# Capacity Enhancement In WCDMA Cellular Network

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## Abstract

**The third generation (3G) cellular system offers high data rate services compared with 1G and 2G systems, for good services and increased number of users, therefore for an operator, it is most important to utilize all possible resources to improve the network capacity and quality of service (QOS).**

**The aim of this paper is to investigate using simulation, the impact of sectorisation, antenna beam width and antenna tilting on capacity. The area of study is a cellular network in urban area with 13*13 Km containing 19 sites, four different sectors used are 1sector,3sectors,4sectors and 6sectors, five different antennas are used in the simulations with $3_{dB}$ beam width of $120^o$,$90^o$,$65^o$ and $33^o$ and also an Omni-directional antenna, two types of tilting considered are mechanical and electrical tilt, the result obtained show that the capacity depends on many parameters (load, interference, service type, sectors number, antenna tilt) and can be increased in the proper choice of these parameters.**

**Keywords: Cellular system, Cell sectorisation, Antenna tilt, Capacity.**

# تحسين ألسعة في ألشبكة الخلوية نوع WCDMA

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## ألملخص

الجيل الثالث للنظام الخلوي يقدم خدمة بيانات عالية بالمقارنة مع الأنظمة السابقة,للحصول على خدمات جيدة ولزيادة عدد المستخدمين لذلك فأن إدارة الشبكة تستعمل كل الإمكانيات المتاحة لتحسين السعة ونوعية الخدمة للشبكة.

الهدف من البحث تحقيق استخدام أمثل للشبكة بالمحاكاة من ناحية, تأثير التقطيع,عرض شعاع الهوائي وتوجيه الهوائي على السعة.تم دراسة شبكة خلوية في مركز مدينة بمساحة 13*13 كم تحتوي على 19 موقع, تم استخدام خمسة أنواع من الهوائيات في المحاكاة بعرض شعاع $120^o$,$90^o$,$65^o$,$33^o$ بالإضافة إلى هوائي غير اتجاهي (Omni-directional antenna), استخدم أربعة أنواع من التقطيع مقطع واحد ,3 مقاطع, 4 مقاطع و6 مقاطع, تم تطبيق نوعين من توجيه ألهوائي ألتوجيه الميكانيكي و الكهربائي, أن النتائج المحصل عليها تبين أن السعة تعتمد على عدة متغيرات ( الحمل, نوعية الخدمة, عدد المقاطع, توجيه الهوائي ) يمكن تحسين السعة في هذا البحث بالاختيار الأمثل لهذه المتغيرات.

**Received: 13 – 12 - 2010** **Accepted: 8 – 5 - 2011**

## 1- Introduction :

In wide band code division multiple access (WCDMA) cellular system the capacity is strongly effect by interference, so reducing the interference leads to improve capacity. Hence, interference level should be kept to minimum as possible at all times to avoid network congestions. The level of interference can be controlled in many ways using cell sectoring, correct base station antenna configurations and antenna tilt.

## 2- Factors Influencing the Capacity of WCDMA System:

- Sectorisation

The capacity in WCDMA system can be improved using cell sectorisation, since sectorisation cell can reduces the interference. Which leads to increase the capacity, the capacity in a cellular system with sectorisation is increased by a factor equal to the number of sectors because the interference is effectively reduced by the same factor. Thus, if Ns is the number of users per sector, than cell capacity (number of users per cell),N, is [1] :

$$N = \Delta \cdot N_S \qquad \ldots(1)$$

Where Δ is the number of sectors per cell. In the cell of three sectors Δ is equal to three ($120^o$ sectoring) the number of interference (co channel interference) sources seen by an antenna is decreased by third compared Omni-directional antenna.

For imperfect sectorisation, the overlap angle Є is introduced as shown in Figure (1), than capacity with imperfect sectorisation ($N_{imp}$) is given by [1] :

$$N_{imp} = \frac{360}{(360/\Delta)+2\epsilon} \cdot N_S \qquad \ldots(2)$$

For large overlap angle, interference leaks to the other sectors directly results reducing capacity. The overlaps in the antenna radiation patterns as well as the influence of the propagation environment on the pattern itself make it difficult to control the interference leakage into neighboring sectors [1].

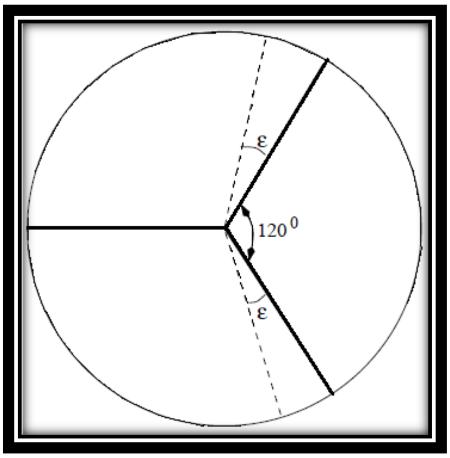

**Figure (1) Sector coverage** with an imperfect radiation pattern of the directional antenna

The sectorisation gain (ξ), can be estimated as the average number of simultaneous of sectorisation users relative to the average number of users of the Omni-site configuration according to Equation (3) [2].

$$\xi = \frac{\text{Number of users of sectored site}}{\text{Number of users of Omni site}} \qquad \ldots(3)$$

- Tilted Antenna

Tilted antenna is another technique that can be used to improve the system capacity. The tilted antenna generally reduces the interference by controlling the range of coverage over a sector as shown in Figure (2) [1][3][4].

