by dividing each of the 90 largest markets into two licenses, wireline and non-wireline. Almost 1,200 applications received for first 90 markets.

1983 - First U.S. commercial cellular service begins in Chicago.

As you can see from reading the above highly simplified regulatory chronology, the introduction of cellular radio has been delayed for many years by FCC proceedings. Realizing this, and noting the tremendous pent up demand for mobile telephone service in urban areas, the FCC tried to accelerate the process of cellular licensing. One of their methods of doing this was the concept of the wireline set-aside. This divided the spectrum allocated for cellular into two bands, with one exclusively reserved for use by the local wireline telephone system and the other basically open to all applicants. Another reason for the creation of the wireline set-aside was to reward the wireline telephone company which initially developed the cellular technology. The wireline set-aside has withstood numerous court tests since its introduction. However, it still is a controversial issue. It is scheduled to expire sometime during the Summer of 1984. The date has not yet been set by the FCC. After the set-aside expires, if there have been no applications for the wireline or non-wireline blocks of frequency, any party can apply for either block. Applications cannot be made, however, by the same party for both blocks of frequencies.

The FCC has also decided to award licenses on a Metropolitan Statistical Area (MSA) basis. This means that a separate application is needed to serve each of the over 200 MSA's in the U.S., plus an application for more rural or remote areas not included in MSA's. So, for example, if a carrier wishes to provide service in an area encompassing both MSA and non-MSA territory, a separate application is required for each. To file in an MSA, a telephone system "presence" is required. This usually means at least one landline subscriber. Telephone systems may file for all non-MSA markets provided that they now serve landline subscribers within the general market area covered by the cellular application. Each applicant is free to define its own Cellular Geographic Service Area (CGSA).

Merely applying for a cellular license does not necessarily commit the applicant to building the system immediately. The FCC requires providers of cellular service to serve at least 75 percent of the potential subscriber market in their proposed service area within three years of the effective date of their construction permit, unless an extension is granted.

The FCC has decided to deregulate mobile customer premises equipment (CPE) to go along with its Computer II decision relating to fixed terminal equipment. The Commission has extended its bifurcated approach to mobile equipment. New

CPE, which includes all new mobile CPE acquired by a carrier or manufactured by an affiliated entity after January 1, 1984, will no longer be tariffed. All other in-place or existing mobile telephone equipment was classified as embedded CPE. Carriers will provide embedded CPE under tariff during a transition period until the manner of detariffing the embedded equipment is determined in CC Docket 81-893. These rules apply to both IMTS and Cellular CPE. Obviously only the rules relating to new CPE will be relevant for cellular.

The FCC is considering more actions concerning cellular radio regulation. As of now, the FCC has stated that during May of 1984, it will begin accepting applications from telephone systems for the wireline carrier block of cellular frequencies for the approximately 150 MSA's below the top 90 markets. This obviously leaves only a small window of opportunity for REA telephone borrowers to take advantage of the wireline set-aside, since it is now set to expire during the Summer of 1984. Throughout the cellular licensing procedure, the FCC has sought to minimize delay by avoiding costly and expensive comparative hearings. They have accomplished this goal by encouraging applicants seeking licenses in the same MSA to combine into one consolidated applicant. In most cases in the top 30 markets this has been done. Wireline carriers have combined with each other to seek the band set-aside for them, and non-wireline applicants similarly have joined together. Because of the pent up demand for mobile service in cities, each group, wireline and non-wireline, has been especially anxious to be first in the market. The Commission has decided that even this process is not moving expeditiously enough, so it issued a Notice of Proposed Rulemaking on October 28, 1983, in CC Docket 83-1096, proposing implementation of a system of random selection or lottery to select cellular licensees from among competing applicants. At this writing, the FCC has not resolved this issue. However, as usual, there is no shortage of speculation concerning the FCC's ultimate decision. My feeling is that the FCC will implement a lottery procedure for selecting applicants for all markets other than the top thirty largest. The date for submitting applications and for the expiration of the set-aside will probably remain the same.

How will this affect rural cellular applicants? There will probably not be very much effect on rural applicants at all. Possibly, it will make it simpler to apply since an application which is not subject to the possibility of comparative hearings may be less rigorous.

Other regulatory actions in the area of cellular radio may include expanding the available frequency space, since urban systems are already complaining that demand is so great that cell splitting cannot create sufficient additional capacity. Also, in CC Docket 81-893, the FCC is proposing to adopt a plan to remove embedded mobile telephone terminal equipment from under tariff. In the future, cellular licensees may be applying to the FCC for construction waivers to expand the three year time frame to which they are committed to building a cellular system.

Now that we have explored the basic facts about cellular which are applicable to everyone, we come to a threshold question: Is cellular mobile radiotelephone the right service for you at this time? Although the application period is approaching and the set-aside expiration is following close behind, a decision on whether to construct a cellular system does not necessarily have to be made immediately. Merely applying for a cellular license does not mean you have to build the system. Of course, if you have no intention at all of building a system, it would be frivolous to apply. On the other hand, if after serious consideration of the feasibility of constructing a cellular system, you conclude that it might be possible on a break-even or better basis in the next few years, it might be prudent for you to hedge your bets and nail down the wireline set-aside while it is still available. Application expenses are really not as high as many of the numbers you've probably heard floating around. It is our understanding that a system can submit a cellular application for under $3,000 per cell. At this price, it seems that applying for a cellular license could be looked upon as a relatively inexpensive insurance policy.

The question of feasibility is obviously one of the key issues in your decision as to whether to invest in a cellular radio system. There are five basic feasibility considerations to investigate.

1. Number of subscribers (penetration rate, size of market, etc.)

2. Average revenue per subscriber.

3. Financing cost.

4. Time period of analysis. (Recovery of costs.)

5. Annual operating expenses.

A realistic estimate of these considerations should yield information which would point to a conclusion regarding the feasibility of investing in cellular radio. A very thorough discussion of how to come up with these figures was provided by Norman C. Lerner, in an article entitled "Cellular Radio: Is the Project Financially Feasible" printed in the Fall 1983 edition of "Rural Telecommunications," the journal of the National Telephone Cooperative Association. Instead of repeating here the analysis providing by Mr. Lerner, we have attached a reprint of the article to this paper for your use.

Other than application expenses and feasibility determination, what other considerations should you be exploring in answering the question of whether cellular radio is the right new service for you at this time. One consideration must be the possibility of other firms providing cellular mobile radiotelephone in your service area. Now, you may say, so what? If I am unable or unwilling to provide the service in my area, why should I object to someone else coming in and building a cellular system? The answers are speculative at this time, but they are still worthy of discussion. If another common carrier enters your serivce area to provide cellular service it may be possible that it may offer toll service to an adjacent metropolitan area, bypassing your local switch and causing the loss of important toll revenue. Also, if you presently have IMTS, the compatibility of cellular nationwide may cause your IMTS customers to abandon your system and go to the cellular firm for service. And of course, if in the future, cellular or another radio technology becomes price competitive with landline service, your best subscribers in your so-called exclusive service area may be up for grabs. So not only does the chance of toll bypass exist, local bypass is not out of the realm of possibility either. Finally, you must look at your dealings with subscribers. Providing cellular is a service to your subscribers. It allows you to remain the exclusive contact to satisfy their telecommunications needs. Entry of another carrier could break that telco/customer bond and allow competition in other areas of your business.

If you do decide that cellular is the right new service for you, how should the company be structured? Are you interested in a joint venture? How about forming a separate subsidiary? Let us begin with joint ventures. We at REA are seeing many proposals for joint ventures with many different types of structures. The decision as to whether to enter into a joint venture, provide the service yourself, or not provide service at all really breaks down into two considerations. First, if you feel that it is viable to provide cellular service but you are inhibited in some way from doing it entirely yourself, a joint venture is a reasonable solution. The second consideration is if you can provide cellular yourself, does a joint venture enhance the feasibility or reduce the risk sufficiently to make sharing ownership worthwhile? This all depends on the particular terms of the joint venture arrangement. It is difficult to generalize since terms vary so widely. However, our basic viewpoint is that it is usually preferable to provide the service through the wireline carrier or group of carriers in the service area. However, if financial or other constraints cause borrowers to seek combination with non-wireline carriers, they should realize that the telco, the wireline carrier, is holding the valuable resource, the set-aside. Thus, the wireline carrier is in a position to explore alternatives such as joint ventures with other non-wireline carriers than the one it is first approached by, or joint ventures with wireline carriers. Remember, possession of the set-aside affords wireline carriers a valuable negotiating tool in determining ownership shares in joint ventures with other entities. Also, for purposes of the wireline set-aside, the equity position assumed by the wireline carrier is important. A minority equity position could endanger an applicant's status as a wireline carrier under the set-aside.

There has been much movement lately on the formation of subsidiaries. If fact, REA has been encouraging subsidiaries for non-telephone service operations, particularly cable television. REA has no objection to the formation of a subsidiary to provide cellular radio service, as long as the profits from the subsidiary flow up to the telephone company. However, since cellular radio is telephone service as defined in the Rural Electrification Act, a separate subsidiary is not required by REA. The FCC also imposes no separate subsidiary requirement on small telephone companies, merely a rule mandating separate accounting. REA has no objection to the telephone system providing cellular as part of telephone company operations.

An important issue for REA borrowers is the financing and general funds policies REA will follow in relation to cellular radio service. As stated above, cellular radio is telephone service under the Rural Electrification Act. This is a key issue in determining REA treatment of proposals for financing and investment in cellular. Current policies concerning IMTS as stated in REA bulletins will also apply to cellular. These policies include:

1. REA only funds borrowers providing complete telephone service (this usually excludes radio common carriers).

2. In order to qualify for financing, the cellular geographic service area must include a significant part of the borrower's local exchange area.

3. The cellular operation must stand on its own for feasibility purposes.

4. The cellular operation must be primarily for the benefit of rural users.

5. A shorter amortization period than the usual 35 years may be employed.

6. As with other telephone purposes, no financing will be provided for terminal equipment.

Borrowers use of general funds for cellular radio is an issue causing much discussion inside and outside of REA. As you know, a general funds expenditure may be treated in three ways:

1. It may be entirely excluded from the calculation of the appropriate level.

2. It may be entirely included in the calculation of the approprite level.

3. It may be excluded from the calculation of the appropriate level up to the amount of allowable distributions by a particular borrower.

The determination of which category the investment falls into decides its general funds treatment. Generally if an investment in cellular radio is feasible, rural, and covers a significant portion of the borrowers service area, it will be entirely excludable. Cellular, since it is a telecommunications purpose, will never be entirely includable in the calculation of the appropriate level. However, investment in cellular is subject to the allowable distribution level when it is not rural, since it is then not an Act purpose.

In summary, cellular mobile radiotelephone may afford many new opportunities for rural telephone systems. REA has sent out two letters to all borrowers encouraging the investigation of the possibility of providing cellular service. However, we have also tried to point out some of the pitfalls. Remember, although cellular radio is a tariffed service, it shares many of the higher risk factors usually associated with deregulated services. There is the possibility of competition, it may be difficult to estimate the market, and the demand may fluctuate according to economic conditions. Deciding whether cellular is the right service for you at this time is a challenge which you face right now. Your response to that challenge, regardless of your conclusion, will be a decision you will have to live with for many years to come. I hope you will devote the time and effort to it that this important issue deserves.

ATTACHMENT

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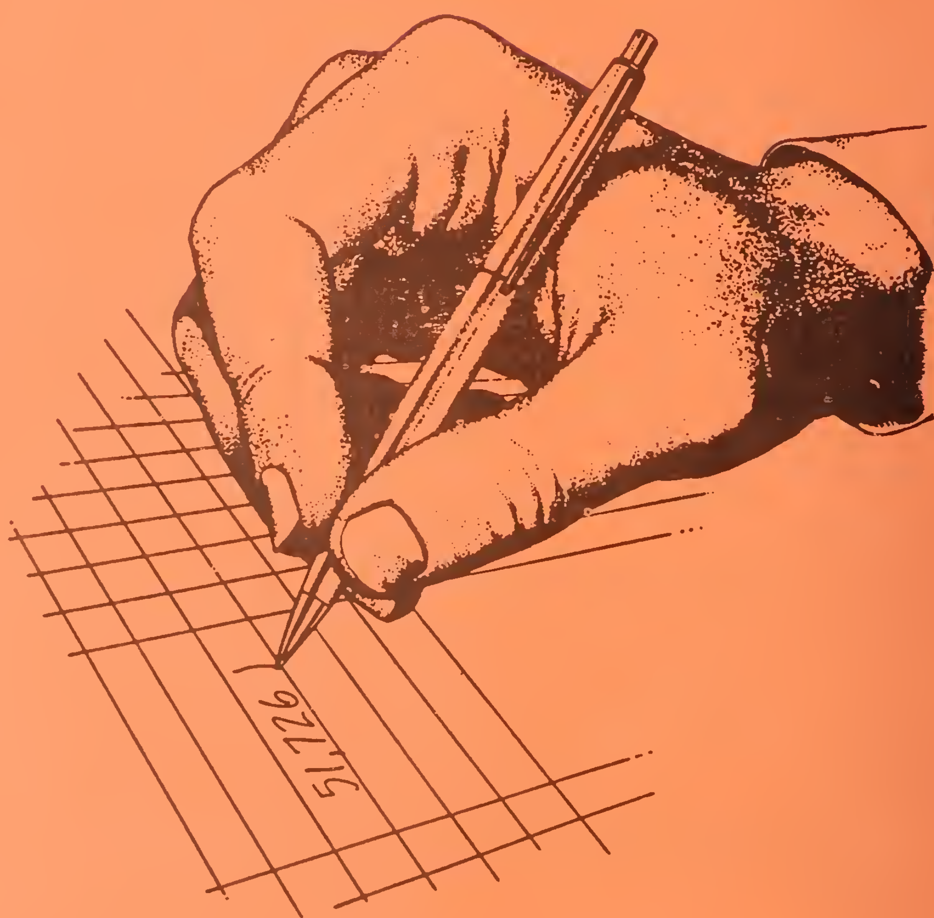
Cellular Radio: Is the Project Financially Feasible?

Before entering a new business, you need to figure out whether the opportunity is worth the price.

by Norman C. Lerner

Telephone system operators that are interested in getting into cellular radio face a difficult question: Is the area proposed for cellular coverage worth the required investment? It may be that alternatives to cellular radio, such as conventional land mobile radio service and the new specialized mobile radio (SMR) service, would meet subscriber needs, particularly if the telephone system is small. Deciding to invest in a cellular system—or any new business venture, for that matter—requires an analysis of the financial feasibility of the project.

As it stands now, the Federal Communications Commission (FCC) will be accepting cellular radio license applications from below the top 90 markets on March 1, 1984. (This date was recently changed from December 1, 1983). To speed up the process of awarding the licenses, the FCC is considering using a "lottery" procedure.* Before developing a detailed application, however, there is a quick way to estimate the financial feasibility of constructing and operating a cellular system. The following approach provides just such an estimate.



*See FCC Docket 83-1096, Notice of Proposed Rulemaking, released October 28, 1983. The successful applicant will be required to construct the cellular system and operate it for at least one year. This requirement is intended to eliminate "speculation" among cellular license applicants.

Norman C. Lerner is president of Transcomm, Inc., an engineering and economic consulting firm specializing in regulatory economics and domestic and overseas telecommunications.

Areas To Consider

Suppose a vendor proposes to build, install, and provide all the equipment for a cellular radio system at a prearranged cash price. The vendor is interested only in selling its equipment and services—not in operating the system. How would a telco know whether the proposed investment is reasonable for the specific market area? The telco would have to develop system revenue and cost projections to compare with the equipment vendor's price. Here are the areas that must be considered:

Number of subscribers. Estimates of the number of cellular radio subscribers can be based on the results of many recent market studies and publications that are now available. Moreover, the managers of local telephone systems have an advantage: they know their service areas, and they know about available alternative services, price structures, and the like. A very rough rule of thumb, however, could be the number of subscribers calculated as a small percentage of the population to be covered by the system—1 percent to 5 percent, for example.

Average revenue per subscriber. Considering the revenue per subscriber separately from the number of projected subscribers provides flexibility in the financial analysis. In other words, the revenue projections can be adjusted—such as by changing the subscriber rates—without changing the projected number of subscribers. However, large changes in estimates of per subscriber revenue would likely have an effect on the number of people who would choose to subscribe. Higher revenues based on higher rates, for example, would reduce the number of subscribers.

Time period of analysis. For the financial analysis, a time framework for operating income projections and for recovering the investment must be chosen—five years or ten years into the future, for example. To keep the analysis simple, it can be assumed that full depreciation of the investment will occur over the same time period chosen for revenue projections.

