DESIGN OF MICROSTRIP LOOP ANTENNA WITH BROADBAND AND MULTIBAND OPERATION FOR WIRELESS COMMUNICATION

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This Thesis was Submitted in Partial Fulfillment of the Requirements for the Master's Degree of Electrical Engineering /communication engineering

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August, 2009

COMMITTEE DECISION

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ACKNOWLEDGEMENT

In the name of ALLAH, the most Gracious, the Most Merciful for giving me the determination and will to complete this study.

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I deeply appreciate the inspirations and guideline that I have received from my supervisor Prof. Mohammad Kamel Abdelazeez for his advice, guidance, support, and encouragement.

I would like to take this opportunity to thank everyone who has contributed either directly or indirectly throughout this thesis.

I would like to thank my colleagues, friends, and lecturers in the Faculty of Electrical Engineering for their help, facilities and for providing conductive working environment.

Finally, I would also like to thank all of my family for their moral support on me, my parents, my brothers and my sisters who give me a real love, prayer and support.

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List of Abbreviations

ABS	Acrylonitrile Butadiene Styrene
DCS	Digital Communication System
DVB-H	Digital Video Broadcasting -Handheld
FEM	Finite Element Method
FR4	Flame Retardant 4
GPS	Global Positioning System
GSM	Global System for Mobile communications
HFSS	High Frequency Simulation Structure
IEEE	Institute of Electrical and Electronics Engineers
MOM	Method of moments
MMICs	Microwave Monolithic Integrated Circuits
OEICs	Optoelectronic Integrated Circuits
PCS	Personal Communication System
PDA	Personal Digital Assistant
PIFA	Planar Inverted-F Antenna
SMA	Sub Miniature version A
UMTS	Universal Mobile Telecommunications System
VSWR	Voltage Standing Wave Ratio
WiBro	Wireless Broadband
Wimax	Worldwide interoperability for microwave access
WLAN	Wireless Local Area Network

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ABSTRACT

In this thesis, microstrip printed loop antenna with area of 10×60 mm^2 capable of generating four resonant modes to form two wide bands centered at about 900 and 2165 MHz to cover all eight operating bands consisting of GSM850/900 and DCS/PCS/UMTS/WiBro/Bluetooth/Wimax operations, respectively is presented. The antenna comprises a loop pattern printed on a thin FR4 substrate of small size and a perpendicular feeding portion printed on the narrow top ungrounded region of the system circuit board. The proposed antenna is suitable to operate as an internal antenna because the antenna occupies a small volume inside the mobile phone housing. This thesis presents detailed design, parametric study and simulation results of the proposed antenna. In particular, the study will focus on the antenna return loss, gain, antenna efficiency, excited surface current density, and radiation pattern characteristics of the antenna. To achieve this, an antenna design software package, called High Frequency Simulation Structure (HFSS) has been selected to simulate the proposed antenna. It also gives a quick review to the topic of microstrip antennas and their characteristics, feeding techniques, and literature review for compact and broadband microstrip antenna.

Chapter One

Introduction

The progress of wireless communications equipment including mobile phones is ever accelerating toward implementation of the ubiquitous society, placing more importance to the antenna technologies day by day. As handsets improve in compactness and functions in recent years, the antennas for these equipments have come under the spotlight, transforming their longstanding impression of “an accessory for wireless communications equipment” into a key device for wireless communication. Naturally, mobile phone handsets are strongly required to be small in size, but small size is not the only prerequisite. They are required to have not only essential characteristics for antennas such as bandwidth and efficiency, but also the suitability for the environment of use specific to mobile phones. A wide variety of antennas have been used on handsets, but they can be split into the following categories:

*Monopole antenna (whip type)***:** It is shown in Fig.1.1which is the probably the most widely recognized antennas used for handheld applications and they are often used because of their classic Omni directional radiation characteristics (Ateef Z.Elsherbeni, et al., 2002).