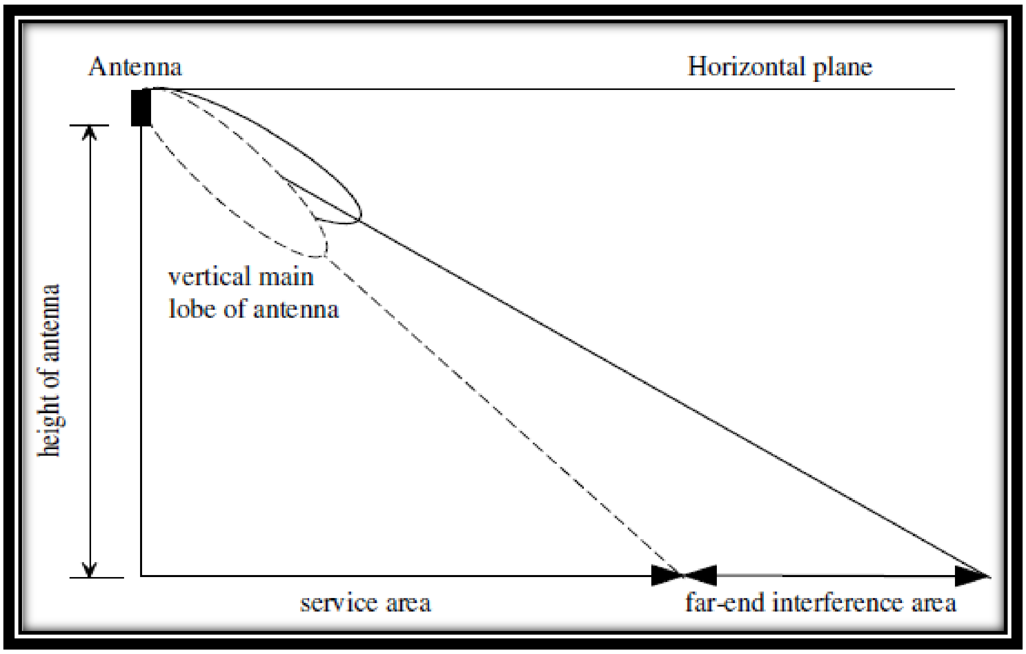


Figure (2) Tilted antenna cell coverage

There are two types of tilting electrical and mechanical tilt. Comparison of mechanical and electrical tilt is as shown in Figure (3). Mechanical down tilt (MDT) refers to setting the down tilt angle by adjusting the antenna support to let the antenna down to a certain position.

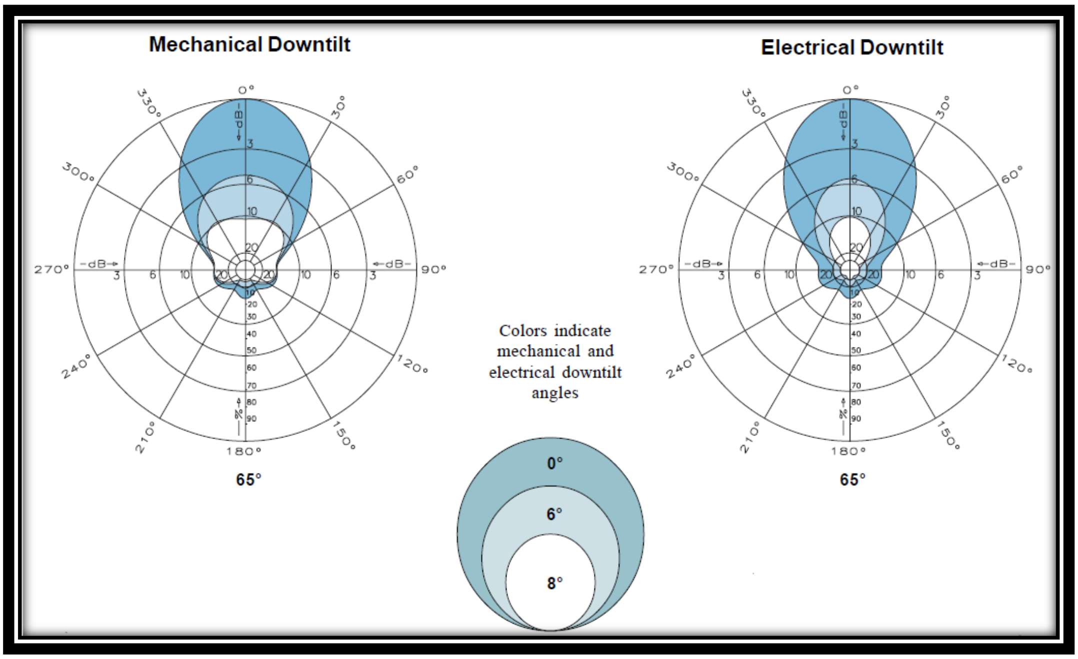


Figure (3) Mechanical and Electrical down tilt

Electricity down tilt (EDT) refers to controlling the down tilt angle by changing the phase of the dipole. Electrically controlled down tilt and the mechanical down tilt have different influence on the back lobe. Electrically controlled down tilt allows further control of the influence on the back lobe, while mechanical down tilt enlarges the influence on the back lobe, as shown in Figure (4) If the mechanical down tilt angle is very large, the emission signals of the antenna will propagate to high buildings in backward direction through the back lobe, thus resulting in additional interference.