Financing cost. The cost of financing the cellular project depends on the type of funds available—such as new equity, a bank loan, general funds, or various combinations—and on the cost of these funds. In addition to the financing costs, the interest rate used in the analysis should include an amount for profit. Otherwise, the analysis will represent only a break-even feasibility without showing the project's profit potential.

Annual operating expenses. The estimate of annual expenses, which should exclude depreciation, can be based on past operating experience. One rough method of calculation would be annual expense taken as a percentage of the initial investment. It could be assumed, for example, that the annual operating expenses would be 12 percent of the equipment vendor's price quotation for the cellular system.

After the initial assumptions are established in these areas, the estimates for future income and expenses can be converted to present values. The present value of net operating income is the figure that is compared to the equipment vendor's proposal to determine its feasibility. If the present value of net operating income is greater than the quoted equipment price, the proposal is financially feasible. If the net operating income is less than the vendor's quotation, the proposal is not feasible for the given assumptions. Changes in some of the assumptions could improve the proposal's feasibility. These changes could include a lower equipment price, a lower expected rate of return (profit), additional subscribers, higher rates, or a combination of adjustments to the original assumptions.

The process for analyzing the financial feasibility of a project involves making initial assumptions, performing calculations, reviewing the results, and making any necessary adjustments. Here is an example.

Assumptions

Proposal. An equipment supplier proposes to provide a turnkey cellular system for $400,000. The system will be constructed and in operation within a year.

Number of subscribers. The cellular sustem will have 100 subscribers by the end of the first year of operation, and 25 new subscribers will be added each year for four more years. That means there will be a total of 200 subscribers by the end of the fifth year (see figure 1).

Average revenue per subscriber. Subscribers to the cellular system will be charged $90 per month, or $1,080 per year. The monthly rate of $90 is based on a fixed charge of $20 plus usage charges; subscribers are projected to use their radios 312 minutes a month (between 14 and 15 minutes each weekday), and a majority of that use is projected during peak hours:

Fixed monthly charge	$20
Usage charges	
Peak rate at $.25 per minute for 75% of usage ($.25 × 234 minutes)	59
Off-peak rate at $.14 per minute for 25% of usage ($.14 × 78 minutes)	11
Average monthly revenue per subscriber	$90

*Another step is required if the tax effects of the cellular operation are to be included. The cost of capital is divided by 100 minus the marginal tax rate. For this example, assuming a marginal tax rate of 50%, the interest rate becomes 20%: 10% divided by (100% minus 50%). This interest rate is then selected from the tables.

Time period of analysis: five years. Subscriber revenues during the first five years will recover the equipment investment and provide a return on that investment.

Financing cost. Assume an average cost of capital: a weighted debt-equity requirement at 10 percent that matches the hypothetical telco's existing financial position:

Debt:	80% of total capital at 8%	6.4%
Equity:	20% of total capital at 18%	3.6%
Weighted cost of capital		10.0%

This assumption includes an allowance for before-tax "profit" in the equity portion of the capital structure.

Annual operating expenses, excluding depreciation: 12 percent of the initial $400,000 investment.

Calculations

Using these initial assumptions, the next part of the financial analysis can be accomplished by converting the estimates of future dollars to present values that can be compared to the vendor's cash price offer of $400,000. This process requires the use of either a financial calculator or prepared tables that convert future values to present values for various interest rates (costs of money). Tables 1 and 2 are provided for this purpose. The numbers in the tables have been calculated from mathematical interest formulas relating present, future, and periodic sums.

Two separate calculations are needed to compute the present value of future revenues from subscribers: one for the "base" number (or uniform series) that is constant for the five-year period, and one for the annual increment of subscribers. Figure 1 shows that in this example the base value is 100 subscribers per year and the annual increment is 25 subscribers.

The first step is to compute the present value of the base number of subscribers. Table 1 is used for this purpose. Remember, it has been assumed that the time period is five years and the cost of money is 10 percent.* The present value of 100 subscribers per year for five years at 10 percent is 379.1:

Base number of subscribers	100
Table 1 value (5 yrs. @ 10%)	×3.791
Present value of annual subscriber base	379.1

This present value of the annual subscriber base can then be converted to a revenue value by multiplying it by the projected average revenue per subscriber ($90 per month, or $1,080 per year):

Present value of annual subscriber base	379.1
Annual revenue per subscriber	×$1,080
Present value of revenue for subscriber base	$409,428

Next, the same kind of calculation must be performed to determine the present value of revenue for the annual increment of 25 subscribers. Table 2 is used for this purpose. (Table 2 can be used only if the number of additional subscribers per year is a constant value—25 per year in this example. Table 2 could *not* be used if it were projected that there would be 25 additional subscribers in the second year, 30 in the third year, 35 in the fourth, etc.)

Annual subscriber increment	25
Table 2 value (5 yrs. @ 10%)	×6.862
Present value of annual subscriber increment (rounded)	171.6
Annual revenue per subscriber	×$1,080
Present value of revenue for annual subscriber increment	$185,328

Figure 1. Cellular Network Subscribers

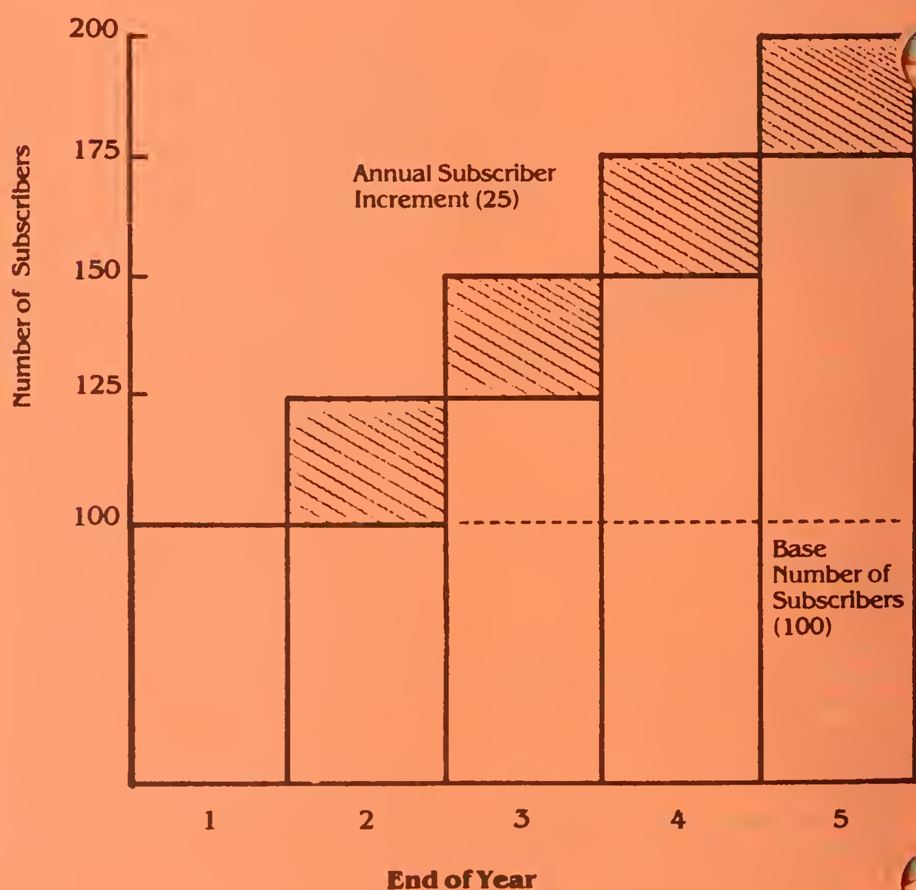


Table 1. Present Equivalent of Uniform Series

Years	Interest Rate 6%	8%	10%	15%	20%	25%
5	4.212	3.993	3.791	3.352	2.991	2.689
10	7.360	6.710	6.145	5.019	4.192	3.571
15	9.712	8.559	7.606	5.847	4.675	3.859
20	11.470	9.818	8.514	6.259	4.870	3.954

Table 2. Present Equivalent of Gradient Series

Years	Interest Rate 6%	8%	10%	15%	20%	25%
5	7.935	7.372	6.862	5.775	4.906	4.204
10	29.602	25.977	22.891	16.979	12.887	9.987
15	57.555	47.886	40.152	26.693	18.509	13.326
20	87.230	69.090	55.407	33.582	21.739	14.893

Table 3. Uniform Series of a Present Sum

Years	Interest Rate 6%	8%	10%	15%	20%	25%
5	.23740	.25046	.26380	.29832	.33438	.37185
10	.13587	.14903	.16275	.19925	.23852	.28007
15	.10296	.11683	.13147	.17102	.21388	.25912
20	.08718	.10185	.11746	.15976	.20536	.25292

Source: *Engineering Economy: Analysis of Capital Expenditures* by Gerald W. Smith, Iowa State University Press, Ames, Iowa, 1973.

Adding the present values of revenue from the subscriber base and the annual increment yields the present value of operating revenue generated for the five years:

Present value of revenue for subscriber base	$409,428
Present value of revenue for subscriber increment	185,328
Present value of operating revenue for 5 yrs. @ 10%	$594,756

The present value of the annual operating expenses must be computed next, again using table 1. Assuming that the annual expenses will average about 12 percent of the initial investment, the present value of annual operating expense is $181,968:

Initial investment	$400,000
	× .12
12% of initial investment	$ 48,000
Table 1 value (5 yrs. @ 10%)	×3.791
Present value of operating expenses for 5 yrs. @ 10%	$181,968

The present value of operating revenue ($594,756) minus the present value of operating expenses ($181,968) yields the present value of net operating income before taxes: $412,788. This is the value that must be compared to the equipment vendor's proposal. Because $412,788 is greater than the quoted equipment price of $400,000, the proposal is feasible under the assumption that the investment will be recovered within five years with a return of no less than 10 percent for the period.

Adjusting the Numbers

Suppose a larger cellular system was required and the equipment vendor's quote was for $600,000 instead of $400,000. Using the same assumptions, the present value of net operating income would be less than the equipment price, indicating that the investment recovery requirements could not be met.

There would be several options. The most direct solution would be a reduction in the vendor price, which would be possible especially if some system reengineering were considered. Other options would include a longer depreciation (write-off) period, a lower rate of return, or both. Tables 1 and 2 show that as the interest rate or capital return requirement decreases, the figures from the tables used to compute the present values increase. For example, the table 2 value for five years at 10 percent—6.862—increases to 7.935 at 6 percent. This indicates that a lower rate of return requirement will result in a greater potential for revenues to recover the equipment cost—even with the same number of subscribers.

Using a longer time period can have the same effect as projecting a lower rate of return. Consider, for example, the same annual subscriber base (100 subscribers), the same annual increment (25 subscribers), and the same cost of money (10 percent). However, assume that there would be no new subscribers beyond the fifth year; in other words, there would still be 200 subscribers at the end of the tenth year of operation. This effectively changes the time period of analysis to ten years. The result is that the present value of net operating income would be about $660,672 for a $600,000 initial investment. Using the longer time period, then, means that the vendor's quotation of $600,000 would be feasible.

All the assumptions can be juggled in the same way, and the required calculations are fairly simple. Basically, the calculations will show that as the time period is extended, or as the subscriber revenues increase, there is an increasing chance for financial feasibility.

Another Approach: Annual Investment Analysis

There is another quick method to determine the financial feasibility of a project. Consider the same assumptions that were used in the first example. The equipment vendor's price quotation of $400,000 can be converted to a series of level annual payments that represent both the cost recovery and the return (cost of capital before taxes) on the investment. Table 3 is used for this approach. Here are the calculations.

Initial investment	$400,000
Table 3 value for 5 yrs. @ 10%	×.26380
Uniform (annual) investment expenditures	$105,520
Annual operating expenses (12% of $400,000)	48,000
Total annual "cost"	$153,520

The telephone system would then need to determine, in some way, whether the annual operating revenue would be sufficient to meet at least this $153,520 financial requirement.

This approach does not eliminate the need for additional estimating, but it allows for more flexibility in projecting the number of subscribers. This kind of analysis may also be more familiar to telco managers because it parallels the revenue requirement/annualization approach that is used to comply with federal and state regulations. The approach used in the original example, however, is generally a better way to determine the overall financial feasibility of a project.

The approaches presented here cannot substitute for detailed and comprehensive financial analyses that are based on specific market surveys and alternative rate designs, capital structures, and cost studies. But they can address all the major considerations quickly within a framework that allows both for flexibility and for an initial evaluation of financial feasibility. •

CONTENTS

SUBCHAPTER H-TELEPHONE SYSTEM DESIGN AND CONSTRUCTION

PART 1765 - TELEPHONE MATERIALS, EQUIPMENT AND CONSTRUCTION

Subpart B - Construction Certification Program

1765.15 - Purpose

The purpose of this subpart is to set forth REA policies and requirements relating to postloan procedures for those telephone borrowers required to follow the Construction Certification Program.

1765.16 - Requirements.

(a) It is REA policy that, as borrowers gain in experience and maturity, the advice and assistance rendered by REA shall progressively diminish. In furtherance of this policy, REA shall designate certain borrowers to fulfill responsibilities for the administration and construction of projects financed by REA administered loans or loan guarantees. Borrowers so designated will be known as "Certified Borrowers", and the program in which they participate will be known as the "Certification Program".

(b) Borrowers will be notified during the preloan processing period if they will be required to follow the Certification Program. Generally, "A" loan borrowers will not be eligible for construction certification.

(c) Generally, the factors which REA will consider in selecting borrowers for the Certification Program will include:

(1) The experience of the staff of the borrower.

(2) The REA assessment of the borrower's ability to handle the Certificaton Program requirements considering the size and complexity of the proposed loan project.

(3) The history of the borrower in following REA's policies and procedures.

(4) Other factors deemed relevant by REA.

(d) Except for the changes specifically stated in this subpart and REA requirements shall apply to Certified Borrowers and must be followed without exception. Failure to comply with applicable requirements may result in an REA decision not to finance a specific project.

(e) REA Reserves the right at any time to require submission of construction documents or to rescind construction certification approval.

1765.17 - Responsibilities

(a) Authorities, otherwise reserved by REA , to be the responsibility of Certified Borrowers:

(1) Approval of engineering and architectural service contracts.

(2) Approval of plans and specifications.

(3) Approval of price quotations and bids, except for procurement of Central Office Equipment by the two step negotiated process where the low price bid is not accepted.

(4) Approval of construction contracts and amendments.

(5) Approval of force account proposals (following REA approval of the force account method of construction).

(6) Inspection and certification of construction performed by work order and force account proposals.

(7) Approval of final documents.

(8) Other authorities as may be specifically granted in writing by REA.

(b) Authorities retained by REA:

(1) Approval to deviate from REA requirements, except as provided in (a) above.

(2) Approval of construction projects or amounts not included in the loan.

(3) Approval of force account methods of engineering and construction.

(4) Approval to make significant deviations from the approved Work Plan.

(5) Approval of interim construction.

(6) Approval to use materials not listed in the List of Materials Acceptable for Use on Telephone Systems of REA Borrowers.

(7) Approval of field trials.

(8) Approval to modify or alter standard forms and contracts.

(9) Approval to open bids when fewer than the required number have been received.

(10) Approval of Outside Plant Layouts.

(11) Other authorities not specifically transferred by this subpart or in writing by REA.

1765.18 - Procedure:

(a) Borrowers selected will be notified in the Area Coverage Design or Supplemental Loan Proposal approval letter or at an earlier time, when necessary.

(b) Certified Borrowers will be required to appoint a minimum of two individuals as certification officals to be responsible for the proper certification of documents and forms.

(1) The "Certifying Officer" will be an officer or employee of the Certified Borrower who is authorized to execute binding agreements on behalf of the Certified Borrower. This Certifying Officer shall sign all contracts, amendments, final documents and the "Certification" on REA Form 158, "Certification of Contract or Force Account Proposal Approval" and REA Form 159, "Summary of Completed Construction."

(2) The "Inspection Certifier" will be an engineer, experienced in telephony, licensed in the state in which the inspection is to be performed,

who will be responsible for all final inspections and will sign the "Inspection - Certification" on REA Form 159. The Inspection Certifier may be an employee of the Certified Borrower or may be the Certified Borrower's consulting engineer.

(3) The "Certification Coordinator" will administer the Certified Borrower's loan project under the Certification Program and will serve as the official point of contact for REA. The Certifying Officer or Inspection Certifier may serve also as the Certification Coordintor.

(c) Certified Borrowers shall submit and obtain REA approval of a Work Plan after a loan is approved but before construction and related engineering begin. If the Certified Borrower wishes to proceed with construction prior to approval of a loan, under interim financing approved by REA, the Certified Borrower shall obtain REA approval of its Work Plan, before construction begins for which interim financing is requested.