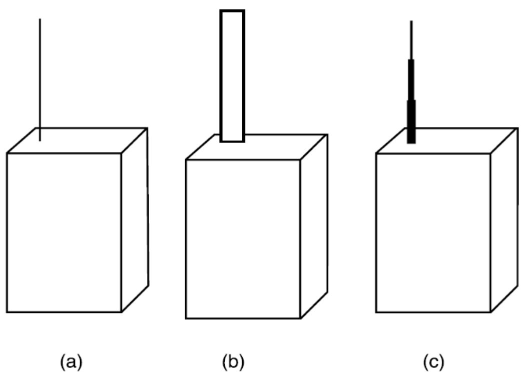


Figure1.1 Monopole antennas on top of a handset (a) Wire monopole, (b) strip monopole, (c) retractable monopole.

Loop antenna: It is shown in Fig.1.2which provides omni directional type of patterns and can be integrated into the wireless handsets having a reasonably low-profile construction. As frequencies increase, the size of the required loop becomes larger relative to wavelength, and the loop can be matched much easier than the electrically small loop at lower frequencies. Although the loop has been used primarily with pagers, this higher frequency usage trend could lead to applications on high frequency wireless handsets in the future (Ateef Z.Elsherbeni, et al., 2002).

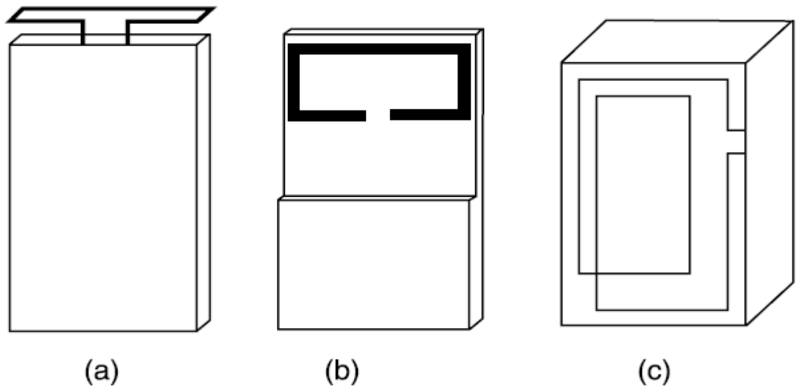


Figure1.2 Loop antennas for wireless systems (a) Top mounted, (b) case or side mounted, (c) multiple loop case mounted

Helical Antennas: It is simple wire wound around a uniform cylinder as shown in Fig. 1.3, with multiple turns like a wire-wound spring. This type of antenna, which is based on the helix used in a traveling wave tube, has an axial mode of radiation and a normal mode of radiation that perpendicular to the axis of the helix. The axial mode helix has been widely used as an end fire directional antenna; however, resonant normal-mode helical antennas are useful as short, vertically polarized radiators, similar to the monopole.

However, the input impedance of the normal-mode helical antennas is sensitive to changes in frequency, which results in narrower bandwidth. Even so, the short normal-mode helix has been widely used in mobile communications systems where a reduced dipole length is needed (Ateef Z.Elsherbeni, et al., 2002) .

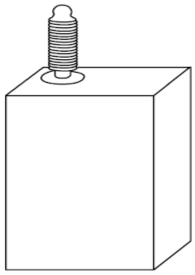


Figure1.3 Helix antenna on top of a handset

Patch Antennas: It is shown in Fig. 1.4, which is based on printed circuit technology to create flat radiating structures on top of dielectric, ground-plane-backed substrates. The appeal of such structures is in allowing compact antennas with low manufacturing cost and high reliability. It is difficult in practice to achieve this at the same time as acceptably high bandwidth and efficiency. Nevertheless, improvements in the properties of the dielectric materials and in design techniques have led to enormous growth in their popularity and there are now a large number of commercial applications. Many shapes of patch are possible, with varying applications, but the most popular are rectangular (pictured), circular and thin strips (i.e. printed dipoles). In the rectangular patch, the length L is typically up to half of the free space wavelength. The incident wave fed into the feed line sets up a strong resonance within the patch, leading to a specific distribution of fields in the region of the dielectric immediately beneath the patch, in which the electric fields are approximately perpendicular to the patch surface and the magnetic fields are parallel to it. The fields around the edges of the patch create the radiation, with contributions from the edges adding as if they constituted a four-element array. The resultant radiation pattern can thus be varied over a wide range by altering the length L and width W (Ateef Z.Elsherbeni, et al., 2002).