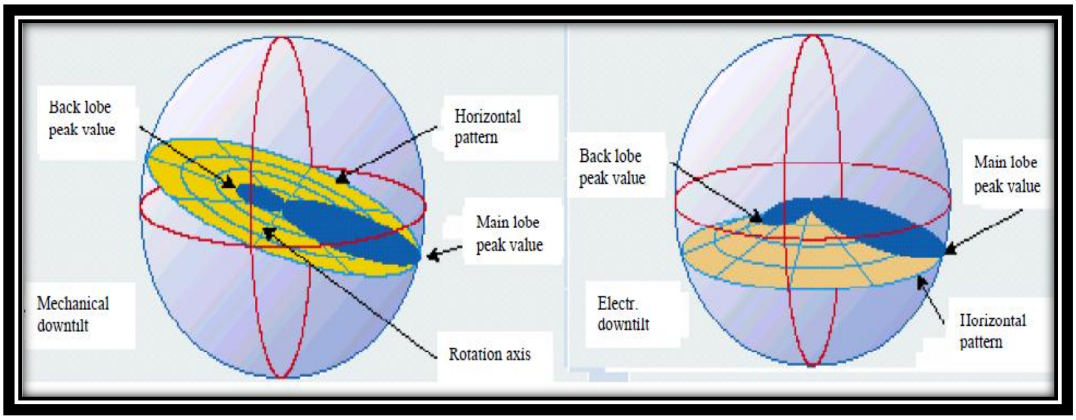


Figure (4) MDT and EDT influence on the back lobe

- Uplink and Down link load factor

In WCDMA system all users use single frequency in the cell for different code, the system interference and capacity can be estimated using the uplink load factor (ηUL). The uplink load factor (include the effect of sectorisation) can be shown as [2][5] :

$$\eta UL = \frac{1}{1+\frac{W}{(Eb/No)\cdot R}} \cdot N \cdot \upsilon \left(1 + i \cdot \frac{Ns}{\xi}\right) \quad \ldots(4)$$

Where $R$ is the bit rate, $W$ is the chip rate, $N$ is the number of served user, $\upsilon$ is the activity factor, $E_b/N_o$ is the signal energy per bit divided by noise spectral density, $i$ is the other to own cell interference ratio, $Ns$ is the number of sectors, $\xi$ is the sectorisation gain.

The downlink load factor (ηDL), can be defined based on a similar principle as for the uplink, although the parameters are slightly different as shown in Equation (5) [5].

$$\eta DL = \sum_{j=1}^{N} \upsilon j \frac{\left(\frac{Eb}{No}\right)j}{W/Rj} \cdot [(1-\alpha j)+ij] \quad \ldots(5)$$

Where N is the number of user per cell, vj is the activity factor of user j, Rj is the bit rate of user j, αj is the orthogonality factor of user j in the downlink, $(\frac{Eb}{No})j$ is the signal energy per bit divided by noise spectral density of user j, ij is the other to own cell interference ratio received by user j.

## 3-Simulator description :

The simulation consists of four parts: initialization, uplink iteration, downlink iteration and post processing of the analysis results [6][7].

- Initialization

The main task of the initialization is to calculate the link loss from each base station to each pixels (1048*1084) in the area considered.

- Uplink iterations

In the uplink iteration process, the target is allocated the minimum transmit power to each base station (BS) for the specific $E_b/N_o$ requirements. When the transmit powers of the mobiles stations to each base station are estimated the best server is determined as the base station, to which the mobile station (MS) has to transmit with minimum power. The minimum transmit powers are then compared to the maximum allowed transmit power of a mobile and terminals exceeding this limit are excluded during this iteration step. If this happens a specified number of iterations in a row, the MS is finally put to outage. After the transmit powers of all mobile stations have been allocated, the interference at each BS can be re-estimated and new loading value and sensitivity is estimated. The impact of the loading on the sensitivity is taken into account by adjusting it with (1-η). Now the mobile station can be re-allocated to a new base station, the mobile station transmit powers are re-estimated and the interference analysis is performed again. This is repeated until the changes in the BS sensitivity values are smaller than specified.

- Downlink iterations

In the downlink iteration the BS transmit powers for each link including power control for all mobile stations receive their signal of BS with the required carrier-to-interference-ratio C/I, defined by Equation (6) [6].

$$\text{Target C/I} = \frac{Eb/No}{W/R} \qquad \ldots(6)$$

Where $E_b/N_o$ is the received requirement of the MS depending on speed and service, W is the chip rate and R is the data rate.

The actual received $(C/I)_m$ of $MS_m$ is calculated using maximum ratio combining (MRC) algorithm according to Equation (7) by summing the C/I values of all links k (k=1…K), $MS_m$ is having [8] :

$$(C/I)_m = \sum_{k=1}^{K} \frac{P_{km}/L_{km}}{(1-\alpha)\cdot\frac{P_k}{L_{km}} + I_{oth,k} + N_m} \qquad \ldots(7)$$

Where α is the orthogonality factor, $P_k$ is the total transmit power of the BS to which link k is established, $L_{km}$ is the path loss from cell k to the $MS_m$, $P_{km}$ is the power allocated from $BS_k$ to $MS_m$, $I_{oth,k}$ is the other cell interference and $N_m$ is the background and receiver noise of the $MS_m$.

The initial transmit powers are adjusted iteratively according to the difference between the achieved and the targeted C/I is achieved.

- Post processing

In the post-processing phase basically all outputs are generated.

## 4- simulation parameters :

Table (1) Parameters used in simulations

| | |
|---|---|
| Chip rate (W) | 3.84Mchips/s |
| Base station maximum transmit power | 43dBm |
| Mobile station maximum transmit power | 21dBm |
| Thermal noise density | -174dBm |
| MS/BS Noise figure | 8/5 dB |
| Path loss model | Okumura-Hata |
| Standard deviations for shadow fading | 7dB |
| P-CPICH | 30dBm |
| Orthogonally factor | 0.5 |
| Base station antenna height | 35m |
| Mobile station antenna height | 1.5m |
| Cable losses | 3dB |

## 5- Network scenarios:

- The scenarios consisting of 19 sites in 169 Km$^2$area, there are four types of sectors (1,3,4 and 6 sectors) and antenna beam width (33$^o$,65$^o$,90$^o$,120$^o$) are used. The site distribution with different sectors is depicted in figures (5-8).