(1) The Work Plan shall provide a description of the proposed construction and methods of purchasing in such detail as to enable REA to moniter the construction program to ensure to its satisfaction that loan purposes are accomplished in an organized construction program.

(2) The Work Plan shall include the following:

(i) The names and qualifications of the proposed certification officials defined in 1765.18, (b).

(ii) A description of the proposed methods of performing construction, purchasing materials and equipment and providing engineering services for the loan project.

(iii) A construction schedule and tabulation of estimated costs of work projects to be performed in accomplishing the loan purposes.

(iv) The proposed source of funds for meeting cost overruns if the total estimated cost of work projects exceeds the loan budget.

(v) Certification by the Certified Borrower's President, the Certification Coordinator and the REA Field Representative, that the Work Plan is accurate and complete.

(d) Under the Certification Program, the Certified Borrower shall follow all standard REA postloan engineering and construction procedures except that the approvals shown in 1765.17, (a) will be made by certification officials rather than REA. The approvals noted in 1765.17, (a), (1), (4) and (5) will be reported immediately to REA using REA Form 158. Approval of closeouts, 1765.17, (a), (6) and (7) will bve reported immediately on REA Form 159.

(e) The Certified Borrower shall develop the internal procedures necessary to meet its responsibilities under the Certification Program, and to provide adequate documentation, satisfactory to REA, that all REA procedures are being followed.

(f) The Certified Borrower shall modify standard REA forms of contract for use under the Certification Program, by inserting an executed copy of the Certification Addendum shown in 1765.20 in each copy of the contract.

(g) As the construction program progresses, the Certified Borrower shall request, by letter REA approval of any significant changes in Work Plan schedules and budgets and in certification officials.

1765.19 - Advance of Loan Funds

Advances of loan funds needed to meet the Certified Borrower's current financial obligations are to be requested on REA Form 481, Financial Requirement Statement (FRS), for construction and engineering items supported by appproprite REA Forms 158 and 159 and may be up to the total amount of approved contracts. For items other than construction or engineering, supporting data, as outlined in 7 CFR Part _________ (Appendix A, REA Bulletin 327-1) should be submitted.

1765.20 - Certification Addendum

CERTIFICATION ADDENDUM

Permission has been obtained by the Owner to proceed with this contract under 7 CFR Part 1765, pursuant to which the references in the REA construction documents requiring approvals and other actions of the REA Administrator will not apply unless REA gives specific notice in writing to the affected parties that a designated approval(s) or action(s) will be required. Certifications by the Contractor of amounts due and certifications of completions of work under the contract are to be construed to be rendered for the purpose of inducing the REA or Rural Telephoe Bank to advance funds to the Owner to make, or reimburse the Owner for payments under this contract.

____________________ Date

____________________ Owner

By____________________ President

____________________ Date

____________________ Contractor

By____________________

1765.21 - How to Obtain the REA Forms.

REA Forms 158, 159 and 481 may be obtained from the Rural Electrification Administration, Administrative Services Division, Room 0175-S, Washington, DC 20250.

"No further benefits may be paid out under this program unless this report is completed and filed as required (7 USC 901 et seq.)"

USDA – REA

CERTIFICATION OF CONTRACT OR FORCE ACCOUNT PROPOSAL APPROVAL

Form Approved
OMB No. 40–R4037

SYSTEM DESIGNATION

INSTRUCTIONS– *Prepare 3 copies. Original copy to be submitted to Area Office with the Financial Requirement Statement, REA Form 481. One copy should be sent to the REA Field* Representative. For detailed instructions, see 7CFR Part 1765 (REA Bulletin 320-23).

NAME OF BORROWER

This certification of contract or force account proposal approval is submitted to support a request for funds in the amount(s) specified therefor on a financial requirement statement, REA Form 481 *where the borrower has received REA approval to administer engineering and construction procedures in accordance with* 7CFR Part 1765 (REA Bulletin 320-23).

PART A. ENGINEERING & ARCHITECTURAL SERVICE (COMPLETE APPLICABLE PORTIONS)

1. INDICATE REA CONTRACT FORM	2. NAME & ADDRESS OF ENGINEER OR ARCH.	3. AMT OF CONTRACT	4. DATE	5. CONTRACT NO. ASSIGNED BY BORROWER
☐ 165 ☐ 217 ☐ 245 ☐ ___ OTHER				

6. AMT. FOR FA ENGINEERING (MAJOR CONSTRUCTION)	7. DESCRIBE BRIEFLY WHAT FA ENGINEERING WILL COVER:

PART B. CONTRACT CONSTRUCTION

1. INDICATE REA CONTRACT FORM	2. METHOD OF AWARD	3. NAME & ADDRESS OF CONTRACTOR
☐ 257 ☐ 397 ☐ 398 ☐ 400 ☐ 511 ☐ 525 ☐ 545 ☐ ___ OR AMEND. FORM ☐ 238 ☐ 526	☐ COMPETITIVE ☐ NEGOTIATED	

4. AMOUNT OF CONTRACT OR AMENDMENT	5. DATE	6. CONTRACT NO. ASSIGNED BY BORROWER

7. DESCRIBE BRIEFLY THE CONSTRUCTION & LOCATION BY EXCHANGE: ______

PART C. FORCE ACCOUNT CONSTRUCTION

1. AMT. OF PROPOSAL	2. DATE	3. PROPOSAL NUMBER ASSIGNED BY BORR.	4. DESCRIBE BRIEFLY THE CONSTRUCTION & LOCATION BY EXCH.

REMARKS

(3) all applicable REA procedures have been followed,

system design or outside plant layout

CERTIFICATION

I certify that (1) the information shown above is correct, (2) the construction indicated above is based on plans and specifications prepared in accordance with a [system design or outside plant layout] *approved by REA and is for purposes for which funds are included in the loan approved or guaranteed by REA,* [(3) all applicable REA procedures have been followed,] *(4) the performance bond requirements, if any, applicable to the form of contract used, have been satisfied, (5) the requirements of the "Buy American" provisions of* [7CFR Part 1790] *(REA Bulletin 344-3) have been complied with where any foreign materials or equipment will be used, and (6) the Equal Employment Opportunity requirements of the REA loan agreement and* 7CFR Part 1787 (REA Bulletin 320-15) have been meet.

______ DATE

______ SIGNATURE OF CERTIFYING OFFICER

REA FORM 158 1-84

"No further benefits may be paid out under this program unless this report is completed and filed as required (7 USC 901 et seq.)"

USDA – REA

SUMMARY OF COMPLETED CONSTRUCTION

FORM APPROVED
OMB NO. 40-R4037

SYSTEM DESIGNATION

SUMMARY NUMBER

INSTRUCTIONS – *Prepare 3 copies. Original copy to be submitted to Area Office with the Financial Requirement Statement, REA Form 481. One copy should be sent to the REA* Field Representative. For detailed instructions, see 7 CFR Part 1765 (REA Bulletin 320-23).

APPROVAL IS REQUESTED FOR THE ENCUMBRANCE OF LOAN FUNDS AS SHOWN IN COLUMN "f" FOR THE COMPLETED CONSTRUCTION DESCRIBED BELOW:

DESCRIPTION OF CONSTRUCTION (a)	TOTAL COST CONSTRUCTION (b)	LESS ADVANCES NOT REQUIRED			NET ADVANCES REQUIRED (f)
		REUSABLE MATERIALS SALVAGED (c)	STATION APPARATUS & EXEMPT MAT. (d)	OTHER (EXPLAIN) (e)	
TOTAL					

CERTIFICATION

We certify that (1) the total costs and net requirements for the construction included above are the actual costs and net requirements for loan funds reflected in the permanent records of this organization, (2) construction was in accordance with the system design or system layout as approved by REA and deviations, if any, did receive REA approval, (3) construction was for purposes included in the loan commitment and deviations, if any, have received REA approval, (4) construction was in accordance with REA specifications using REA acceptable materials, (5) the requirements of the "Buy American" provision required under ~~*REA Bulletin 344-3*~~ 7 CFR Part 1790 *have been complied with where any foreign made materials or equipment were used in construction, (6) the Equal Employment Opportunity provisions of the REA loan agreement have been satisfied,* (7) final documents have been approved and all applicable REA procedures have been followed, *and* (8) *all loan agreement and mortgage provisions have been met. We further certify that regulatory body and other approvals required for this construction have been obtained and that there have been no previous requests for approval of the net advance required for the construction covered hereby.*

DATE

SIGNATURE OF CERTIFYING OFFICER

NAME OF BORROWER

INSPECTION – CERTIFICATION

I hereby certify that sufficient inspection has been made of the construction reported by this summary and its supporting documentation *to give me a reasonable assurance that the construction complies with applicable specifications and standards and meets appropriate code requirements as to strength and safety,* and that the documentation complies with applicable REA accounting practices. *This certification is in accordance with* accepted *engineering practice.*

INSPECTION PERFORMED BY

NAME OF INSPECTION FIRM

SIGNATURE OF INSPECTION CERTIFIER

DATE

LICENSE NUMBER

ACCOUNTING VERIFICATION (REA USE ONLY)

Telecommunications Standards

E. J. Cohen
Engineering Management and Standards Engineer
Telecommunications Engineering and Standards Division

Why should manufacturers or purchasers have their freedom to produce or buy exactly what they wish obstructed by standards? Just think a moment about the many advantages of standardization. Imagine trying to purchase light bulbs if each lamp manufacturer used a different and unique socket. Or how about buying oil or gasoline for your car without the SAE ratings on these items? Closer to home, imagine trying to engineer a telephone system without the American Wire Gauge (AWG) standards. No two cable manufacturers would produce comparable cables, so no two jobs would have the same system design. Imagine the gigantic problem of providing nationwide telecommunications if each telephone company had its own unique signalling system and transmission requirements.

So, standards are essential. They simplify our life. With standards, manufacturers may concentrate on fewer designs, thus lowering costs, improving delivery, and in general doing a more effective job. Operating telephone companies can easily provide uniform service, not only nationally, but throughout the world. Thanks to standards, telephone companies can effectively design, construct, and maintain their systems with a minimum of engineering effort and product evaluation.

Who prepares these standards which impact the telecommunications industry? How are they prepared? And how can we effectively reflect our concerns and protect our interests? Unfortunately, a comprehensive reply to these three fundamental questions would require hundreds of pages. So let's briefly develop an overview of the standards industry.

Procedures for developing standards vary widely, depending on the sponsor and intended application for the standard. At one extreme is the American National Standards Institute (ANSI) procedure for voluntary consensus standards preparation. ANSI emphasizes that all activities must be open to public participation and that <u>all</u> segments of the affected industry be given fair representation in voting on the standard produced.

As these standards are routinely developed in committees representing a broad cross section of the industry, frequent compromises must be hammered out. The result is usually fair to all concerned and represents the best industry position available. But building a consensus on a new or revised standard takes a lot of time. Can such standards be effective? Sure! Perhaps the best example is the National Electrical Code (NEC), which is developed by 20 panels, each of which is carefully balanced among all interested segments of the industry.

At the other extreme are standards developed unilaterally by a single organization and imposed by that organization on others. A typical example is the procurement specification, developed by the staff of an operating telephone company, and used as the criteria for purchasing equipment.

There are many modes of operation between these extremes. For example, some standards developers limit voting membership on their committees to a given segment of the industry such as manufacturers or operating telephone companies. The standards developed in this way, while useful, face an uphill struggle to obtain wide acceptance and their adoption may lead to antitrust entanglements.

The procedures used by REA in preparing its standards illustrates another intermediate mode of operation. While REA retains sole responsibility for the contents of its specifications,. it circulates drafts widely throughout all segments of the industry for comment. When comments are received, every reasonable effort is made to resolve them to the mutual satisfaction of all involved before issuing the document.

Who sets the standards that impact our industry? Many organizations are involved, from the American Society for Testing and Materials (ASTM) to Underwriters Laboratories (UL). Each has its own area of concern, method of operation, and in some cases, built-in biases which may be reflected in the standards they produce.

The situation has become more complex due to deregulation and implementation of the Modified Final Judgement. Many of the standards created and maintained by the unified Bell System may be adopted by existing standards developers. Others may find a home under new organizations, such as the Exchange Carriers' Standards Association (ECSA), which has come into being as a result of the breakup of the Bell System. Still other standards may simply cease to exist as a result of the breakup. Only time will tell.

Figure 1 provides a brief overview of organizations involved in domestic standards affecting our industry. As you can see, it's a long list! Among these standards developers, communication and coordination can be difficult. With this in mind, IEEE has been working with ANSI to create a Coordinating Committee on Telecommunications Standards (CCTS) which will report to ANSI's Electrical and Electronics Standards Board. The first report of this Committee, containing primarily lists of standards being developed by those in Figure 1, was more than 70 pages long! And these are just domestic standards; International standards impact us nearly as much and their development is an entirely different ball game.

So why should we become involved in standards work? Figure 2 is a sign very prominently posted in my office; a fact of life I encounter every day. A classic example, from the bad old days before there were national standards .

Figure 1 - The Players in the Telecommunications Standards' Industry

American National Standards Institute (ANSI). Contrary to popular opinion, ANSI does not develop standards! ANSI coordinates standards development and determines if those developed by others are accepted by a broad enough segment of those impacted to qualify as American National Standards.

American Society for Testing & Materials (ASTM). ASTM is the world's largest single source of standards. While not directly into electronics or telephony, ASTM has many standards, including those on finishes or raw materials, which are applicable to telecommunications.

C-2 Committee. The C-2 Committee is the ANSI accredited standards developing body which creates the National Electrical Safety Code (NESC). The secretariat, or sponsor for C-2 is the IEEE.

Electronic Industries Association (EIA). An organization of the manufacturers of electronic equipment, EIA is quite active in fiber optic and telecommunications terminal equipment.

Exchange Carriers' Standards Association (ECSA). A newcomer to the standards industry, ECSA is planning to form an ANSI accredited committee (the T-1 Committee) to maintain some of the former Bell System specifications and create new ones as required.

Federal Communications Commission (FCC). While hardly a consensus standards developer, FCC has had significant impacts on technical standards for the industry.

Institute of Electrical and Electronic Engineers (IEEE). The only ANSI accredited standards developing organization presently involved in telecommunications standards, IEEE represents an amalgamation of many professional societies addressing a cross section of electrotechnology. The IEEE segment dealing with telecommunications has already produced a large number of standards.

National Fire Protection Association (NFPA). The National Electrical Code (NEC), which addresses safety in electrical installations at the subscriber's premises, is prepared by a committee of the NFPA.

Rural Electrification Administration (REA). While not an actual voluntary consensus standards developer, REA standards have developed significant standing in the industry. As discussed earlier, REA actively seeks industry input as part of its standards development.

Underwriters Laboratories (UL). UL is perhaps the best known agency operating in the field of safety. While not yet too deeply involved in telecommunications, deregulation and the resulting increase in customer provided equipment will inevitably bring UL into this field.

U.S. Telephone Association (USTA). USTA has developed some standards in the past, and with the breakup of the Bell System, could become a more significant factor in future telecommunications standards development.

Figure 2

This product would look great -- if only we could find the right test.

Anonymous Manufacturer

REA Bulletin 344-2, LIST OF MATERIALS Acceptable for Use on Telephone Systems of REA Borrowers

E. J. Cohen
Engineering Management and Standards Engineer
Telecommunications Engineering and Standards Division

One of the most frequently used, and perhaps least understood, documents published by REA is Bulletin 344-2, commonly referred to as the "List of Materials". It is a compilation of products, routinely used in the construction of telephone plant, which have been accepted by REA. Products are indexed both alphabetically and by the item codes, two or three letter designators, established in the REA Form 515, Telephone System Construction Contract.

Users must understand the List of Materials' limitations to use it effectively. Foreign products, and items which REA feels are of limited use, such as toll switches, or of low cost and readily available, such as bolts, do not presently appear in the List of Materials. The List is not a catalog. Catalog numbers appear only in some cases where manufacturers produce more than one similar product and only one is REA accepted.

The List of Materials is available on a subscription basis from the Government Printing Office (GPO). New editions appear every two years and supplements are produced approximately every two months. REA furnishes one free subscription to each borrower and makes the document available to anyone via the enclosed form.

Items are accepted by REA as of the date that an REA Technical Standards Committee (Telephone) (TSC(T)) acts favorably on a manufacturer's request for listing. Likewise, revocation of acceptance is normally as of the date of Committee action. Unfortunately, due to processing and printing delays, the List of Materials routinely lags three to four months behind these actions. To partially alleviate the impact of this lag, manufacturers are issued a letter over the signature of the TSC(T) Chairman, notifying them of Committee action. This letter is sent shortly after the Committee acts, and may be used to inform borrowers that a product is indeed accepted. The REA field staff is also alerted quickly to actions by the Committee. They can therefore be contacted with any questions on the status of acceptance for products. The ultimate source for up-to-the-minute information on REA acceptance of products is the office of the Engineering Management and Standards Engineer (EMSE) at (202) 382-8698, however, calls to the EMSE for this purpose are discouraged except in situations of real need.