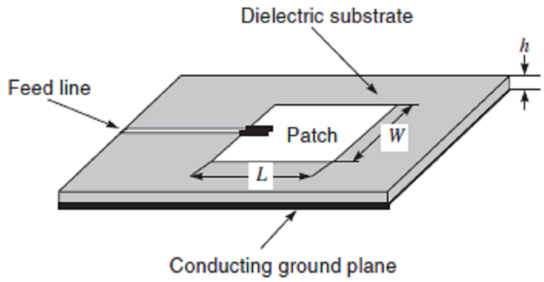


Figure1.4 Microstrip patch antenna.

Planar Inverted-F Antennas (PIFA): The planar inverted–F antenna is popular for portable wireless devices because of its low profile, small size, and built-in structure. The other major advantages are easy fabrication, low manufacturing cost, and simple structure. Also, PIFA's inherent bandwidth is higher than the bandwidth of the conventional patch antenna (since a thick air substrate is used). The basic PIFA (a "grounded" patch antenna λ/4 patch length instead of the conventional λ/2) consists of a ground plane, a top plate element, a feed wire feeding the resonating top plate, and a shorting plate that is connecting the ground and the top plate at one end of the resonating patch (Wong 2002). Fig.1.5 shows the geometry of the quarter PIFA.

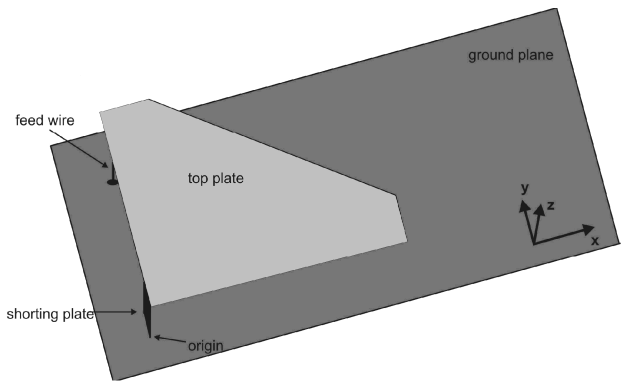


Figure1.5 The top view of PIFA structure

1.1The Challenges of Handset Antenna Design

There are many research in this area attempting to design antennas suitable to use for mobile phone where all the published paper focus on four technological tasks to be overcome at the development of antennas for mobile phone handsets are described below.

Compact size: to efficiently radiate an electromagnetic wave into free space, the size of an antenna should basically be something in the order of the wavelength radiated, which is inversely proportional to the frequency, for example, the wavelength at 900 MHz that is used in the GSM system is 330mm, which is much larger than the size of the handsets currently use. One of the features of modern mobile phones systems is low carrier frequency and broad bandwidth, which makes a major obstacle in the way of antenna development. It is inevitable in general that the radiation characteristics of an antenna degrade as the antenna size reduces or the frequency becomes lower. In particular, compact size and broad bandwidth conflict with each other. Thus, how to downsize an antenna without degrading its bandwidth is the design policy of great interest when designing compact antenna.

Multiband operation: Multi-band wireless phone has become popular recently because they permit people to use the same phone in multi network that have different frequencies. Table 1.1 lists a few useful wireless applications and their operating frequencies. Systems that require multiband operation require antenna that resonate at the specific frequencies. This only adds complexity to the antenna design problem (Hiroyuki Tamako, et al., 2004).

Table 1.1**:** Frequency bands for a few wireless applications

Wireless applications	Frequency bands in MHz
GSM-850	824-894
GSM-900	890-960
GPS	1565-1585
DCS	1710-1880
PCS	1850-1990
UMTS	1920-2170
WiBro	2300-2390
Bluetooth	2400-2483
Wimax	2500-2690

Complete built-in antenna: The sizes and weights of mobile handsets have rapidly been reduced due to the development of modern integrated circuit technology and the requirements of the users. Conventional monopole-like antennas have remained relatively large compared to the handset itself. Thus, built-in antennas are becoming very promising candidates for applications in mobile handset. Most built-in antennas currently used in mobile phones are based on planar inverted-F antennas (PIFAs).Such internal mobile phone antennas usually excite large surface currents on the system ground plane of the mobile phone, which functions as an effective radiation portion, especially for the lower frequency operation in GSM-850 and GSM-900. Owing to the large exited surface currents on the system ground plane, especially in the region near the internal antenna (Hiroyuki Tamako, et al., 2004).