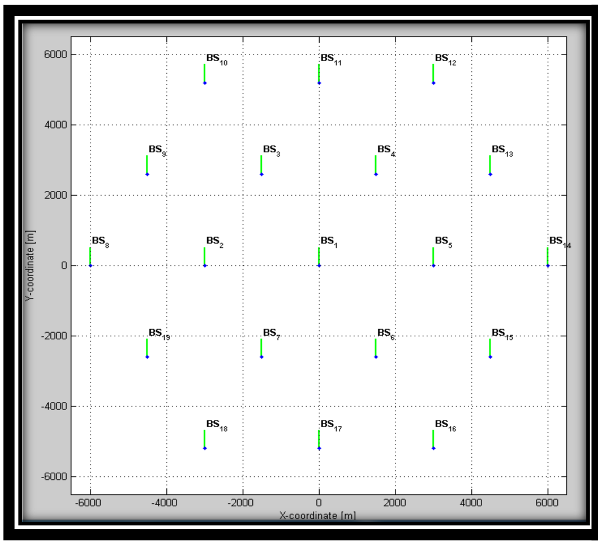


Figure (5) 19 sites with one secto

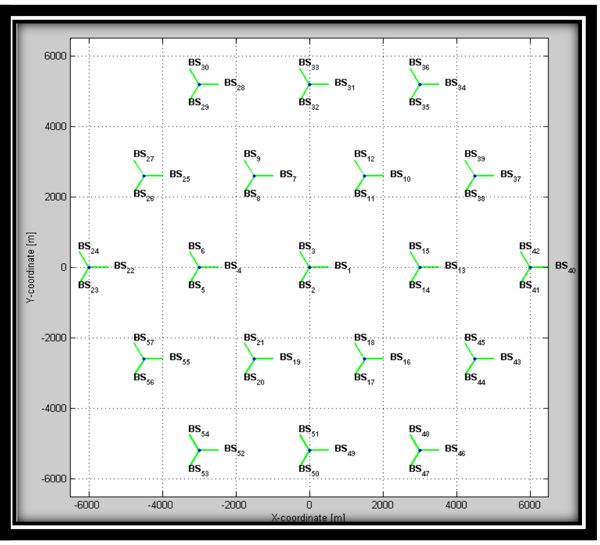


Figure (6) 19 sites with three sectors

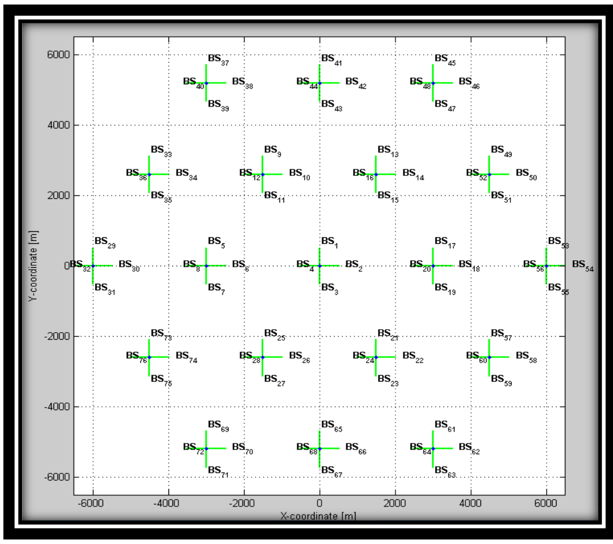


Figure (7) 19 sites with four sectors

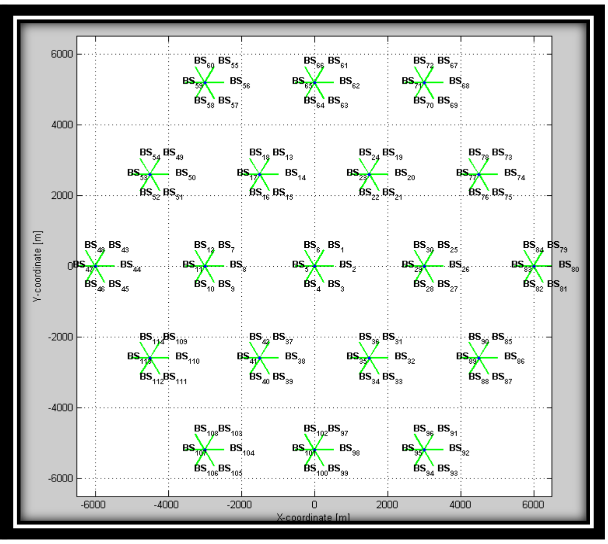


Figure (8) 19 sites with six sectors

- The users distribution is assumed to be uniform with a typical 1.5m antenna height with different bit rate of transmitted data as shown in figures (9) and (10).