REA grants Letters of Technical Acceptance to satisfactory foreign products and to other acceptable items not listed for the reasons mentioned earlier. These letters indicate that, from a technical standpoint, the products are fully acceptable for use on the systems of REA Borrowers. Other restrictions, such as compliance with paragraph IV.C of REA Bulletin 344-3. Buy American Requirement, apply to the purchase of products covered by Letters of Technical Acceptance. Also, the burden of informing a potential buyer that a product has Technical Acceptance is placed squarely on the manufacturer. Routinely this is done by issuing copies of the letter to each salesman. So when a new product crosses your desk, don't be afraid to ask if it has REA acceptance and, if it doesn't appear in your List of Materials, to ask for a copy of the letter from REA informing the manufacturer of such action!

United States Department of Agriculture

Rural Electrification Administration

Washington D.C. 20250

February 1, 1983

SUBJECT: REA Bulletin 344-2, "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers"

TO: Consulting Engineers, Contractors, Supply Manufacturers, Material Distributors, and Pole Treating Companies

The "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers" is to be printed and placed on sale on a two-year basis by the Government Printing Office with the basic issue followed by 11 supplements.

A new basic issue of the list dated January 1983 is to be made available for distribution during the early part of 1983. To avoid delays, it is important that subscription arrangements with the Government Printing Office be made promptly. The subscription fee is $70.00 domestic ($87.50 foreign) and will include one copy of the basic list and one copy each of 11 supplements. The new basic issue dated January 1983 replaces the January 1981 basic issue and its 11 supplements.

In the past REA has furnished one (1) subscription to Bulletin 344-2 free of charge to each REA Telephone Borrower and each listed manufacturer and supplier. While borrowers will continue to receive this complimentary copy, starting with the 1983 edition, manufacturers and suppliers will be required to purchase any desired subscriptions.

If you are presently a subscriber to Bulletin 344-2 you will be sent a renewal notice and order blank by the Superintendent of Documents. The order form below should be used only if you are not presently a subscriber to Bulletin 344-2, or if you are a manufacturer or supplier and wish to purchase a replacement for the discontinued complimentary subscription.

John H. Arnesen

Assistant Administrator - Telephone

ORDER BLANK

TO: Superintendent of Documents
Government Printing Office
Washington, D. C. 20402

Enclosed is $_____ (Check or money order). Please enter ____ subscription(s) to REA Bulletin 344-2, "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers," dated January 1983 for two years ($70.00 domestic, $87.50 foreign).

Name: ________________________________

Address: ________________________________

City, State and Zip Code: ________________________

Field Trials

E. J. Cohen
Engineering Management and Standards Engineer
Telecommunications Engineering and Standards Division

Draft Codification of REA Bulletin 345-45, Field Trials

PART 1772-TELEPHONE STANDARDS AND SPECIFICATIONS

Sec.

1772.1-1772.2 (Reserved)

1772.3 - Field Trials

1772.4-1772.96 (Reserved)

1772.97 Incorporation by Reference of Telephone Standards and Specifications

Authority: 7 U.S.C. 901 et seq. and 7 U.S.C. 1921 et seq.

1772.3 Field Trials

(a) Except as covered in Bulletin 345-3, no loan funds shall be advanced for any project if any item to be included in the project is not on the applicable REA List, if any. When new items of materials or equipment are considered for acceptance by REA or when a previously accepted item has been subjected to such major modifications that its suitability cannot be determined based on laboratory data and/or field experience, a field trial shall be required if REA so determines. This field trial consists of limited field installations of the materials or equipment in closely monitored situations designed to determine, to REA's satisfaction, their operational effectiveness under actual field conditions. Field trials are to be used only as a means for determining, to REA's satisfaction, the operational effectiveness of a new or revised product under actual field conditions. Both the manufacturer and borrower are responsible for assuring that the field trial is carried out and that the required information on the product's performance is received by REA in a timely manner. The use of materials or equipment derived from new inventions or concepts untried within the telephone industry is defined as "an experiment" and shall be handled as a special case using procedures considered appropriate by REA to meet the individual experiment.

(b) To qualify for a field trial, the new and improved materials and equipment must appear to REA to offer one or more of the following benefits:

(1) Improved performance.

(2) Cost.

(3) Broader application.

(c) The item of material or equipment subject to field trial may be only part of the total amount of materials or equipment included in a bid or it may be the key component of the facility or system proposed; therefore, REA shall have authority to require that a satisfactory plan be provided to maintain or restore service in the event that the materials and equipment fail to meet established performance requirements. REA shall limit the quantity of new materials and equipment installed on any field trial and shall also limit the number of field trials for a given product to what REA considers reasonable to provide the necessary information.

(d) A borrower may participate in a field trial only if, in REA's opinion, the borrower possesses:

(1) Adequate financial resources so that no delay in the project will result from lack of funds.

(2) The financial stability to overcome difficulties which may result from an unsuccessful field trial. The borrower must be able to restore and maintain service until the manufacturer meets its financial obligations with respect to the field trial.

(3) Qualified personnel to enable it to discharge its responsibilities.

(4) A record satisfactory to REA for maintaining equipment and plant facilities for providing REA with information when requested.

(5) Willingness to participate in the field trial and awareness of the effort and responsibility this entails.

(e) The test site for the field trial shall be, in REA's opinion, readily accessible and provide the conditions, such as temperature extremes, high probability of lightning damage, etc., for which the product is being evaluated. A field trial shall continue for a minimum of six months, or for a longer period of time determined by REA to be required to obtain conclusive data that the item either fulfills all requirements or is unacceptable. REA has sole authority to terminate a field trial at any time should it determine that the equipment is not performing satisfactorily and that this lack of performance may, in REA's opinion, cause service degradation or hazards to life or property. The material or equipment involved shall be covered by an REA specification or a suitable standard acceptable to REA. The supplier is required to submit test data to show conformance with the applicable specification or standard. Further testing shall be performed if required by REA personnel.

(f) Field trials shall be conducted in accordance with the instructions set forth in this regulation and the agreement relating to the specific application. Both the supplier and the borrower shall agree, and obtain REA approval before the start of the trial, on the following:

(1) The specific purpose of the field trial;

(2) Ownership of items during trial;

(3) Starting date and duration;

(4) Responsibility for costs and removal of items in the event of noncompliance with the specification or purpose intended and arrangements for service continuity or restoration;

(5) Responsibility for testing, test equipment and normal operation and maintenance during the trial period;

(6) Availability of test equipment on site during the trial period; and

(7) Responsibility for spare parts and components consumed during the trial period.

(g) Both the supplier and the borrower shall keep REA informed of the status of a field trial. These reports shall not be limited to details of problems or failures encountered during installation and subsequent operation but shall include information on progress of the field trial. If these reports are not received in a timely manner, REA shall have the authority to deny or suspend loan funds related to these products until the delinquent reports are received.

(h) Before a borrower purchases materials or equipment that require a field trial, prior approval must be obtained from REA and REA Form 399b, REA Telecommunications Equipment Field Trial (available from the Director, Administrative Services Division, Rural Electrification Administration, Room 0175, South Building, U.S. Department of Agriculture, Washington, DC 20250, will be completed by REA and must be signed by both the borrower and supplier as an indication that they understand their responsibilities in the field trial. Assurance must also be obtained from REA that the "particular item" that is the subject of the field test is eligible for a field trial.

To obtain this assurance, any proposal for use of an item on a field trial basis shall be forwarded to the Chief, Area Engineering Branch, for review and approval. (Approved by OMB 0572-0059)

(i) Procedures for establishing field trials for the various categories of equipment:

(1) Electronic transmission equipment including:

(i) Voice frequency repeaters

(ii) Trunk carriers

(iii) Subscriber carrier

(iv) Point-to-point radio (Microwave)

(v) Coaxial cable system electronics

(vi) Fiber optic cable system electronics

(vii) Multiplex equipment

(viii) Mobile and fixed radiotelephone and

(ix) Other items of electronic equipment associated with transmission.

The procedure set forth in Bulletin 385-2,"Purchasing and Installing Special Electronic Equipment",shall be followed except that the Special Equipment Contract (Including Installation), REA Form 397, shall be used in all purchases of electronic equipment for field trials. In addition, the borrower and supplier shall execute three copies of a "Supplemental Agreement to Equipment Contract for Field Trial," REA Form 399, or a "Supplemental Agreement to Equipment Contract for Field Trial (Secondary - Delivery, Installation, Operation)", REA Form 399a, as well as three copies of the REA Form 399b, "REA Telecommunications Equipment Field Trial", and forward them, together with three copies of the executed contract and specifications, to the Chief, Area Engineering Branch. A limited number of copies of REA Forms 399, 399a, and 399b are available from REA upon request from the Director, Administrative

Services Division, Rural Electrification Administration, Room 0175, South Building, U.S. Department of Agriculture, Washington, D. C. 20250. Additional copies may be reproduced by the user as needed.

(2) Central office equipment, including:

(i) Central office dial equipment

(ii) Direct distance dialing equipment

(iii) Automatic number identification equipment

(iv) Line concentrators

(v) Remote switching equipment and

(vi) All other items of equipment associated with switching equipment, such as loop extenders.

The procedure set forth in Bulletin 384-1 "Purchasing and Installing Central Office Equipment" shall be followed except that "The Central Office Equipment Contract (Including Installation)", REA Form 525, shall be used to purchase switching equipment for field trials. In addition, the borrower and supplier shall execute three copies of a "Supplemental Agreement to Equipment Contract for Field Trial," REA Form 399, or a "Supplemental Agreement to Equipment Contract for Field Trial (Secondary - Delivery, Installation, Operation)", REA Form 399a, as the case may be, as well as three copies of the REA Form 399b, "REA Telecommunications Equipment Field Trial", and forward them, together with three copies of the executed contract and specification to the Chief, Area Engineering Branch.

(3) Protection equipment and materials, outside plant equipment and materials, and all other equipment and materials, which includes all items not covered in Subsections (i)(1) or (2) above, shall be handled as described

in Section 1760-5 except that the borrower's purchase order form is to be used for purchasing materials and equipment in these categories. In addition, the borrower and supplier shall execute three copies of the "Supplemental Agreement to Equipment Contract for Field Trial," REA Form 399, or a "Supplemental Agreement to Equipment Contract for Field Trial (Secondary - Delivery, Installation, Operation)", REA Form 399a, as the case may be, as well as three copies of the REA Form 399b, "REA Telecommunications Field Trial", and forward, together with three copies of the purchase order to the Chief, Area Engineering Branch.

(j) For all items except Electronic Central Office Equipment, suppliers and manufacturers must furnish warranties or guarantees satisfactory to REA against the failure of the material and equipment used in the field trial. Terms of this warranty must not be less than the provisions of the standard warranty included in the "Telephone System Construction Contract", REA Form 515, or the warranty provided for similar materials and equipment included in the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers", REA Bulletin 344-2. In lieu of a warranty, materials and equipment are sometimes furnished to REA borrowers on a reduced or no cost basis. Terms of such arrangements should be fully covered in field trial proposals forwarded by borrowers to the Chief, Area Engineering Branch for review and approval.

For the purchase of electronic central office equipment, suppliers and manufacturers are to provide warranties as provided in the applicable REA contract form: REA Form 397 for electronic equipment and REA Form 525 for central office equipment. Forms 399 and 399a, which apply to field trials of these devices, specify that the term of the warranty does not begin until the satisfactory conclusion of the field trial.

Indexing Terms: As required by 1 CFR 18.20, the following are the indexed terms and list of subjects:

Loan programs - communications

Telecommunications

Telephone

Dated: ______________________________
Administrator

SUPPLEMENTAL AGREEMENT TO EQUIPMENT CONTRACT FOR FIELD TRIAL

AGREEMENT, made as of ____________________, between ____

(hereinafter called the "Seller") and ____ (hereinafter called the "Purchaser").

In consideration of the mutual undertakings herein contained and of approval by the Administrator of the Rural Electrification Administration (hereinafter called the "Administrator"), of the Material or Equipment Contract between the Seller and the Purchaser dated ____________________, as revised by this Supplemental Agreement for Field Trial, the parties hereto agree as follows:

1. Installation of the Material or Equipment described herein pursuant to the Equipment Contract or Purchase Order shall be on a field trial basis and shall be subject to the following provisions, because the Material or Equipment is not on the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers."

(a) During the field trial, which shall be a minimum of ______________ months following completion of the installation and initial testing of the material or equipment, or such longer period as may be required to obtain conclusive results, the Administrator may make such examinations, measurements and observations of the Material or Equipment at the site of the installation as may be necessary to determine whether the Material or Equipment is performing satisfactorily in accordance with applicable REA specifications or requirements. The purchaser may cancel the contract without penalty if within the first three months after the in-service date the Material or Equipment cannot be made to perform satisfactorily within the applicable specification requirements.

(b) The Seller shall promptly make such mechanical or electrical changes as may be required by the Administrator to make the Material or Equipment conform to applicable REA specifications or requirements. Such changes shall be made by the Seller at no additional expense to the Purchaser.

(c) If the Material or Equipment cannot be made to conform to applicable REA specifications or requirements, the Seller shall promptly remove same, if feasible, from the premises at no expense to the Purchaser, and in all instances shall promptly refund to the Purchaser any payments which may have been made by the Purchaser to the Seller including all material or equipment cost and labor cost.

(d) Notwithstanding the provisions of the Material or Equipment Contract, final payment for the field trial items shall not be due until completion of the field trial to the satisfaction of the Administrator.

2. This Agreement shall become effective only upon approval in writing by the Administrator of the Contract which it supplements. Description of item for field trial and cost, including installation cost, if only part of the overall purchase is affected ____

____

____

____________________	____________________
(SELLER)	(PURCHASER)
By ____________________	*By* ____________________
TITLE ____________________	TITLE ____________________

SUPPLEMENTAL AGREEMENT TO EQUIPMENT CONTRACT FOR FIELD TRIAL

(Secondary - Delivery, Installation, Operation)

AGREEMENT, made as of ______________________, between ______________________________________

(hereinafter called the "Seller") and ______________________________________(hereinafter called the "Purchaser").

In consideration of the mutual undertakings herein contained and of approval by the Administrator of the Rural Electrification Administration (hereinafter called the "Administrator"), of the Material or Equipment Contract between the Seller and the Purchaser dated

______________________, as revised by this Supplemental Agreement for Field Trial, the parties hereto agree as follows:

1. Installation of the Material or Equipment described herein pursuant to the Equipment Contract or Purchase Order shall be on a field trial basis and shall be subject to the following provisions because the Material or Equipment is not on the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers."

(a) During the field trial, which shall be a minimum of ____________ months following completion of the installation of the material or equipment, or such longer period as may be required to obtain conclusive results, the Administrator may make such examinations, measurements and observations of the Material or Equipment at the site of the installation as may be necessary to determine whether the Material or Equipment is performing satisfactorily in accordance with applicable REA specifications or requirements. When the field trial is categorized as "Secondary" the Purchaser may cancel the contract without penalty if the in-service date of the "Primary" field trial is delayed more than three months due to fault of the Seller or, if within the first three months after the in-service date the Material or Equipment cannot be made to perform satisfactorily within the applicable specification requirements.

(b) The Seller shall promptly make such mechanical or electrical changes as may be required by the Administrator to make the Material or Equipment conform to applicable REA specifications or requirements. Such changes shall be made by the Seller at no additional expense to the Purchaser.

(c) If the Material or Equipment cannot be made to conform to applicable REA specifications or requirements, the Seller shall promptly

(i) remove, where feasible, the same from the premises at no expense to the Purchaser, and

(ii) replace the same with comparable equipment selected by the Seller and approved by the Purchaser and REA so as to fulfill the Seller's obligations under the Material or Equipment Contract. The Seller shall not be paid with an amount greater than the price originally contracted for. Such payment shall be made as provided in the Material or Equipment Contract.

(d) Notwithstanding the provisions of the Material or Equipment Contract, no payment for the field trial items shall be due until completion of the primary field trial to the satisfaction of the Administrator.