Isolation characteristic: The isolation characteristics of an antenna indicate whether its performance is stabilized or not against the environmental changes. Much importance has been placed on the isolation characteristics of a mobile phone antenna from the two viewpoints as shown below. The first relates to the foldable casing consisting of the main circuit board and display. More specifically, whether or not the same level of communication sensitivity can be maintained between the two conditions where the casing is folded or unfolded. The second is concerned with the performance stability against the influence of the human hand and head. This is a problem specific to handsets, such that the equipment is used near the head while being held by the hand. Since human body is a loss dielectric, the electromagnetic waves radiated during the communication are absorbed by the human body thus considerably degrading the radiation efficiency. There is a general requirement of improving this efficiency. In response to such a requirement, a design methodology for compact antennas has been suggested to make use of the ground plane or the entire casing as a radiator (Hiroyuki Tamako, et al., 2004).

1.2 Microstrip antenna

Microstrip patch antennas have several well-known advantages over other antenna structures, including their low profile and hence conformal nature, light weight, low cost of production, robust nature, and compatibility with microwave monolithic integrated circuits (MMICs) and optoelectronic integrated circuits (OEICs) technologies. Because of these merits, forms of the microstrip patch antenna have been utilized in many applications such as in mobile communication base stations, space borne satellite communication systems, and even mobile communication handset terminals. Unfortunately, the expression, “there is no such thing as a free lunch,” also applies to microstrip patch technology. Despite the previously mentioned features, microstrip patch antennas suffer from several inherent disadvantages of this technology in its pure form, namely, they have small bandwidth and relatively poor radiation efficiency resulting from surface wave excitation and conductor and dielectric losses. A schematic diagram of a microstrip patch antenna is shown in Fig. 1.6. Here an arbitrarily shaped metallic conductor is etched on a grounded dielectric laminates. A microstrip patch antenna is a resonant-style radiator so one of its dimensions must be approximately λg/2, where λg is a guided wavelength taking into consideration the surrounding environment of the printed antenna. It is apparent that the properties of the substrate, namely, its dielectric constant, ε_r and its thickness play a fundamental role in the performance of the printed antenna (Kumar and Ray, 2003).

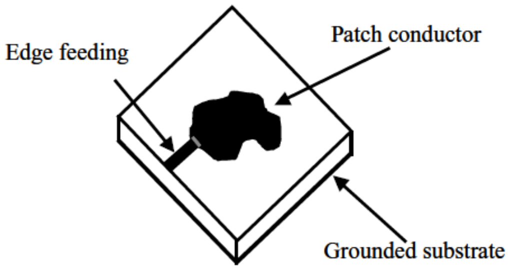


Figure1.6 Schematic diagram of arbitrarily shaped microstrip patch antenna.

Four fundamental techniques to feed a microstrip patch antenna include edge fed, probe fed, aperture coupled, and proximity coupled. These can be further simplified into direct (edge and probe) and non-contact (aperture and proximity-coupled) methods. The properties of each feeding method are summarized below.

Edge-Fed Patches: One of the original excitation methods for a microstrip patch antenna is the edge-fed, or microstrip-line fed technique. A schematic diagram representing this method is shown in Fig.1.7. Here a microstrip feed line of width w_f is in direct contact with a rectangular patch conductor of length *L* and width *W*.

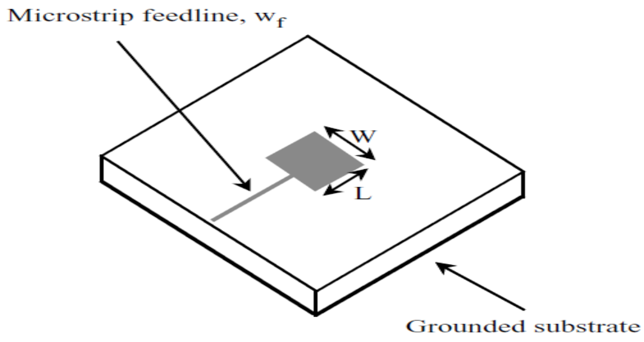


Figure1.7 Schematic diagram of edge-fed microstrip patch antenna.