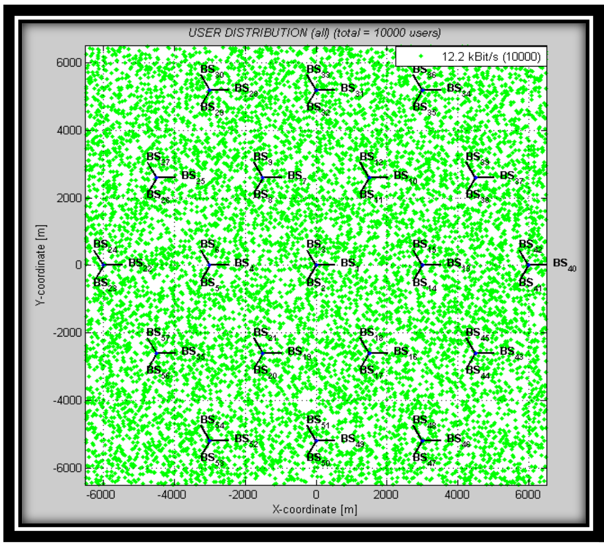


Figure (9) 12.2kbps users initial distributions with three sectors network

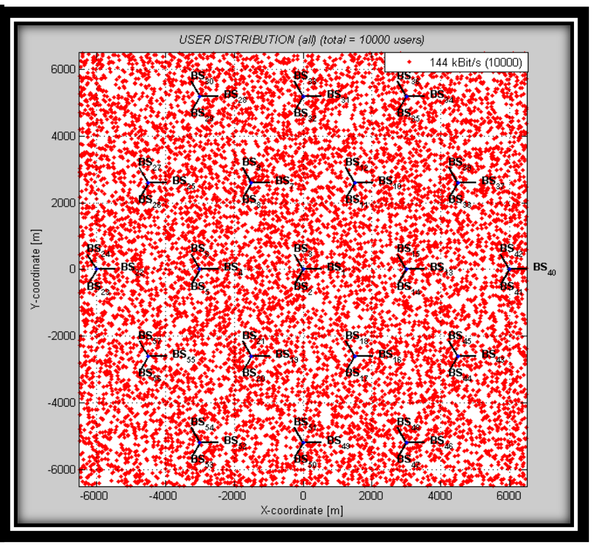


Figure (10) 144kbps users initial distributions with three sectors network

## 6-Simulation and Results:

In this section, simulation program were developed using matlab (Release 2010a). Figures (11,12) show the number of sectors versus the capacity for different bit rates (12.2kbps,144kbps), as shown in the figures, increasing the cell sectors leads to increased capacity due to reducing the interference using directional antennas, while the number of users is decreased when using high data rate (144kbps) because the power consumed in downlink direction is higher

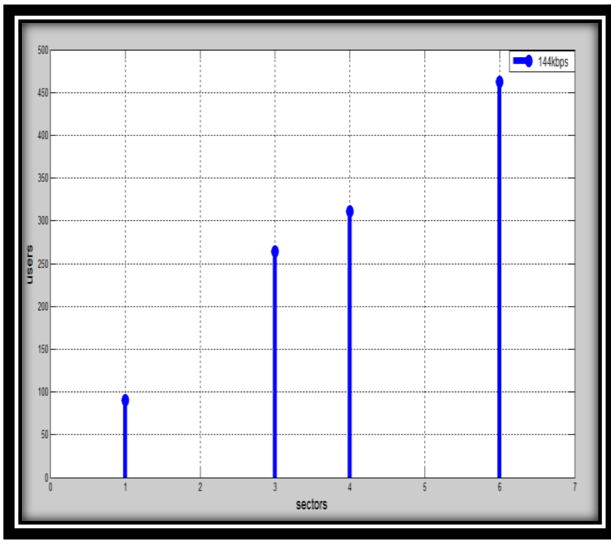


Figure (11) Different sectorisation with users used 12.2kbps

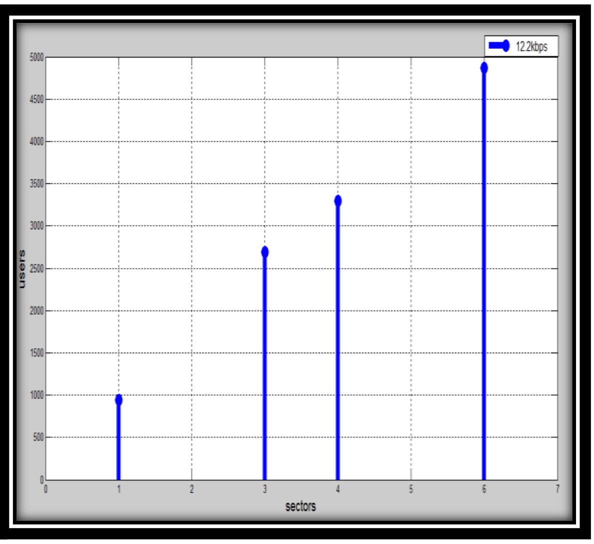


Figure (12) Different sectorisation with users used 144kbps

Figure (13) illustrates the number of sectors (with different antenna beamwidth) versus the sectorisation gain.