2. This Agreement shall become effective upon approval in writing by the Administrator of the Contract which it supplements. Description of item for field trial and cost, including installation cost, if only part of the overall purchase is affected______________

____

____

______________________________	______________________________
(SELLER)	(PURCHASER)
By ______________________________	*By* ______________________________
TITLE ______________________________	TITLE ______________________________

REA FORM 399a *(Rev. 8-82)*

USDA - REA **TELECOMMUNICATIONS EQUIPMENT FIELD TRIAL**	DATE	FIELD TRIAL NUMBER	*FORM APPROVED OMB No. 0572-0059 Expires 07/31/84*

A. GENERAL

1a. BORROWER NAME AND ADDRESS *(Number, Street, City, State, Zip)*	1b. REA PROJECT NUMBER

2a. DESCRIPTION, QUANTITY, AND COST OF ITEMS UNDERGOING FIELD TRIAL *(Include catalog numbers and estimated total installed cost.)*

2b. SUPPLIER NAME AND ADDRESS *(Number, Street, City, State, Zip)*	3a. REA CONTRACT NUMBER
	3b. REA CONTRACT DATE

4. SPECIFIC FIELD TRIAL LOCATION(S) *(CDO, trunk route, etc.)*

5. FIELD TRIAL PURPOSE *(Specify in detail what aspect of performance is to be evaluated.)*

6a. STARTING DATE *(Month, Day, Year)*	7. INSTALLATION TO BE MADE BY *(Name and Address IF OTHER THAN 2b ABOVE)*
6b. DURATION	
8. INSTALLATION COST TO BE BORNE BY *(Name and Address IF OTHER THAN 1a ABOVE)*	9. OWNERSHIP OF ITEMS DURING FIELD TRIAL *(Name and Address IF OTHER THAN 1a ABOVE)*

B. ASSIGNMENT OF RESPONSIBILITIES

1. INITIAL TESTS TO BE PERFORMED BY ☐ Supplier ☐ Borrower ☐ REA
Comments:

2a. INITIALLY, TEST EQUIPMENT WILL BE PROVIDED BY ☐ Supplier ☐ Borrower ☐ REA
Comments:

2b. SUBSEQUENTLY, TEST EQUIPMENT WILL BE PROVIDED BY ☐ Supplier ☐ Borrower ☐ REA
Comments:

3. MAINTENANCE OF ITEMS TO BE PERFORMED BY	4. COSTS AND ARRANGEMENTS FOR SERVICE CONTINUITY OR RESTORAL IN EVENT OF REMOVAL OF ITEMS TO BE BORNE BY
☐ Supplier ☐ Borrower	☐ Supplier ☐ Borrower

C. ROUTINE STATUS REPORTS

1. SUPPLIER'S REPORTS TO REA *(TESD Branch Chief)*	1a. REPORT DATES
__________ __________ U.S. Department of Agriculture, Rural Electrification Administration 14th and Independence Avenue, S.W. Washington, D.C. 20250	

1b. NATURE OF INFORMATION TO BE REPORTED SHALL INCLUDE *(Specify)*

2. BORROWER'S REPORTS TO REA *(AREA Branch Chief)*	2a. REPORT DATES
__________ __________ U.S. Department of Agriculture, Rural Electrification Administration 14th and Independence Avenue, S.W. Washington, D.C. 20250	

2b. NATURE OF INFORMATION TO BE REPORTED SHALL INCLUDE *(Specify)*

D. SPECIAL CONSIDERATIONS

SPECIFY

E. ACCEPTANCE BY BORROWER AND SUPPLIER

We the undersigned have read this document and understand the requirements placed on us by it. They shall be executed by us to the best of our abilities.

__________ (SELLER)	__________ (BUYER)
By __________	*By* __________
Title __________	*Title* __________

F. REA COORDINATION

COORDINATOR	SIGNATURE	TITLE Engineering Management and Standards Engineer	DATE
RECOMMENDED	SIGNATURE	TITLE Branch Chief __________ Branch, TESD	DATE
	SIGNATURE	TITLE Engineering Branch Chief __________ Area - Telephone	DATE
APPROVED	SIGNATURE	TITLE Director TESD	DATE
	SIGNATURE	TITLE Director __________ Area - Telephone	DATE

G. ADDITIONAL APPROVAL *(IF COST EXCEEDS $250,000)*

APPROVED	SIGNATURE	TITLE ASSISTANT ADMINISTRATOR - TELEPHONE	DATE

Codes

E. J. Cohen
Engineering Management and Standards Engineer
Telecommunications Engineering and Standards Division

National Electrical Code

The 1984 edition of the National Electrical Code (NEC) is now available. If you have not already ordered copies, you should do so quickly. They may be obtained at a cost of $15.00 from:

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269
Phone: (617) 328-9290

Discounts are available for large orders if, for example, a state association bulk orders for its members.

The purpose of the National Electrical Code (NEC), as stated in Article 90-1, is: ". . . the practical safeguarding of persons and property from hazards arising from the use of electricity." The thrust of the NEC is SAFETY. Simple compliance will not automatically provide an installation which is efficient, convenient, or even adequate for good service. The NEC covers the installation of conductors and related equipment within or on public or private buildings or structures.

The NEC can be traced to 1897, when various insurance, electrical, architectural, and allied agencies, alarmed by the increase in electrical fires and injuries, assumed responsibility for establishing these first installation guidelines. Since 1911, the National Fire Protection Association has sponsored the NEC, using American National Standards Institute (ANSI) Voluntary Consensus Standards Procedures (a phrase we will explain further in a future segment of the Code. Panel 16, chaired by D.. H. Ware of Belco, for example, prepares Article 770 and Chapter 800 among other sections. The rigid schedule below is imposed to assure the Code's timely revision. Several of these dates are crucial to anyone wishing to have the NEC modified.

Date	Event
November 23, 1984	Deadline for receipt of proposed changes.
January 7-26, 1985	Codemaking panels meet.
June 17, 1985	NEC Tech. Committee Report (Preprint) available.
October 28, 1985	Deadline for receipt of comments on TCR.
December 2-14, 1985	Codemaking panels meet.

April 11, 1986	NEC Tech. Committee Document (Proposed 87 NEC) available.
May 19-22, 1986	Annual meeting of NFPA.
September 1986	1987 NEC available.

Anyone desiring to have a revision incorporated in the 1987 Code must have that proposal to NFPA by November 23, 1984, or it will not even be considered. On June 17, 1985, the "Technical Committee Report of the NEC" becomes available. This contains all proposed revisions submitted and the tentative disposition of each. The general public has until October 28, 1985, to comment on these proposed changes and this is routinely the last chance for the general public to influence Code development. So be alert to the Code, and take time to make it reflect your needs!

Some of the changes incorporated in the 1984 NEC which are of interest to us are as follows (refer to your 1981 NEC for original wording):

270-74 Exception 4. This has been reworded slightly and the following fine print note added for clarification:

"Use of an isolated equipment grounding conductor does not relieve the requirement for grounding raceway system and outlet box."

This is of particular interest in digital central office installations employing a complex ground window system.

250-81(a). A phrase is added to the last sentence permitting the supplemental electrode to be bonded to "any grounded service enclosure." Another paragraph is added to 250-81(a) stating that the sole bond to a made supplemental electrode need not be larger than #6 Cu or 4 Al.

Article 770 - Optical Fiber Cables. A new article covering these systems is included in the Code for the first time. Its scope is as follows: "The provisions of this article apply to the installation of optical fiber cable along with electrical conductors." This article does not cover the construction of optical fiber cables. It also does not cover the installation of optical fiber cables in circumstances other than those covered in this article.

Article 800 - Communications Circuits. From the standpoint of the telecommunications operating company, this is the most significant article of the Code as it addresses our subscriber premises installations. There are numerous possible changes which should be reviewed carefully.

Various Paragraphs. The term "light" is changed to "electric light" to avoid confusion with optical fiber systems.

800-3(b). Cables for use in vertical runs in shafts must now be listed (i.e., UL accepted) as having adequate fire resistance to avoid spreading fire from floor-to-floor. The present exception remains substantially unchanged.

800-3(d). This section is substantially reworded to improve clarity without significantly altering intent. The following fine print note is added, suggesting an acceptable criteria for "low smoke producing material" for the first time:

"One method of defining low-smoke producing materials is by establishing an acceptable value of the smoke produced per the UL 910 test to a maximum peak optical density of 0.5 and a maximum average optical density of 0.15. Similarly, fire-resistant cables may be defined as having a maximum allowable flame travel distance of 5 feet (1.52M) in the UL 910 test."

While the exact definition is of little use to the man in the field, the fact that the Code includes a definition which can be evaluated in a laboratory is significant. We may soon see material advertised as meeting "low smoke producing" as defined in 800-3(d).

800-11(a) (Overhead Conductors on Poles and In-Span. This section is revised for conformance with the New National Electrical Safety Code (NESC) and to address in-span clearances as well as separation at the pole. This change mandates a minimum of 12" in-span separation between communications and power and 40" separation at the pole.

800-11(b) (Overhead Conductors) on Roofs. The change adds a second exception permitting a reduction in clearance from 8' to 18" above overhanging portions of a roof if not more than 4' of drop is above the overhang and the drop terminates in a through the roof raceway or support. A similar exception has been in Section 230-24(a) for some time.

800-31(b)(2)(Grounding, Protector Ground) Size. Since telephone companies use a #14 AWG or coarser wire for the protector ground, the Code now reflects this fact.

800-31(b)(5) (Grounding) Electrode. The panel substantially revised this section to consolidate requirements and emphasize the importance of connecting to the nearest portion of the grounding electrode system.

National Electrical Safety Code

The 1984 edition of the National Electrical Safety Code (NESC) is also available. As with the NEC, if you have not already ordered copies you should do so quickly. The cost is $14.75 per copy plus a $2.00 handling charge on each order. The NESC can be procurred from:

IEEE Service Center
445 Hoes Lane
Piscataway, NJ 08854
Phone: (201) 981-0060

Discounts are available here for large orders.

The National Electrical Safety Code (NESC) provides rules for the practical safeguarding of persons during the installation, operation or maintenance of electric supply and communication lines and their associated equipment. By addressing both aerial and buried plant, the NESC provides requirements for all outside plant facilities. Work on the Codes began in 1913 by the National Bureau of Standards, responding to an alarming increase in accidents during the construction of outside plant. Today, the ANSI accredited C-2 Committee, with its IEEE secretariat, develops the Code. C-2 employs essentially the same Voluntary Consensus Standards Procedures as NFPA. It also adheres to a rigid schedule, as shown below, to assure timely revisions of the NESC.

Date	Event
September 15, 1984	Deadline for receipt of proposed changes.
October 29, 1984	Subcommittees begin to review proposals.
March 1, 1985	NESC Preprint available.
July 31, 1985	Deadline for receipt of comments on Preprint.
October 1985	Subcommittees meet.
August 1, 1986	NESC Committee Letter Ballot.
May 15, 1987	1987 NESC to ANSI.
August 1987	1987 NESC available.

The critical dates for revision of the NESC are September 15, 1984, by which all proposals for changes must be received, March 1, 1985, when the summary of proposals and tentative disposition of each becomes available, and July 31, 1985, when final public comments are due. Keep these dates in mind and please participate as necessary to make this Code responsive to your needs.

Some of the changes incorporated in the 1984 NESC which are of interest are as follows: (Again, refer to your 1981 Code for original wording).

016. To clarify what installations are covered by this revision, the following clause is added to the end of 016:

"---and shall apply to new installations and extensions whose design and approval was started after the expiration of that period."

017. The Code is dual dimensioned in customary and soft (i.e., rounded to nearest whole number) metric. As proposed for adoption in the U.S., the metric units are information only and the customary units are mandatory.

Section 2

Definitions. Conductor line has been defined to include communications cables. Designated person is newly defined as follows: "Designated Person. A qualified (underline added-ed) person designated to perform specific duties under the conditions existing. Syn Designated Employee."

97.D.2. This new section permits the primary and secondary neutrals of an MGN power system to be isolated by a spark gap, or equivalent, with breakdown of 3kV or less. Earlier editions of the Code, Rule 97.D (intended to apply to ungrounded or single grounded systems) were interpreted to permit this connection with a 10kV breakdown. See discussion on "Stray Voltage in Dairy Farms" for impact of this situation.

214.A.5. Revised to read as follows: "Lines and equipment with recorded defects which could reasonably be expected to endanger life or property shall be promptly repaired, disconnected, or isolated." (underline test added-ed)

231.B Revised to read as follows:

1. Where there are curbs, supporting structures shall be located a sufficient distance from the street side of the curbs to avoid contact between ordinary vehicles using and located on the traveled portion of the roadway and the structures, support arms, or equipment attached thereto up to 15 feet (4.6m) above the road surface. In no case shall such distance be less than 6 inches (150 mm).

2. Where there are no curbs, supporting structures should be located a sufficient distance from the roadway to avoid contact by ordinary vehicles using and located on the traveled way.

231.C Exception 4. A new Exception 4 permits clearance of 7' at industrial sidings if there is space to load or unload cars.

Table 232-1. There are a few changes here. For example, the required clearance between communications conductors or cables and residential driveways is increased from 10' to 12'.

Table 233-1. There are significant revisions in both category headings and clearances required, so this table should be reviewed carefully.

233.B.1 Exception. Revised to read as follows:

Exception: The horizontal clearance between anchor guys of different supporting structures may be reduced to 6 inches and may be reduced to 2 feet between other guys, span wires and neutral conductors meeting Rule 230E1. (underlined test added-ed).

234A.1 Exception. A new exception to this rule exempts communications conductors and cables, as well as guys and messengers which meet Rule 230E1 from wind displacement calculations.

234.E. Title has been revised to: Minimum clearance of wires, conductors, or cables installed over or near swimming areas (underlined test added-ed). New Exception 2 exempts communications conductors and cables, guys and messengers and anything meeting Rule 230C1 which will require only 10' clearance.

Table 234.3. A column has been added to address communications plant.

235.B.3. As a clarification, communications cables and conductors as well as guys and messengers and several other items are considered line conductors at 0 voltage.

Table 235.6. Add a paragraph to footnote 1 as follows:

"The minimum clearance from an insulated or effectively grounded guy, to a communication cable, may be reduced to 3 inches when abrasion protection is provided on the guy or communication cable."

238. Title change to: "Vertical Clearance Between Certain Communication and Supply Facilities Located on the Same Structure."

238.D Exception. If a drop loop of conductors entering a luminaire bracket is covered by suitable nonmetallic covering, clearance above a communication cable may be reduced to 3" by this new exception.

Table 238.1. Title revised to include communications.

241.C. As clarification, this will read as follows:

"At crossings, wires, conductors, or other cables of one line are considered to be at crossings when they cross over another line, whether or not on a common supporting structure, or when they cross over or overhang a railroad track of the traveled way of a limited access highway. Joint use or colinear construction in itself is not considered to be at crossings.

1. ----"

316. The caveat in this section has been reworded to encourage cooperation between power and communications utilities in reducing induced voltage problems.

320.A.5.a. Line 3, change "60" below the top ----" to "50" below the top ----".

Station Protection in the Deregulated Environment

E. J. Cohen
Engineering Management and Standards Engineer
Telecommunications Engineering and Standards Division

In today's deregulated environment, with subscriber ownership of terminal equipment becoming the norm rather than the exception, station protection assumes a new and vital importance. When the telephone company had end-to-end responsibility for the network, we knew that protection was coordinated with the vulnerability of terminal equipment and that an adequate margin existed to prevent damage from all but the most severe surges. That control is now gone, and some of the new generation of terminal equipment available for subscriber purchase is quite vulnerable to surges.

The explanations for this vulnerability vary; from simple economics (protection costs money, and the producer of a $10 throw-away telephone may have little margin for such "luxuries") to ignorance on the part of designers (no engineering school teaches surge protection as part of its regular curricula) or to other similar reasons. But no matter how the vulnerability comes about, it can spell trouble for the exchange carrier. We have conditioned our subscribers to call us when experiencing difficulty with telephone equipment. So when the subscriber calls us because a new super duper $400 answering device failed during its first thunderstorm, and we tell him to take it back to the point of purchase for repair, he will be unhappy. When the store informs him that the warranty is invalid because an over-voltage surge on the telephone line damaged the unit he will be extremely unhappy! If our station protector isn't 100% up to specification, and the subscriber discovers this and takes legal action we may be lucky to escape with the cost of repairs. Even if our installation is okay and the customer/manufacturer must bear the cost of repairs, we have lost the goodwill of a subscriber--a valuable commodity in our service-oriented industry.

We need to make sure that our installations are in full compliance with the National Electrical Code in effect at the time of the installation or the last major rehab. Installers, either our own or working for us on contract, must be impressed with the importance of this compliance and motivated to make that extra effort to handle difficult installations. Ideally, new services should be designed to enter the premises very close to the power service entrance so that these two can be bonded together easily and effectively. Bonding jumpers and ground wires must be protected against accidental damage by the subscriber or others. After all the best designed grounding and bonding system is useless if critical connections are severed. The issue of adequate mechanical protection for these links and the question of when and by whom they were cut may again cost us money.