Typically the microstrip feed line comes in contact with one of the radiating edges of the patch, as shown in Fig. 1.7, although cases where the contact is located along the width of the patch have also been examined. Edge-fed patches have several advantages over other feeding techniques. One of the key features of this technology is its ease of fabrication, because the feed layout and patches can be etched on one board. For this reason many large planar arrays have been developed using edge-fed patches. It is also very easy to control the level of the input impedance of an edge-fed patch. Simply by inserting the feed into the patch conductor the impedance at resonance can be adjusted from very high 150 to 250 Ω when the contact point of the feed line and the patch at the radiating edge of the patch, down to a couple of ohms if the contact point is near the center of the patch (Kumar and Ray, 2003).

Edge-fed patches in their simplest form are relatively easy to model, if electrically thin material is used. Simple transmission line models can be utilized to give estimations of the input impedance performance of the antenna. For cases when thicker materials are used, the modeling of the performance is not too straightforward. This is because of the current distribution of the discontinuities associated with the contact point between the microstrip line and the patch antenna (Kumar and Ray, 2003).

Probe-Fed Patches: Probe feeding a microstrip patch antenna is another form of the original excitation methods proposed in the mid-1970s. A schematic diagram representing this configuration is shown in Fig.1.8, in which a probe of radius r_0 extends through the ground plane and is connected to the patch conductor, typically soldered to it. The probe or feeding pin is usually the inner conductor of a coaxial line; hence, probe feeding is often referred to as a coaxial feed. The probe position provides the impedance control in a similar manner to inserting the feed for an edge-fed patch. Because of the direct contact between the feed transmission line and the patch antenna, probe feeding is referred to as a direct contact excitation mechanism (Kumar and Ray, 2003).

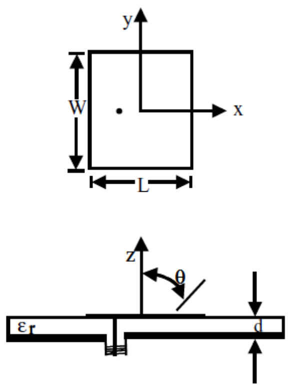


Figure 1.8 Schematic diagram of probe-fed microstrip patch antenna.

The probe-fed patch has several key advantages. First, the feed network, where phase shifters and filters may be located, is isolated from the radiating elements via a ground plane. This feature allows independent optimization of each layer. Second, of all the excitation methods, probe feeding is probably the most efficient because the feed mechanism is in direct contact with the antenna and most of the feed network is isolated from the patch, minimizing spurious radiation. The high efficiency of this printed antenna has seen a renaissance of the probe-fed-styled patch, despite the added complexity of developing a connection. Probe-fed microstrip patches have similar issues to edge-fed patches; namely, their bandwidth is somewhat small and these printed antennas are somewhat difficult to accurately analyze. The probe used to couple power to the patch can generate somewhat high cross-polarized fields if electrically thick substrates are used. Also because this antenna is no longer single-layer geometry, as a result of the location of the feed network, it is more complicated to manufacture (Kumar and Ray, 2003).

Aperture-Coupled Patches: Because of the shortcomings of the direct contact feeding techniques, namely, the small inherent bandwidth and the detrimental effect of surface waves, non-contact excitation mechanisms were introduced. The first of these is the aperture-coupled patch. A schematic diagram of this printed antenna, as given in Fig.1.9, shows how separate laminates are used for the feed network and the patch antenna (Kumar and Ray, 2003).