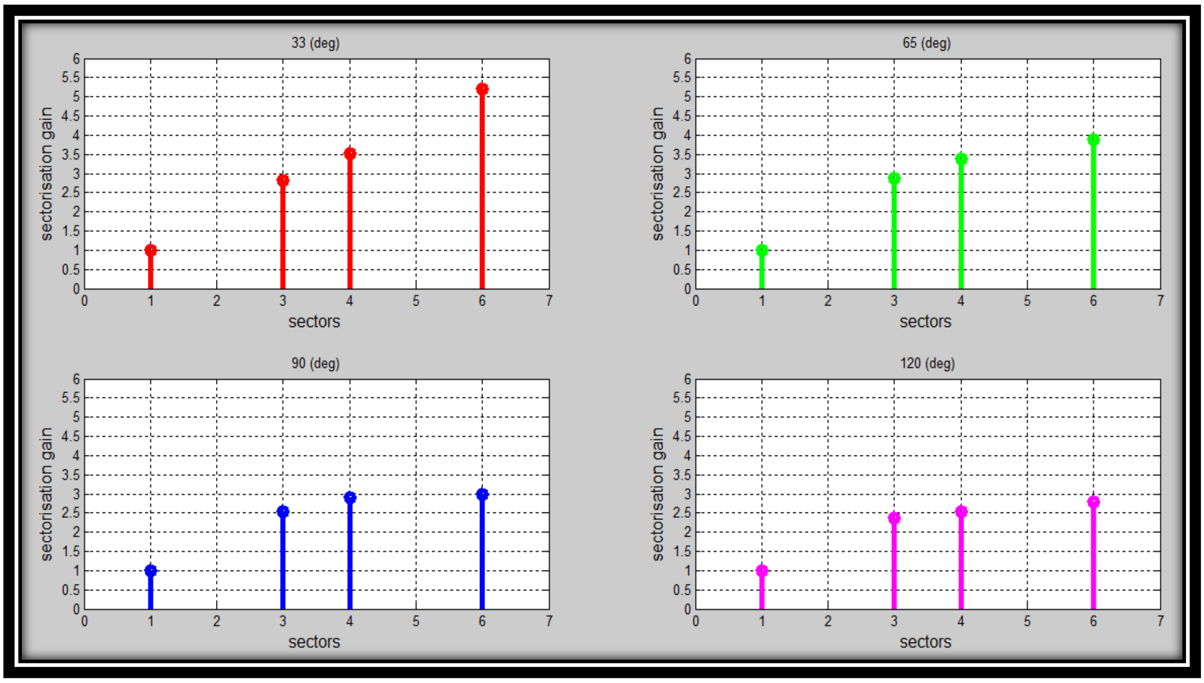


Figure (13) Sectorisation gain for different antenna beamwidth

Figure (14) illustrates the antenna beamwidth (for different Sectorisation) versus interference, while Figure (15) illustrates antenna beam versus number of users. In the simulations, the 65$^o$ antenna is optimum for the three sectors case and the 33$^o$ antenna is best for the four and six sectors scenario.

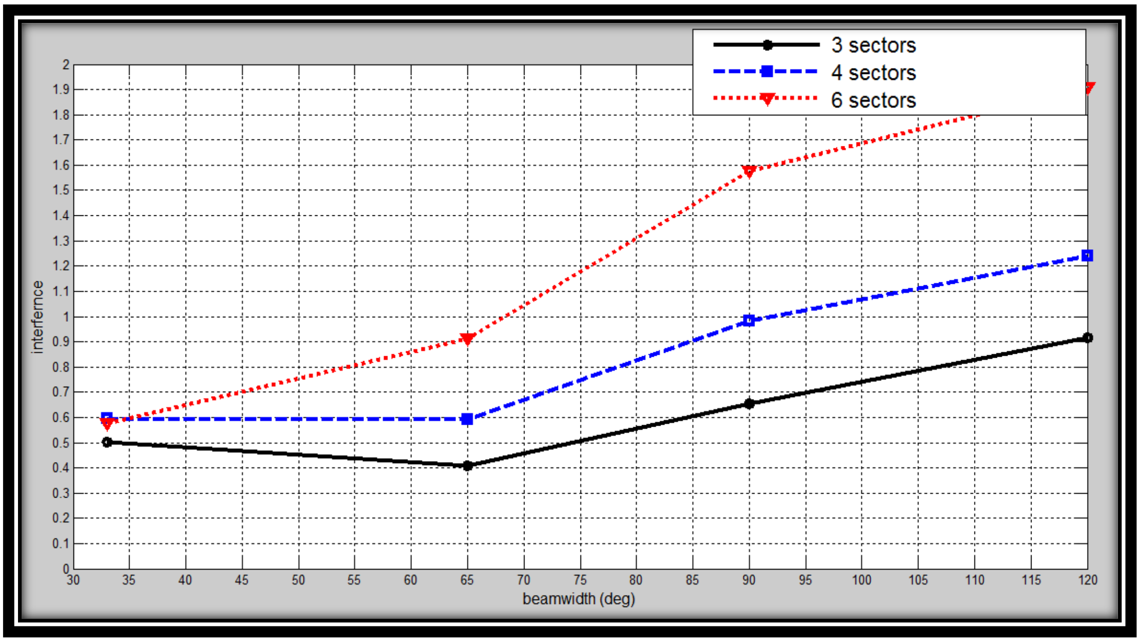


Figure (14) Impact of the antenna beamwidth on interference

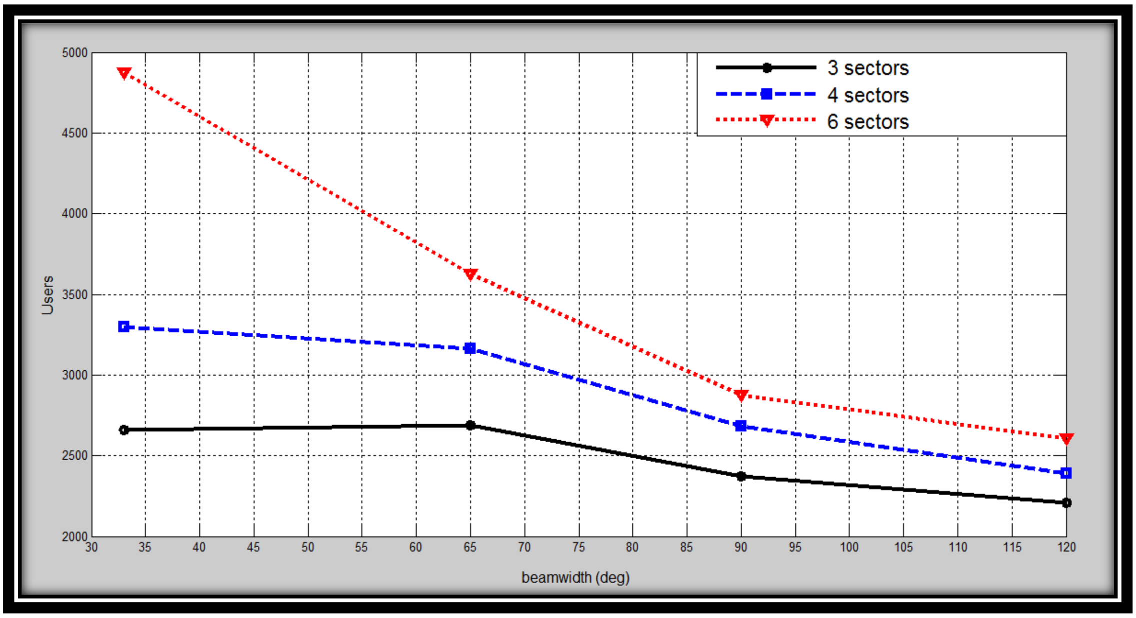


Figure (15) Impact of the antenna beamwidth on the capacity

The results related to the sectorisation study are shown in Table (2). In the case of Omni directional sites, the capacity is very poor and only 937 users could be served. Table (2) cleary indicates that with higher sectorisation, the more users can be served. Simultaneously the amount of interference leaking into neighboring cells increases, but with proper choice of the antenna beamwidth also these effect can be controlled to acceptable level (0.4092 is the optimum value for three sectors, then three sectors is good choice for this network). Also form Table (2) it can be noticed that for each sectorisation case the selection of the antenna beamwidth is important. The amount of users per site however is increasing but not linearly with the number of sectors, because of overlaps in the sectors leaking interference from one sector to another.