Our repairmen must also be told about the importance of station protection and taught not to tamper with its effectiveness in an effort to solve other problems. One area that comes to mind is the removal of carbon blocks from a station protector as the "ultimate solution" to repeated noise problems caused by dusted carbons. While this may indeed silence the noise complaints, it could also silence the subscriber should a surge occur while the phone is in use. There is enough concern about this situation that two manufacturers, both presently listed by REA, have developed cost competitive protectors which, in one case grounds the line when an arrester is removed and, in the other, makes it difficult if not impossible to terminate the circuit. Even UL is concerned about the possibility and it appears likely that UL 497, Protectors for Communications Circuits, will be revised in some way to reflect this concern.

Another potential source of damage or trouble is the subscriber! Steps must be taken to discourage the subscriber, who is now selecting telephones at the local department store and installing them himself with wire and hardware purchased similarly from tampering with the station protector or deliberately disconnecting the ground wire. (After all, what useful purpose could possibly be served by connecting a length of bare copper wire to a water pipe??)

With the growth of consumer owned telecommunications equipment, and the potential for consumer harm, UL is becoming active in this field, UL 1459, Telephone Equipment, aimed directly at subscriber owned terminal equipment is presently well under development. Before long, the UL label on telephone equipment may be as comon as that same label on other appliances such as toasters! And its a good thing. UL may be able to enforce some measure of coordination between surges in the environment and hazards from terminal equipment. One such category which 1459 has already addressed is supplementary protection in terminal equipment.

One "band-aid" fix for inadequate surge withstand capability in terminal equipment is for the manufacturer to place a relatively low voltage arrester from each line to ground within the terminal equipment itself. This is known as the supplementary protection and, in some situations, it can be a serious hazard. The supplementary protector parallels the station protector and fires at a significantly lower voltage. When the supplementary unit fires, the current flow through it reduces the line to ground voltage at the station protector to the point where that unit may never break down. As a result, the full energy of the surge is carried by the house wiring including the plug and jack--an excellent scenario for a fire! UL 1459 will probably require a current limiting device, such as a fuse, if supplementary protectors are employed.

In summation, station protection is becoming more important in our competitive telecommunications environment. Operating telephone companies and equipment manufacturers need to be aware of the problems and act accordingly. Standards developers with an interest in safety, such as UL, are already involved.

Stray Voltage Problems

E. J. Cohen
Engineering Management and Standards Engineer
Telecommunications Engineering and Standards Division

In recent years there has been a large increase in complaints related to so-called "stray voltages" on farms. Some of the corrective actions taken to resolve them may have a major impact on the telephone systems financed by REA. The attached April 27, 1983, and September 24, 1981, letters from J. S. Zoller, Assistant Administrator - Electric, to All REA Electric Borrowers provides details on the sources and symptoms of the problem.

As described in the attached letters, one of the sources of these stray voltage problems is voltage on the power system neutral. This may be caused by loads on the farm that is experiencing problems or from other loads along the line. It is impossible to operate a power distribution system, particularly single phase lines, in such a manner as to maintain neutral voltages at less than the critical levels for milking parlors. As a quick fix, some sources are advocating the isolation of the power system primary and secondary neutrals, either through a spark gap or a low voltage isolation device.

National Electrical Code (NEC), Article 800-31(b), requires that the station protector ground be connected to the electrical system ground. Similarly, for safety considerations, telephone system outside plant is frequently grounded or bonded to the electrical system neutral. Thus, the shield on the telephone facility could serve as a means of bypassing the neutral isolating device should one be employed. Not only may this render the isolation device ineffective in eliminating stray voltage problems but, under some circumstances, the shield could carry significant currents which are normally carried by the neutral if the isolating device were not installed.

NEC Article 800-31(a) permits the metal sheath of aerial cables entering a building to be interrupted close to the entrance to the building by an insulating joint or equivalent device under some conditions. Likewise, the shield of a buried service drop may be isolated at the pedestal. These options should be used judiciously and the shield should be grounded at the premises whenever possible. Not only does this isolating joint increase the hazard of personnel shock, but it may reduce shielding for the cable. REA construction practices rely on the existence of multiple grounds available at subscribers' premises for electrical protection as well as noise shielding. Removal of a significant number of these ground paths from the shield could result in noise or overvoltage problems.

Subscribers should be made aware that other systems, such as CATV or a metallic water service, could bypass the neutral isolating device. As a result, the subscriber with stray voltage problems should be urged to consider an equipotential plane approach, as described in the attached letters, as a solution.

2 Attachments

United States Department of Agriculture
Rural Electrification Administration
Washington D.C. 20250

APR 27 1983

SUBJECT: Stray Voltage in Dairy Farms

TO: All REA Electric Borrowers

In September 1981 a letter was sent to you on the above subject. A summary of the stray voltage phenomenon was provided along with a recommendation that appropriate information concerning the subject be made available to local contractors and to consumers who are involved in dairy, swine farrowing and similar operations.

The stray voltage phenomenon and proper solutions to problems at the affected facilities are critically important to consumers involved in dairy, swine farrowing, and similar operations. We strongly urge you to make appropriate information available to your consumers by use of bill stuffers, direct mailing or other suitable means. A sample notice that could be sent to consumers is included with this letter. The notice could, of course, be modified to suit your needs.

Questions are often asked regarding responsibility for dealing with the stray voltage phenomenon. We recognize that a small voltage on electric system neutrals is a normal condition that always exists. The voltage is variable depending on many factors. Consumers whose service requirements are more stringent than the service normally supplied to all consumers can and should construct their facilities in such a way to satisfy their special requirements. However, the consumers may not be aware of the critical nature of their operation or of the things that can be done to prevent them from having problems. We strongly urge you to assist your consumers who have, or are likely to have, stray voltage problems. The information you can supply, and your cooperation in helping them to avoid or alleviate problems, is very important.

Our September 1981 letter contained a bibliography of representative papers on the stray voltage phenomenon. Many additional papers have been published by the American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, Michigan 49085. Since 1981, considerable work has been done on the installation of equipotential planes in existing dairy facilities. Papers describing successful and economical installations should be available in the near future. The only difficult part is installation of the grounding conductors in the concrete floor. This can, however, be done by grooving the floor, perhaps a section at a time, with a carbide or diamond-tooth saw. For most efficient conductor use, the grooves are cut parallel and a few inches apart in the most critical areas. Spacing can probably be increased in the less critical areas. Quick setting grout is used to secure the conductors in the grooves. The use of concrete grooving saws makes the equipotential plane the preferable method of dealing with the critical existing installations. The equipotential plane should certainly be installed in all new installations.

JOE S. ZOLLER

JOE S. ZOLLER
Assistant Administrator - Electric

Enclosure

Suggested Bill Stuffer or Letter to Members:

STRAY VOLTAGE

As farms have become more electrified over the years, a previously little-known condition has grown to serious proportions in some dairy, swine farrowing and similar operations. The term commonly used to describe the phenomenon is "stray voltage." A small electric potential (voltage) exists between grounded neutral and earth on any electric system. This voltage will also exist on conductive objects that are connected to the electric system neutral for safety in the event of a fault. These voltages are usually too low to be felt by humans due to the insulation effect of skin, shoes, etc., and perhaps a higher natural tolerance. Suckling pigs and dairy cattle are, however, very sensitive to extremely low voltages because of natural low tolerance and the type of contact (tongue and teat-end contact, for example) with conductive objects. The special and critical aspects of livestock contacting these low voltages that normally exist should be considered in all dairy, swine farrowing and similar operations.

SYMPTOMS

Since most research has been done on dairy farms, we shall discuss these installations. How does a dairy operator determine whether or not a problem may exist? The University of Minnesota Agricultural Extension Service lists seven symptoms and stresses that animal reactions will vary based on the severity of the problem.

1. Uneven milk let-down: This is the most common symptom expressed by dairy operators. The number of cows affected and the severity of the milk let-down problem appear to be dependent on the level of stray voltage present. The mechanism of how this occurs is not understood. When milk let-down is uneven, longer milking time becomes apparent and stripping is required.

2. Cows extremely nervous while in the parlor: This trait is often characterized by the cows dancing or stepping around almost continuously while in the parlor stall. However, dairy operators are reminded that cows may become nervous for other reasons, such as malfunctioning milking equipment or rough handling by the operator.

3. Cows reluctant to enter the parlor: When cows are subjected to stray voltages in the parlor stalls, they soon become reluctant to enter the parlor. In extreme cases cows have had to be driven into the parlor and there is a tendency to "stampede" out of the parlor upon release. But again, this symptom is not specific since cows may be trained to expect the parlor operator to chase them into the milking stalls.

4. Increased mastitis: When milking is incomplete, more mastitis than normal is likely to occur. All that is required is the presence of infectious bacteria. This, in turn, will result in an increased somatic cell count.

5. Reduced feed intake in the parlor: If cows detect stray voltage while eating from the grain feeders, a reluctance to eat and reduced feed intake is almost certain to occur.

6. Reluctance to drink water: Stray voltages may reach the cows in stall barns through the water supply or metal drinking cups. Thus, cows soon become reluctant to drink.

7. Lowered milk production: Each of the symptoms described previously is associated with stress, reduced nutrient intake, or disease. In any case, a drop in daily milk production is to be expected. Even when the stray voltage problem has been corrected, milk production may remain abnormally low for awhile because of the associated problems.

EVALUATION

It must be noted again here that many other factors may contribute to the above symptoms. A careful evaluation of all possible causes is necessary and will lead to the earliest possible resolution of the problem. This evaluation should include consideration of problems with equipment, disease, nutrition, etc. If stray voltage is suspected, initial assistance may be obtained from your electrician. We can also provide additional information that may be of assistance to you. Equipment dealers and creamery field representatives are also becoming more familiar with stray voltage and may be able to lend valuable assistance. Remember that this is a relatively new field, and not all veterinarians, electricians or creameries will be familiar with the problem.

NEW CONSTRUCTION

If you are considering new construction or extensive remodeling of your dairy, or similar facility, an ounce of prevention is worth a pound of cure. New facilities can easily and economically be constructed to avoid future stray voltage problems. Many University Agricultural Extension Services have excellent publications to enable you to avoid future stray voltage problems by proper design of your facilities.

EXISTING CONSTRUCTION

Once stray voltage has been identified and measured, there still remains the problem of a solution. It is, however, possible to alleviate stray voltage problems in existing facilities. Information on means of alleviating the problem can be obtained from various University Agricultural Extension Services. We can also provide or help you to obtain helpful information.

United States Department of Agriculture

Rural Electrification Administration

Washington D.C. 20250

September 24, 1981

SUBJECT: Stray Voltage in Dairy Farms

TO: All Electric Borrowers

In recent years, there has been a large increase in complaints related to stray voltage on farms. Generally, the complaints involve dairy operations although reports have also involved swine farrowing units. These complaints often relate to new dairy facilities which, at minimal extra cost, could have been constructed so as to preclude current flow through the livestock due to stray voltage. There is general agreement among most people who have done research in this area that very low voltages (as low as 0.25 to 0.5 volts) may, under certain conditions, cause problems for livestock. It seems therefore that dairy operations, swine farrowing operations, etc., should be considered as critical loads with stringent requirements which are not met by the normal electric service.

The purpose of this letter is to provide a brief summary of certain aspects of the stray voltage phenomenon and to recommend that borrowers make appropriate information concerning the subject available to local contractors and to co-op members who are involved in dairy, swine farrowing, and similar operations. The information provided to members should discuss methods of preventing stray voltage problems in the livestock (dairy) facilities. Numerous technical papers have been written on the phenomenon and a brief bibliography of a representative sample of the papers is included with this letter. The papers provide valuable information and are recommended reading for borrowers' personnel who may be involved with the stray voltage problem.

There are two basic causes of voltage on the electric system neutral. They are improper or faulty wiring and/or equipment, and normal load current flowing in the neutral and to ground. Although a few of the improper or faulty wiring and equipment conditions can occur on power suppliers' facilities, most occur on consumers' facilities. A list of actual situations as reported by Stetson, Soderholm and Shull in ASAE Paper No. 80-3505 includes:

- Electric trainer grounded to water line in barn
- Imbalance in 120-volt loads
- Intermittent short in fan motor switch wiring
- Insulation failure in wiring to submersible pump motor
- Contact between ground conductor and 240-volt switch
- Neutral conductor too small
- Service conductor too small
- High resistance (poor) neutral connection
- Bare wires in outlet box
- Unbalanced load on the legs of the consumer's three-wire service to the barn

Parallel neutral connection from two entrance panels
Leakage across wet spider web
Rodent damage to wiring
120-volt solenoid connected from line to ground
Faulty water heater element

Where conditions such as the above exist, it is, of course, necessary that they be corrected. Determining the specific cause of voltage in the livestock facility can be extremely difficult due to the complexity of the situation and often the sporadic nature of the voltage. Because of this, and for other reasons discussed later, it is highly recommended that gradient control (equipotential plane) be designed and built into all such facilities. If the facility is properly constructed with an equipotential plane, there will be essentially no voltage across the livestock even though voltage with respect to remote earth may exist on the neutral. This will be further discussed in the following paragraphs.

Even if all the farm wiring and equipment is operating normally, it is still likely that dairy cattle or other livestock in inadequately constructed facilities may be receiving slight electric shocks that can be troublesome. This can be caused by potential differences due to normal system neutral potential. Electric potential voltage on the grounded system neutral is a normal system condition. The magnitude of this voltage will depend on several factors including load current, system (including consumer) grounding, and whether the primary line is single-phase or three-phase. Generally, sufficient grounding can be obtained to keep the neutral voltage low enough so that people do not feel a tingle. The power supplier should strive to keep the voltage on the neutral as low as practical through system grounding practices.

It should be realized, however, that the neutral system potential cannot be kept at the 0.25 to 0.5 volt level which is generally believed to be necessary to assure that dairy cattle will not be affected by the voltage. It should also be realized that the system neutral potential is not the most significant criterion for determining the likelihood of shock to dairy cattle. The important element related to shock is the current. The driving force for current is not potential - it is potential difference between the contact points on the animal, usually between extremities such as mouth, hooves, teat ends, etc. The potential difference across a dairy cow would not be expected to be at the same voltage level as the potential of the electric system neutral with respect to remote earth because varying degrees of electric bonding generally exist in the dairy facilities. Also, the concrete floor is probably not at remote earth potential with respect to the electric system neutral.

Potential difference between all likely dairy cow contact points in the dairy barn, including the concrete floor, can be held to very low voltage values (practically zero volts) by adequate bonding of all contact surfaces. The concrete floor can be bonded by means of closely spaced mesh in the floor. This is generally referred to as creating an equipotential plane and is more fully explained in several of the referenced published papers. Not mentioned in the referenced papers, but also important, is a metal ring or rim installed around the edge of the concrete and bonded with the rest of the system. Ideally, the equipotential plane should extend throughout the entire dairy facility, however, of particular concern to the dairy farmer should be maintaining equipotential planes at water bowls or watering places, mangers or eating places, stalls or places the animals touch, and milking parlors and related milking equipment.

A second method available to the dairy farmer for limiting the potential on the system neutral in the dairy facilities is by use of an isolation transformer. If the transformer is placed at the service to the dairy facilities and all metallic paths between the dairy facilities' electric and grounding system and the rest of the farm's electric and grounding system are eliminated, the neutral potential within the dairy facilities will be very low. It is important to make measurements to confirm that the two electric systems are isolated and it is sometimes difficult to locate connecting paths between the grounded neutrals of the two different systems. Underground metallic water lines or gas lines interconnecting the two systems may need to be interrupted.

Isolation of the entire service neutral from the primary neutral by placing a gap or a surge arrester between the systems is not recommended. This technique sacrifices the safety aspects of the solidly interconnected grounded systems. The gap interrupts the metallic return path that is relied upon to ensure operation of the protective device in the event of a fault which places primary voltage on the neutral of the secondary system. The NESC provision permitting the non-interconnected neutrals (spark gap interconnection) was originally written to apply to a delta primary system which has no neutral conductor. It was to provide for a gap only between the primary surge arrester grounding conductor and the secondary system neutral.

SUMMARY:

1. Proper system grounding practices should be followed by the power supplier and the consumer in order to maintain system neutral potential as low as practical. It is impossible to define a minimum practical value because of the many varying factors that can affect system neutral potential.

2. In certain situations, livestock are extremely sensitive to very small voltages (perhaps 0.25 to 0.5 volts). Under normal operational conditions, voltage on the electric system neutral will generally exceed these levels. In areas of high earth resistivity, the system neutral voltage may normally exceed these levels by a wide margin.