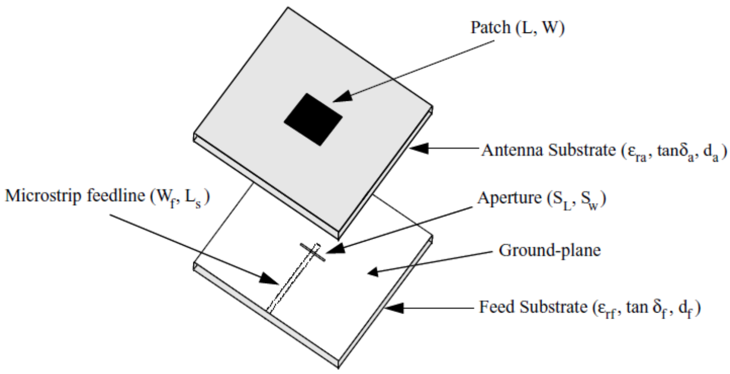


Figure1.9 Schematic diagram of aperture-coupled microstrip patch antenna.

The laminates are separated by a ground plane and coupling between the feed, in this case a microstrip line and the patch antenna is achieved via a small slot in the ground plane.

The configuration shown in Fig.1.9 has advantages over its direct contact counterparts. Unlike the edge-fed patch antenna, independent optimization of the feed and antenna substrates can be achieved. Unlike the probe-fed configuration, no vertical interconnects are required, simplifying the fabrication processes and also adhering to the conformal nature of printed circuit technology. However, alignment issues can be important and also multilevel fabrication processes are typically required. A multilayered antenna can create other problems. The presence of small gaps between the layers of dielectric can significantly alter the input impedance nature of the antenna, especially at high frequencies, where these gaps appear larger electrically. Also, the material required to bond the layers could play a significant role in the performance of the antenna. If the bonding material is loss and is located near, for example, the slot, the efficiency of the antenna is reduced. The aperture-coupled patch has more design parameters than the direct contact fed patches and therefore has more flexibility or degrees of freedom for the antenna designer. Despite its somewhat complex appearance, the aperture-coupled microstrip patch antenna is relatively easy to accurately model, even when using full-wave analyses. The reason for this is that unlike for the direct contact fed patches, there are no abrupt current discontinuities. Thus, relatively simple, accurate, computationally fast, full wave analyses are easy to develop. In its original form the aperture-coupled patch has similar bandwidth and gain responses as the direct fed patches; however, it is very easy to significantly enhance the impedance bandwidth of this antenna. Aperture-coupled microstrip patch antennas are probably the most utilized microstrip patches in today's global market (Kumar and Ray, 2003).

Proximity-Coupled Patches: The second form of non-contact fed patches created to overcome the shortcomings of the direct contact fed patches is the proximity-coupled patch. A schematic diagram of this printed antenna is shown in Fig.1.10. The microstrip antenna consists of a grounded substrate where a microstrip feed line is located. Above this material is another dielectric laminate with a microstrip patch etched on its top surface. Please note there is no ground plane separating the two dielectric layers. The power from the feed network is coupled to the patch electromagnetically, as opposed to a direct contact. This is why this form of microstrip patch is sometimes referred to as an electromagnetically coupled patch antenna (Kumar and Ray, 2003).

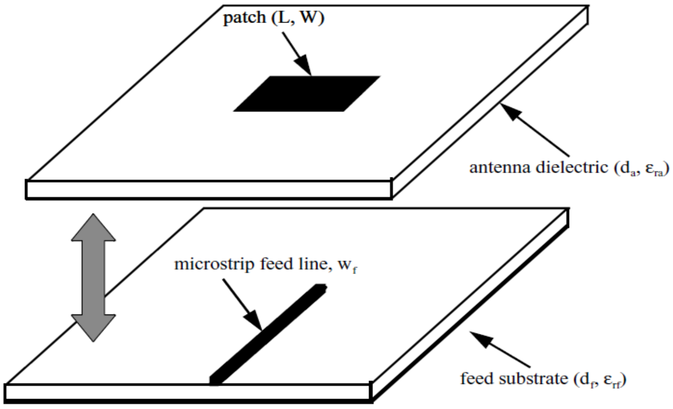


Figure1.10 Schematic diagram of proximity-coupled microstrip patch antenna.