Table (2) The impact of the antenna selection on capacity and interference

| Antenna Types | Served users | Interference ( I other/I own) |
|---|---|---|
| Omni-case | 937 | 0.5900 |
| Three sectors case | | |
| $33^o$ | 2660 | 0.5019 |
| $65^o$ | 2689 | 0.4092 |
| $90^o$ | 2372 | 0.6528 |
| $120^o$ | 2209 | 0.9167 |
| Four sectors case | | |
| $33^o$ | 3300 | 0.5895 |
| $65^o$ | 3164 | 0.5948 |
| $90^o$ | 2683 | 0.9814 |
| $120^o$ | 2387 | 1.2415 |
| Six sectors case | | |
| $33^o$ | 4873 | 0.5766 |
| $65^o$ | 3626 | 0.9138 |
| $90^o$ | 2878 | 1.5763 |
| $120^o$ | 2604 | 1.9073 |

Figure (16) illustrates the antenna tilt (MDT and EDT) versus interference for three sectors, the down tilt angle increases for both the MDT and the EDT since interference decrease due to the overlap between adjacent sites is decreased.

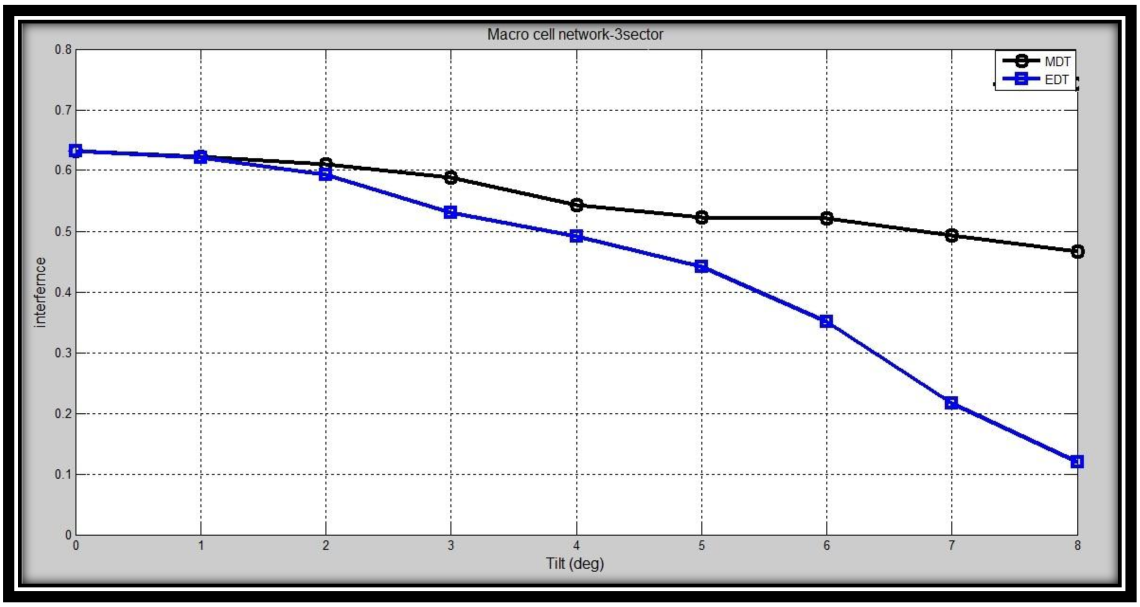


Figure (16) Impact of antenna tilt on interference-3sector network

Figure (17) illustrates the antenna tilt (MDT and EDT) versus interference for six sectors, as shown in figure the EDT decrease the interference more than MDT because MDT may deform the pattern (see Figure 3).