3. Two methods which have been successfully applied by dairy farmers to limit potential differences to the low levels desired for dairy operations are the equipotential plane and the isolation transformer. The equipotential plane is simply an extension of the normally applied concept of bonding equipment, enclosures and similar conductive surfaces together. It should be incorporated into the construction of all new livestock facilities. It can be added to existing facilities, although not as easily or economically as incorporating it into the initial construction. Perhaps a more economical procedure at an existing facility is the installation of an isolation transformer. Both methods have been discussed in the referenced papers.

4. Isolation of the primary and secondary neutrals through a spark gap is not recommended because of the uncertainty of protective device operation in the event of a fault involving the primary phase conductor and the secondary neutral.

Joe S. Zoller

JOE S. ZOLLER
Assistant Administrator - Electric

Enclosure

Bibliography of Representative Papers

Stray-Voltage Problems in Dairy Milking Parlors, Šoderholm, L.H., 1979 - ASAE Paper No. 79-3501 (American Society of Agricultural Engineers, St. Joseph, Michigan 49085)

Extension Folder 552-1980, Agricultural Extension Service, University of Minnesota, Applemen, R.D., and Cloud, H.A., 1980 (University of Minnesota, Minneapolis, Minnesota 55455)

Neutral to Earth Voltage in Dairy Facilities - 2 Case Studies, Gustafson, R.J., Drache, D.B., and Cloud, H.A. - ASAE Paper No. NCR 80-305

Investigations of Stray Voltages, Stetson, L.E., Soderholm, L.H., Shull, H., 1980 - ASAE Paper No. 80-3505

Stray Voltage Problems and Solutions in Michigan, Lillmars, L.D., Sunbrook, T.C., 1980 - ASAE Paper No. 80-3504

Stray Voltage in a Swine Farrowing Unit - A Case Study, Stetson, L.E., Beccard, A.O., DeShazer, J.A. - ASAE Paper No. 79-3502

INSTRUCTIONS FOR

PREPARING THE

<u>BORROWERS ENVIRONMENTAL REPORT</u>

BORROWERS ENVIRONMENTAL REPORT (BER)

A. SCOPE OF THE PROJECT

B. A DISCUSSION OF THE NEED FOR THE PROJECT

C. ALTERNATIVES TO THE PROPOSED PROJECT

   A. NO ACTION

   B. ALTERNATIVE ROUTES

   C. ALTERNATIVE CONSTRUCTION METHODS

   D. CONSERVATION

D. A DESCRIPTION OF EXISTING ENVIRONMENT

E. A DISCUSSION OF THE ENVIRONMENTAL IMPACTS OF THE PROPOSED PROJECT

F. A DESCRIPTION OF UNUSUAL OR SENSITIVE ENVIRONMENTAL ISSUES WITHIN THE PROJECT AREA

G. A STATEMENT THAT THE APPLICANT WILL FOLLOW ANY GUIDANCE PRESENTED IN THE U. S. DEPARTMENT OF THE INTERIOR (USDI)/U.S. DEPARTMENT OF AGRICULTURE (USDA) ENVIRONEMTNAL CRITERIA FOR ELECTRIC TRANSMISSION SYSTEMS WHICH IS APPLICABLE TO THE CONSTRUCTION OF TELEPHONE PROJECTS

H. A COMMITMENT FROM THE APPLICANT TO CONSULT WITH THE SOIL CONSERVATION SERVICE (SCS), FEDERAL OR STATE LAND MANAGEMENT AGENCIES (IF SUCH LANDS WILL BE USED IN A PROJECT), OR THE APPROPRIATE LOCAL AGENCY ON EROSION CONTROL AND REVEGETATION PROCEDURES, AND TO FOLLOW ALL REASONABLE RECOMMENDATIONS

I. COPY OF LEGAL NOTICE ALONG WITH THE REQUIRED ADVERTISEMENT FOR CONSTRUCTION IN A FLOOD PLAIN OR WETLANDS

J. COPIES OF CORRESPONDENCE OR COMMENTS FROM ENVIRONMENTAL AGENCIES WHICH HAVE JURSISDICTION IN YOUR AREA

AGENCIES NORMALLY REQUIRED TO BE CONTACTED

1. STATE HISTORIC PRESERVATION OFFICE - (SHPO) - HISTORIC AND CULTURAL SITES.

2. U. S. FISH & WILDLIFE SERVICE - (USFWS) - TREATMENT AND ENDANGERED SPECIES.

3. FEDERAL EMERGENCY MANAGEMENT AGENCY - (FEMA) - FLOOD PLAIN MAPS.

4. U.S. FISH & WILDLIFE SERVICE - (USFWS) - WETLANDS.

5. STATE CONSERVATIONIST: IMPORTANT FARMLANDS, RANGELANDS, AND FOREST LAND.

ADDITIONAL AGENCY CONTACT MAY BE REQUIRED

1. U. S. DEPARTMENT OF INTERIOR: (USDI) - WILD AND SCENIC RIVERSTUDY GROUP.

2. STATE COASTAL RESOURCES OFFICE: (SCRO) - COASTAL ZONE MANAGEMENT.

3. FEDERAL AVIATION ADMINISTRATION: (FAA) - NAVIGABLE AIRSPACE HAZARDS.

4. U. S. FOREST SERVICE - BUREAU OF LAND MANAGEMENT, NATIONAL PARK SERVICE OR FISH & WILDLIFE SERVICE: IMPACTS ON FEDERAL LANDS.

5. U. S. FISH & WILDLIFE SERVICE (USFWS) - COASTAL BARRIERS.

HISTORIC PRESERVATION

A. AUTHORITY

1. NATIONAL HISTORIC PRESERVATION ACT OF 1966.
2. EXECUTIVE ORDER 11593, MAY 13, 1971.
3. "PROCEDURES FOR THE PROTECTION OF HISTORIC AND CULTURAL PROPERTIES," 36 C.F.R. §800 ET SEQ.

B. POLICY - TO PRESERVE FOR PUBLIC USE HISTORIC SITES, BUILDINGS, AND OBJECTS OF NATIONAL SIGNIFICANCE FOR THE INSPIRATION AND BENEFIT OF THE PROPLE OF THE U. S.

C. FINDINGS REQUIRED

1. IDENTIFY PROPERTIES LISTED OR ELIGIBLE FOR LISTING IN THE NATIONAL REGISTER LOCATED WITHIN THE PROJECT'S POTENTIAL ENVIRONMENTAL IMPACT. INCLUDES CONSULTATION WITH THE STATE HISTORICAL PRESERVATION OFFICER (SHPO) TO APPLY CRITERIA TO DETERMINE IF THERE ARE SITES ELIGIBLE FOR LISTING.
2. FINDING OF NO EFFECT, NO ADVERSE EFFECT OR ADVERSE EFFECT. APPLY "CRITERIA OF EFFECT" AND MAKE ONE OF THE ABOVE THREE FINDINGS.

CRITERIA OF EFFECT _ THE "CRITERIA OF EFFECT" IS AS FOLLOWS: "WHEN ANY CONDITION UNDERTAKING CAUSES ANY CHANGE, BENEFICIAL OR ADVERSE, IN THE QUALITY OF THE HISTORICAL, ARCHITECTURAL, ARCHAEOLOGICAL, OR CULTURAL CHARACTER THAT QUALIFIES THE PROPERTY UNDER THE NATIONAL REGISTER CRITERIA." FOR INSTANCE, VISUAL IMPACTS MAY CREATE ADVERSE EFFECTS.

ENDANGERED SPECIES

A. AUTHORITY

1. ENDANGERED SPECIES ACT OF 1973, AS AMENDED, 16 U.S.C. §§1531-1543.
2. INTERAGENCY COOPERATION REGULATIONS, 50 C.F.R. §§402.01 - 402.05.

B. POLICY - "TO PROVIDE A MEANS WHEREBY THE ECOSYSTEMS UPON WHICH ENDANGERED SPECIES AND THREATENED SPECIES DEPEND MAY BE CONSERVED, TO PROVIDE A PROGRAM FOR THE CONSERVATION SUCH ENDANGERED SPECIES AND THREATENED SPECIES, AND TO TAKE SUCH STEPS AS MAY BE APPROPRIATE TO ACHIEVE THE PURPOSES OF THE TREATIES AND CONVENTIONS (BETWEEN THE UNITED STATES AND OTHER COUNTRIES TO PROTECT ENDANGERED SPECIES)" (16 U.S.C. §1531(B)).

C. JURISDICTION OF ACT - THE ACT HAS JURISDICTION OVER THOSE SPECIES WHICH THE SECRETARY OF THE INTERIOR DESIGNATES AS ENDANGERED OR THREATENED, AND OVER THOSE AREAS WHICH THE SECRETARY OF THE INTERIOR DESIGNATES AS A "CRITICAL HABITAT" (16 U.S.C. §1533).

D. FINDINGS REQUIRED

1. CONDUCT A BIOLOGICAL ASSESSMENT TO DETERMINE IF THE PROPOSED ACTION MAY ADVERSELY AFFECT A LISTED SPECIES OR CRITICAL HABITAT (50 C.F.R. §402.04(A)).
2. IF AGENCY FINDS NO EFFECT ON LISTED SPECIES OR CRITICAL HABITAT, THEN NO SECTION 7 CONSULTATION IS REQUIRED. FWS MAY STILL REQUEST CONSULTATION EVEN IF AGENCY HAS DETERMINED THAT THERE IS NO EFFECT, SO INFORMAL CONSULTATION WITH LOCAL FWS OFFICE SHOULD PROVIDE EVIDENCE FOR SUCH FINDING.
3. IF THE AGENCY DETERMINES THAT ITS ACTION MAY AFFECT A LISTED SPECIES OR CRITICAL HABITAT, IT MUST CONSULT WITH THE FISH AND WILDLIFE SERVICE (50 C.F.R. §402.04(A)(3)). THE FWS WILL THEN STUDY THE PROPOSED ACTION AND ISSUE A BIOLOGICAL OPINION AND RECOMMENDATIONS.

FLOODPLAIN MANAGEMENT

AUTHORITY EXECUTIVE ORDER 11988, AS AMENDED "FLOODPLAIN MANAGEMENT" 5/24/77

POLICY AVOID TO EXTENT POSSIBLE LONG AND SHORT TERM ADVERSE IMPACTS ASSOCIATED WITH OCCUPANCY AND MODIFICATION OF FLOODPLAINS. AVOID DIRECT OR INDIRECT FLOODPLAIN DEVELOPMENT WHERE PRACTICABLE ALTERNATIVE FOUND

REQUIREMENTS

1. DETERMINE IF CONSTRUCTION IN 100-YEAR FLOODPLAIN OR 500-YEAR FLOODPLAIN - (INVOLVES CRITICAL ACTION FACILITY)

2. USE HUD FLOODPLAIN MAP OR FEDERAL EMERGENCY MANAGEMENT AGENCY MAP

3. IF WORK AFFECTS FLOODPLAIN CONSIDER ALTERNATIVES TO AVOID ADVERSE EFFECTS AND INCOMPATIBLE DEVELOPMENTS

4. PROVIDE FOR PUBLIC REVIEW AND COMMENT - PUBLISH LEGAL NOTICE AND NEWS ARTICLE OR ADVERTISEMENT

5. IF FINDING OF "NO PRACTICABLE ALTERNATIVE" LIST WAYS ACTION CAN BE DESIGNED OR MODIFIED TO MINIMIZE HARM TO FLOODPLAIN

6. PROVIDE FOR ALL POSSIBLE FLOODPROOFING

7. INFORM ANY PRIVATE PARTIES PARTICIPATING IN WORK OF HAZARDS

WETLANDS

AUTHORITY EXECUTIVE ORDER NO. 11990, "PROTECTION OF WETLANDS" 5/24/77

POLICY AVOID TO EXTENT POSSIBLE LONG AND SHORT TERM IMPACTS ASSOCIATED WITH DESTRUCTION OR MODIFICATION OF WETLANDS. AVOID DIRECT OR INDIRECT SUPPORT OF NEW CONSTRUCTION IN WETLANDS WHERE PRACTICABLE ALTERNATIVE FOUND

REQUIREMENTS (A) DETERMINE IF PROJECT LOCATED IN WETLAND

(B) IF LOCATED IN WETLAND MUST AVOID UNDERTAKING OR PROVIDING ASSISTANCE UNLESS THERE IS NO PRACTICABLE ALTERNATIVE - NEED TO INCLUDE ALL PRACTICABLE MEASURES TO MINIMIZE HARM TO WETLANDS

(C) PROVIDE FOR PUBLIC REVIEW AND COMMENT - PUBLISH LEGAL NOTICE AND NEWS ARTICLE OR ADVERTISEMENT

IMPORTANT FARMLAND, PRIME RANGELAND AND PRIME FOREST LAND

AUTHORITY

1. FARMLAND PROTECTION POLICY ACT OF 1981, 7 U.S.C. 420
2. USDA SECRETARY'S MEMORANDUM 9500-3, 3/22/83

POLICY

1. TO ASSURE U.S.A. RETAINS FARM, RANGE, FOREST LAND BASE SUFFICIENT TO PRODUCE ADEQUATE SUPPLIES FOR HIGH QUALITY FOOD FIBER, WOOD, ETC.
2. ASSIST INDIVIDUAL LAND - HOLDERS AND STATE AND LOCAL GOVERNMENTS IN DEFINING AND MEETING NEEDS FOR GROWTH AND DEVELOPMENT IN SUCH WAYS MOST PRODUCTIVE FARM, RANGE AND FOREST LANDS ARE PROTECTED
3. TO ASSURE APPROPRIATE LEVELS OF ENVIRONMENTAL QUALITY

FINDINGS REQUIRED

NO ACTION MAY BE TAKEN WHICH WOULD CONVERT FARMLAND, PRIME RANGELAND AND PRIME FOREST LAND INTO OTHER USES UNLESS -

1. DEMONSTRATED, SIGNIFICANT NEED FOR THE ACTION
2. NO PRACTICABLE ALTERNATIVE ACTIONS OR SITES

WILD AND SCENIC RIVERS

A. AUTHORITY - WILD AND SCENIC RIVERS ACT OF 1968, AS AMENDED, 16 U.S.C. §§1271-1287.

B. POLICY - "CERTAIN SELECTED RIVERS OF THE NATION WHICH, WITH THEIR IMMEDIATE ENVIRONMENTS, POSSESS OUTSTANDINGLY REMARKABLE SCENIC, RECREATIONAL, GEOLOGIC, FISH AND WILDLIFE, HISTORIC, CULTURAL, OR OTHER SIMILAR VALUES, SHALL BE PRESERVED IN FREE-FLOWING CONDITION, AND THAT THEY AND THEIR IMMEDIATE ENVIRONMENTS SHALL BE PROTECTED FOR THE BENEFIT AND ENJOYMENT OF PRESENT AND FUTURE GENERATIONS" (16 U.S.C. §1271)

C. JURISDICATION OF ACT - A RIVER OR PORTION OF A RIVER IS UNDER THE JURISDICTION OF THE ACT IF:
1. INCLUDED BY ACT OF CONGRESS, OR
2. DESIGNATED BY LEGISLATIVE ACT OF THE STATE IN WHICH IT IS LOCATED, AND UPON APPLICATION BY THAT STATE TO THE SECRETARY OF THE INTERIOR, DESIGNATED AS A WILD AND SCENIC RIVER (16 U.S.C. §1273(A)).

D. PROHIBITED ACTION - "THE FEDERAL POWER COMMISSION SHALL NOT LICENSE THE CONSTRUCTION OF ANY DAM, WATER CONDUIT, RESERVIOR, POWERHOUSE, TRANSMISSION LINE, OR OTHER PROJECT WORKS UNDER THE FEDERAL POWER ACT, AS AMENDED, ON OR DIRECTLY AFFECTING ANY RIVER WHICH IS DESIGNATED (AS A WILD AND SCENIC RIVER), OR WHICH IS HEREAFTER DESIGNATED FOR INCLUSION IN THAT SYSTEM, AND NO DEPARTMENT OR AGENCY OF THE UNITED STATES SHALL ASSIST BY LOAN, GRANT, LICENSE, OR OTHERWISE IN THE CONSTRUCTION OF ANY WATER RESOURCES PROJECT THAT WOULD HAVE A DIRECT AND ADVERSE EFFECT ON THE VALUES FOR WHICH SUCH RIVER WAS ESTABLISHED" (16 U.S.C. §1278(A)).

COASTAL ZONE MANAGEMENT

A. AUTHORITY

1. FEDERAL COASTAL ZONE MANAGEMENT ACT OF 1972, AS AMENDED.
2. "FEDERAL CONSISTENCY WITH APPROVED COASTAL MANAGEMENT PROGRAMS".

B. POLICY

"TO PRESERVE, PROTECT, DEVELOP, AND WHERE POSSIBLE, TO RESTORE OR ENHANCE, THE RESOURCES OF THE NATION'S COASTAL ZONE FOR THIS AND SUCCEEDING GENERATIONS" AND "FOR ALL FEDERAL AGENCIES ENGAGED IN PROGRAMS AFFECTING THE COASTAL ZONE TO COOPERATE AND PARTICIPATE WITH STATE AND LOCAL GOVERNMENTS AND REGIONAL AGENCIES IN EFFECTUATING THE PURPOSES OF (THE FEDERAL COASTAL ZONE MANAGEMENT ACT OF 1972)".

C. REQUIRED FINDINGS - EACH FEDERAL AGENCY MUST:

1. DETERMINE WHICH OF THEIR ACTIVITIES DIRECTLY AFFECT THE COASTAL ZONE OF STATES WITH APPROVED MANAGEMENT PROGRAMS.

2. DETERMINE WHETHER SUCH ACTIVITIES WILL BE UNDERTAKEN IN A MANNER CONSISTENT TO THE MAXIMUM EXTENT PRACTICABLE WITH APPROVED STATE MANAGEMENT PROGRAMS.

3. PROVIDE STATE AGENCIES WITH SUCH CONSISTENCY DETERMINATIONS AT THE EARLIEST PRACTICABLE TIME IN THE PLANNING OR REASSESSMENT OF THE ACTIVITY.

NAVIGABLE AIRSPACE HAZARDS

A. **Authority**

Federal Aviation Administration (FAA) has sole authority on this issue. 14 CFR Part 77, Subpart B.

B. **Policy**

To insure the safety of aircraft, airport operations, and airways. Indentification of objects which may have an effect on and prove hazardous to navigable airspace.

C. **Required Findings**: - Each Federal Agency must:

1. Assure that the FAA has been notified, where appropriate, and that its requirements are reflected in the BER's.
2. Give adequate notice to FAA for any kind of construction or alteration described in 14 CFR 77.13(a).
   A. Any construction or alteration of more than 200 feet in height above the ground level of the site.
   B. Any construction or alteration of greater height than an imaginary surface extending outward and upward at one of the following slopes:
      1. 100 to 1 for a horizontal distance of 20,000 feet (3.79 miles or 6.10 kilometers) from the nearest point of the nearest runway of an airport with at least one runway more than 3,200 feet in length.
      2. 50 to 1 for a horizontal distance of 10,000 feet (1.89 miles or 3.05 kilometers) from the nearest point of the nearest runway of an airport with no runway more than 3,200 feet in length.
      3. 25 to 1 for a horizontal distance of 5,000 feet (0.95 mile or 1.52 kilometers) from the nearest point of the landing and takeoff area of a heliport.
   C. When requested by FAA, any construction or alteration that would be in an instrument approach area and might exceed 14 CFR Part 1794, Subpart C obstruction standards.

NOTE: A "no hazard" determination expires 18 months after its effective date if the proposed construction has not been started or completed. Additional time is allowed if a FCC construction permit is required.

IMPACTS ON FEDERAL LANDS

CONTACTS INCLUDE:

U. S. FOREST SERVICE

BUREAU OF LAND MANAGEMENT

NATIONAL PARK SERVICE

U. S. FISH AND WILDLIFE SERVICE

(AS APPROPRIATE)

COASTAL BARRIERS

AUTHORITY — COASTAL BARRIER RESOURCES ACT OF 1982 16 U.S.C. 3501-3510

POLICY — TO MINIMIZE LOSS HUMAN LIFE, WASTEFUL EXPENDITURE FEDERAL REVENUES AND DAMAGE TO FISH, WILDLIFE, OTHER NATURAL RESOURCES ASSOCIATED WITH COASTAL BARRIERS ALONG ATLANTIC AND GULF COASTS BY RESTRICTING FEDERAL EXPENDITURES

REQUIRED FINDINGS

1. DETERMINE WHETHER FEDERAL ASSISTANCE IS MADE AVAILABLE
2. WILL PROPOSED ACTION (WORK) TAKE PLACE WITHIN COASTAL BARRIER RESOURCES SYSTEM - USE DEPARTMENT OF INTERIOR MAP
3. IF SO, WILL WORK QUALIFY WITHIN A SECTION 6 EXCEPTION - FOR LIST OF EXCEPTION REVIEW COASTAL BARRIER RESOURCES ACT
4. IF SO, CONSULT WITH SECRETARY OF INTERIOR FOR PERMISSION TO CONTINUE - MUST BE CONSISTENT WITH THE PURPOSES OF CBR ACT
5. IF PROPOSED ACTION WILL TAKE PLACE WITHIN COASTAL BARRIER RESOURCES SYSTEM - DOES NOT FIT WITHIN SECTION 6 EXCEPTION OR DOES FIT BUT DOES RECEIVE PERMISSION FROM SECRETARY OF INTERIOR HALT FURTHER EXPENDITURES

INSTRUCTIONS ON COMPLIANCE WITH FEDERAL ENVIRONMENTAL REGULATIONS THE BORROWER'S ENVIRONMENTAL REPORT (BER)

All Federal Agencies are required to comply with various Federal environmental statutes before taking actions which may be detrimental to the environment. In order to comply with these statutes, each loan applicant is required to submit a Borrower's Environmental Report (BER) to REA so that REA may evaluate the effects of the proposed loan and fulfill its duties under the National Environmental Policy Act (NEPA) and other environmental laws and regulations. The BER will normally be prepared by the borrower with the guidance and review of the REA field representative.

In preparing the BER, the borrower should first contact the environmental agencies which have jurisdiction in its area, as appropriate, to determine all environmentally sensitive factors or areas known to exist within or near the project boundaries. Sample letters to environmental agencies are included with this instruction packet. Copies of all correspondence received from these agencies should be attached to the completed BER. When the agency correspondence suggests alternatives or mitigation measures to reduce adverse impacts on the environment, the BER should present the borrower's position on these comments. In addressing a comment the borrower should state that either (1) the comment will be incorporated into the proposed construction, (2) another type of mitigation will be used and the reason for the decision, or (3) no mitigation of alternatives is practicable and the basis for this conclusion.

All borrowers are normally required to contact the following agencies:

1. State Historic Preservation Office - Historic and Cultural Sites

2. U.S. Fish & Wildlife Service - Threatened and Endangered Species and general wildlife concerns

3. Federal Emergency Management Agency - Floodplain Maps

4. U.S. Fish & Wildlife Service - Wetlands

5. State Conservationist - Important Farmlands, Rangelands, and Forest Land

In addition, some borrowers will be required to contact the following agencies, as appropriate:

1. U.S. Department of the Interior, Interagency Wild and Scenic Rivers Study Group - Wild, Scenic, Recreational, or Inventory Rivers

2. State Coastal Resources Office - Coastal Zone Management

3. Federal Aviation Administration - Navigable Airspace Hazards

4. U.S. Forest Service, Bureau of Land Management, National Park Service or U.S. Fish and Wildlife Service (as appropriate)-impacts on Federal lands

5. U.S. Department of Interior - Coastal Barriers

A list of addresses for the agencies which handle environmental matters in your state is enclosed.

Where a proposed project will be located in a wetland or floodplain, the borrower shall also have published a legal notice, along with a news article and/or advertisement, to attract the attention of the general public in a newspaper or newspapers of general circulation in the county in which the proposed construction will take place. The notice should describe the nature, location, and extent of the proposed action and indicate the availability and location of additional information. The notice should invite comments with respect to environmental effects of the proposed construction, to be submitted to the borrower within thirty (30) days of publication of the notice. Copies of all comments received from the public should be attached to the completed BER as well as the borrower's position on those comments related to environmental impacts. A sample legal notice is enclosed.

The following information and commitments should be included in the BER:

A. The scope of the project. Present a brief narrative statement describing the proposed project, including a description of the construction process. Sufficient detail should be included to allow a reviewer to adequately understand the nature of the project. Figures, maps (especially U.S. Geological Survey) and pictures may be helpful.

B. A discussion of the need for the project.

C. Alternatives to the proposed project. All reasonable alternatives should be discussed, including but not limited to: (a) no action, (b) alternative routes, (c) other methods to provide service, (d) alternative construction methods and materials.

D. A description of the existing environment. This section should include a narrative description of the existing environment that may be affected by the proposed project.

E. A discussion of the environmental impacts of the proposed project. Both general environmental impacts and sensitive environmental factors that may be affected by the project should be discussed.

F. A description of usual or sensitive environmental issues within the contemplated project area which would warrant special consideration by REA. Such factors include, but are not limited to: wilderness areas, Federal and State managed lands, wetlands, floodplains, threatened and endangered species (including critical habitat), cultural resources (archaeological and historic), Indian reservations, and important farmland.

G. A statement that the applicant will follow and guidance presented in the U.S. Department of the Interior (USDI)/U.S. Department of Agriculture (USDA) Environmental Criteria for Electric Transmission Systems which is applicable to the construction of telephone projects.

H. A commitment from the applicant to consult with the Soil Conservation Service (SCS), Federal or state land management agencies (if such lands will be used in a project), or the appropriate local agency on erosion control and revegetation procedures, and to follow all reasonable recommendations.

It is important to begin contacting all appropriate agencies as soon as possible so that processing of your loan application will not be delayed. Any questions you may have on these matters may be directed to your REA General Field Representative or the REA (Area Office).

SAMPLE LETTER FOR WETLANDS, FLOODPLAINS, WILD AND SCENIC RIVERS, AND IMPORTANT FARMLAND/RANGELAND/FOREST LAND

The (company name) is currently making an application to the Rural Electrification Administration (REA) for a loan to finance certain telephone facilities, including (purposes listed in application). Enclosed is a map identifying the location of our known construction activities.

These projects do not normally require an Environmental Impact Statement or an Environmental Assessment under the REA requirements for compliance with the National Environmental Policy Act. Nevertheless, (company name) is seeking information on possible enviromental effects from these projects, including effects to wetlands, floodplains, wild and scenic rivers, prime farmland, rangeland, forest land, threatened or endangered species, and historic or cultural resources. We request your review of these projects for possible effects on your areas of concern, and any recommendations you have to minimize or avoid these effects.

We would appreciate a response within thirty days to avoid undue delay in construction. If you need further information or wish to discuss our projects, please feel free to call (name) at (Telephone number). Thank you for your cooperation.

Enclosure

SAMPLE LETTER FOR THE STATE HISTORIC PRESERVATION OFFICER
(for a Construction Plan)

(ABC Cooperative) is in the process of preparing a financing assistance application to the Rural Electrification Administration (REA), for the installation and improvement of telephone facilities in (X, Y and Z) Counties, Michigan. The planned facilities are needed during the next five years to provide initial service to new subscribers and maintain adequate service to our present subscribers. A map showing the proposed location and general area of the construction and a concise description of the work is attached.

(ABC Cooperative) would appreciate receiving a list of any properties and their locations which are eligible for or have been proposed for inclusion in the National Register of Historic Places, or any other areas of specific cultural concern that may be affected by the proposed construction or modifications.

To assist REA in its compliance with Advisory Council on Historic Preservation regulations (36 CFR 800), we request your views on effects of the planned activities on significant cultural resources. Should your office believe that further studies or mitigation is warrented, please describe the basis for your recommendations.

We would appreciate a response from your office within thirty (30) days to avoid undue delay in the proposed project. If there are any questions or need for additional information, please contact (name) at (telephone number).

SAMPLE LETTER TO ENDANGERED SPECIES OFFICE,
U.S. FISH & WILDLIFE SERVICE

The (company name) is currently making an application to the Rural Electrification Administration (REA) for a loan to finance certain telephone facilities, including (purposes listed in application). Enclosed is a map identifying the location of our known construction activities.

The proposed projects do not represent "construction" projects as defined in the proposed USFWS regulations implementing the Endangered Species Act. Since most of the projects will be (underground cable) (constructed along public road right-of-way), we do not anticipate that there will be any affects to threatened or endangered species or other general wildlife concerns.

We would appreciate a response within thirty (30) days to avoid undue delay in construction. If you need further information or wish to discuss our projects, please feel free to call (name) at (telephone number). Thank you for your cooperation.

Enclosure

SAMPLE ANNOUNCEMENT FOR CATEGORICALLY EXCLUDED ACTIVITIES LOCATED IN A FLOODPLAIN AND/OR WETLANDS (LEGAL NOTICE AND ADVERTISEMENT REQUIRED)

The (name and address of REA borrower) announces that it is making an application for a (loan) or (loan guarantee) from the Rural Electrification Administration which will provide for the construction and upgrading of approximately____kilometers (______ miles) of telephone lines and service drops within its service area of ______________________________ Counties, construction of a new building near _______________ in _____________County, and construction of a maintenance warehouse and yard near_________ in_________ County.

The proposed telephone lines will cross approximately ______ kilometers (__________miles) of 100-year floodplain and _____ kilometers (______ miles) of wetlands. These floodplain and wetland areas are located adjacent to the __________River near__________ in ______________County. In addition, the new building in __________ County will occupy approximately _____hectares (_________ acres) within a 100-year floodplain.

The (name of REA borrower) has considered a variety of alternatives, including no action, and believes that there is no practicable alternative that will avoid location of facilities in the floodplain and wetland areas. Where a facility will be located in a floodplain or wetland area, (name of REA borrower) has tried to select those practicable alternatives that avoid or minimize adverse effects and incompatible development. (At the REA borrower's discretion, these may be briefly described (e.g., underground cable.)

Additional information on the proposed construction may be obtained from (point of contact) of (name of REA borrower) at the address given above or by telephoning (telephone number).

Comments on the environmental aspects of the proposed construction should be submitted in writing to (name of REA borrower) at the above address within thirty (30) days of the publication of this notice. A copy of all comments received will be sent to the Rural Electrification Administration for its independent evaluation.

CHECK LIST FOR REVIEWING BORROWER'S ENVIRONMENTAL REPORTS (BER)

Date ______ Adequacy ______

BER

______ ______ . Project description

______ . Justification of project need

______ . All reasonable alternatives considered

______ . Discussion of environmental impacts

Commitment to follow guidelines in USDI/USDA

______ ______ ."Environmental Criteria for Electric Transmission Systems", which are applicable to the Construction of Telephone Projects

Maps

______ . USGS 7 1/2 or 15 minute maps showing corridors, sites and alternatives or detailed county maps.

Others as needed includes:

______ . Prime farmland, rangeland or forestland, usually from the Soil Conservation Service.

______ . Wetlands, as defined by the Wetlands Office of the U.S. Fish and Wildlife Service (some mapping information may be available on USGS maps.)

______ . Floodplains, usually from the Corps of Engineers or the Federal Emergency Management Agency of Housing and Urban Development.

______ . Critical habitats, from the Endangered Species Office of the U.S. Fish and Wildlife Service.

______ . Cultural resources, from the State Historic Preservation Officer and the National Register of Historic Places.

______ . Federal and State lands, parks, wildlife management areas, and refuges.

Legal Notice:

______ ______ . Legal notice and either news article of advertisement if project will impact either wetlands or floodplains. Amounts and location of impacts must be identified in legal notice and either article or advertisement.

______ ______ . Response letters received if any.

AGENCY CONTACTS AND SENSITIVE ISSUES FOR BER

Date | Adequacy

State Conservation (U.S. Soil Conservation Service)

______ . Important farmland, forestland and prime rangeland impacts

______ . Commitment to consult SCS regarding erosion control revegetation, etc.

______ ______ . Letter from SCS giving clearance or comments

U.S. Army Corps of Engineering (COE)

______ . Floodplains impacts, if any

______ ______ . River crossing and dredging permits, if applicable

______ ______ . Letter from COE giving clearance or comments

U.S. Fish and Wildlife Service (FWS) (and/or National Marine Fisheries Service (NMFS), if applicable)

______ ______ . Response letter from Endangered Species Office of U.S. Fish and Wildlife Service on possible impacts to threatened or endangered species.

______ ______ . Response letter from FWS on wetlands impacted (if applicable)

State Historic Preservation Officer (SHPO)

______ ______ . Response letter from State Historic Preservation Office (SHPO) on possible impacts to known or eligible National Register Properties.

______ ______ . Commitment to halt construction and contact REA and the SHPO if cultural resources are discovered during construction.

State Department of Natural Resources DNR or equivalent

______ . Consistency with land use plans, impacts on natural resources, etc.

______ ______ . Comment letter from DNR

Federal or State land manager (e.g., U.S. Forest Service, Bureau of Land Management, etc.) if such lands are crossed

______ . Impacts on designated Federal lands.

______ ______ . Response letters from Agencies if Federal lands are crossed.

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