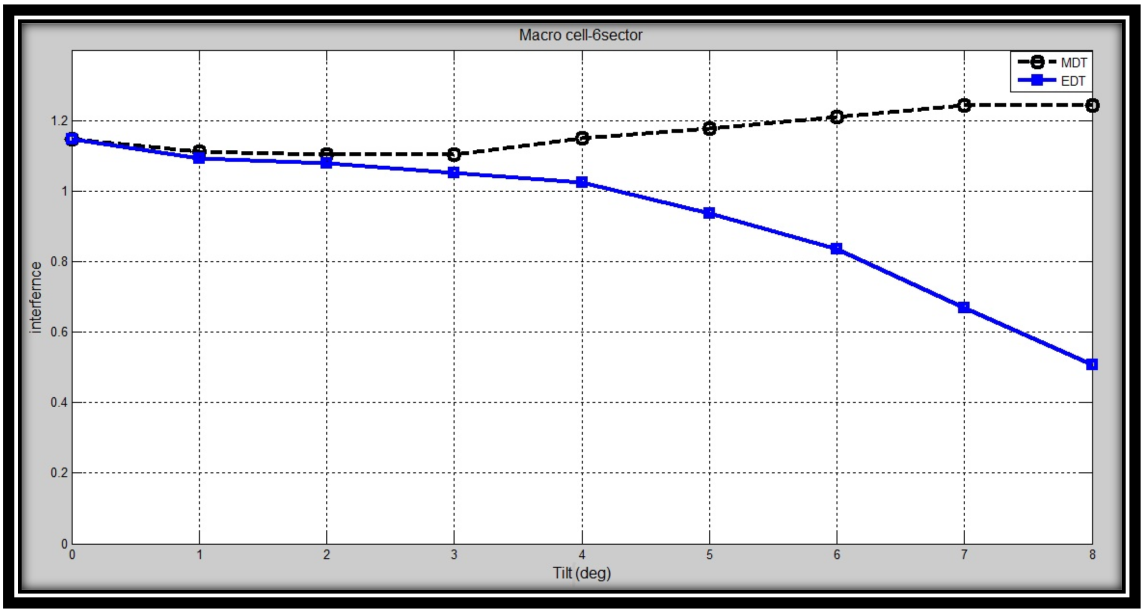


Figure (17) Impact of antenna tilt on interference-6sector network

Figure (18) illustrates the antenna tilt (MDT and EDT) versus capacity, as shown in the figure, the EDT improves capacity more than MDT, because the larger angle leads to more deformation in the radiation pattern, hence it is difficult to control the interference.

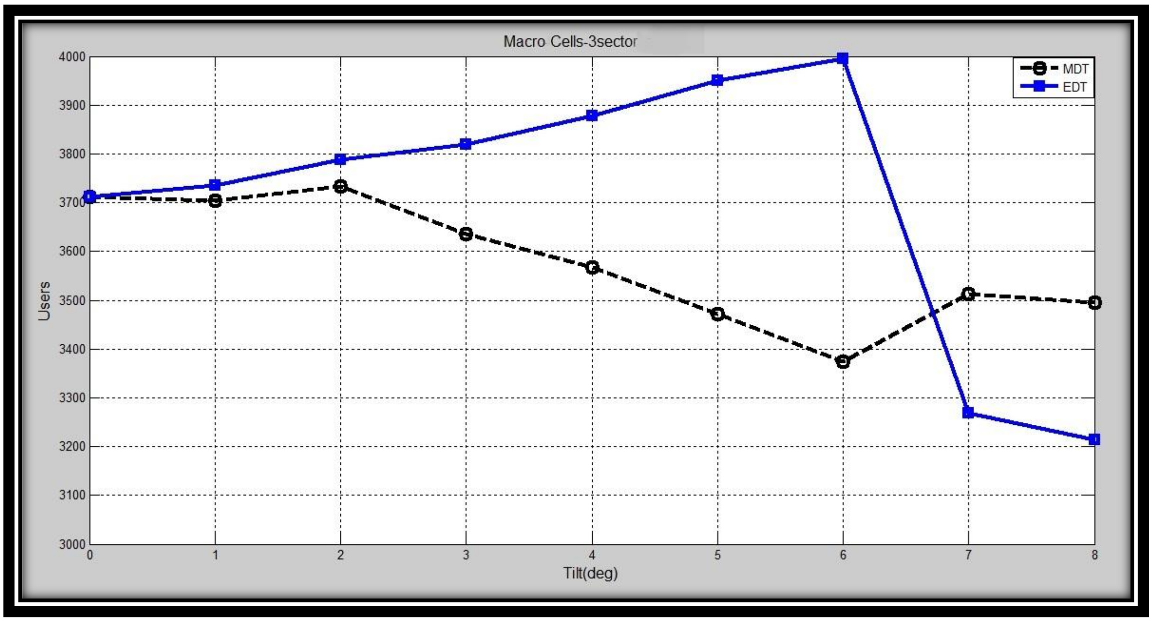


Figure (18) Impact antenna tilt on capacity

## 7- Conclusions :

From the results obtained the following conclusions can be drawn:

- The higher the cell sectorisation offers the more the capacity to the network, but to achieve this the antenna selection is very crucial to effectively control the interference.

- For each sectorisation case an optimum beamwidth exists.
- Increasing the cell sector/site leads to increasing number of handoff (soft/softer), thus increasing the load on the switching and control link elements of the mobile system, so balance between load and capacity is required.
- The capacity gains with simulated network topology for MDT from 3700 users to 3730 users, when EDT capacity gain from 3700 users to 4000 users.
- The EDT controls the interference occurring between the adjacent main lobes, side lobes and back lobes, while in MDT the control of the main adjacent lobes is less effect that the EDT.
- For optimum planning to WCDMA network the choice three sectors with $65^o$ antenna beamwidth and $6^o$ EDT.

## References :

[1] T.V. Nguyen," Capacity Improvement Using Adaptive Sectorisation in WCDMA Cellular Systems with Non-Uniform and Packet Mode Traffic" , PhD. Thesis ,Victoria University, Melbourne, Australia, March. 2005.

[2] J.Laiho and A.Wacker," Radio Network Planning and Optimization for UMTS", 2nd edition John Wiley & Sons Ltd, 2006.

[3] T.Isotalo,J Niemela and J.Lempiainen, "Electrical Antenna Down Tilt in UMTS Network", institute of communication engineering, Tampere university of technology, Finland,2005.

[4] "Comparison of Mechanical and Electrical Down tilt", Available on web site, www.kathrein-scala.com/tech_bulletins/MEdowntilt.pdf

[5] H.Holma and A.Toskala "WCDMA FOR UMTS HSPA Evolution and LTE ",5th edition John Wiley and Sons Ltd, 2010.

[6] A. Wacker, et al., "NPSW Matlab implementation of static radio network planning tool for WCDMA", Documentation; Version 5.0.0, 2005.

[7] A. Wacker, et al., “NPSW Matlab implementation of static radio network planning tool for WCDMA”, Code; Version 5.0.0, 2005.

[8] A.Wacker , Kari Sipila and Antti Kuurne, " Automated and Remotely Optimization of Antenna SubsysteAm based on Radio Network Performance " , proc of IEEE,2002. PP. 752-756.

The work was carried out at the college of Engineering. University of Mosul