A key attribute of the proximity-coupled patch is that its coupling mechanism is capacitative in nature. This is in contrast to the direct contact methods, which are predominantly inductive. The difference in coupling significantly affects the obtainable impedance bandwidth, because the inductive coupling of the edge- and probe-fed geometries limits the thickness of the material useable. Thus, bandwidth of a proximity-coupled patch is inherently greater than the direct contact feed patches. As with the aperture-coupled patch, full-wave analyses are not too difficult to develop for the proximity- coupled patch because of the lack of a current discontinuity between the feed network and the radiating element. The proximity-coupled microstrip patch has some shortcomings. The feed and antenna layers are not fully independent, because power must be coupled efficiently to the antenna. Therefore, these printed antennas can have relatively high spurious feed radiation, although not as high as for an edge-fed case. The antenna is a multilevel structure and thus alignment procedures are important. Small air gaps between the feed substrate and the laminate for the antenna can affect the coupling to the patches and, therefore, care must be taken when fabricating these antennas (Kumar and Ray, 2003).

1.3 Compact and Broadband microstrip antenna

In order to meet the miniaturization requirements of mobile phones, researchers have given much attention recently to design compact microstrip antenna with multiband operation. This section will present the previous works in literature of designing compact and broadband microstrip antenna in addition to what mentioned in (Wong, 2002) and (Kumar and Ray, 2003). A novel thin internal GSM/DCS patch antenna for a portable mobile terminal is reported by (Wong, ea al., 2006), were internal dual-band patch antenna with a small thickness of 3 mm for application in global system for mobile communication/digital communication system (GSM/DCS) mobile terminals such as the mobile phone or personal digital assistant (PDA) phone is presented. The patch antenna occupies an area of 15×60 mm^2, with its top patch embedded with a simple T-shaped slit, which separates the top patch into two resonant paths to generate two resonant modes for 900/1800 MHz operation. Then, by extending a small portion of the top patch beyond the top edge of the system ground plane of the mobile terminal, the antenna can provide two wide bandwidths covering the GSM/DCS bands.

Also, Chih-Hsien Wu and kin-lu Wong (2008) performed a research report to develop internal shorted planar monopole antenna embedded with a resonant spiral slot for penta band mobile phone application. An internal shorted planar monopole antenna embedded with a resonant spiral slot for GSM850/900/DCS/PCS/UMTS operation in the mobile phone is presented. The planar monopole is printed on FR4 substrate of small size 10 × 45 mm^2. A coupled feed printed on the top no-ground portion of the system circuit board is used to excite both the planar monopole and the spiral slot to generate two wide bands covering GSM850/900 and DCS/ PCS/UMTS operation, respectively. The antenna is also suitable to integrate with the associated electronic components, such as the speaker, to achieve a compact integration of the antenna inside the mobile phone.

A novel of printed compact S shaped monopole antenna with a perpendicular feed for penta band mobile phone application was suggested by (Chih-Hsien Wu and kin-lu Wong, 2007) . The S-shaped monopole antenna has a uni-planar structure and can be printed on an FR4 substrate of small size 10 × 45 mm^2 to achieve a compact configuration. By mounting the antenna over the top edge of the system ground plane of the mobile phone and feeding it using a perpendicular feed, the antenna occupies a small volume in the top portion of the mobile phone. This makes it especially suited for application in the thin mobile phone in which the embedded internal antenna is required to be small in occupied volume and narrow in width. In addition, the antenna can generate two wide operating bands at about 900 and 2000 MHz to cover the GSM850/900 and DCS/PCS/UMTS operation, respectively.

Research report was performed by (Chun-l Lin and Kin-Lu Wong, 2007) to develop an internal meandered loop antenna for GSM/DCS/PCS multiband operation in a mobile phone with the user's hand. An internal meandered loop antenna for application in a mobile phone for global system for mobile communication/digital communication System/personal communication system (GSM/DCS/PCS) multiband operation is presented. Along the symmetric metal-strip loop structure of the antenna, there are meandered sections for adjusting the antenna's resonant frequencies and widened sections for improving the impedance matching. The antenna's first and second resonant modes (half- and one-wavelength modes) excited at about 900 and 1800 MHz for GSM/DCS operation. With the meandered sections in the loop structure, the antenna's third resonant mode (1.5-wavelength mode) can be adjusted to be close to the second resonant mode at 1800 MHz to achieve a wider upper band for DCS/PCS operation.

Internal compact dual band printed loop antenna for mobile phone application (Chi and Wong, 2007) proposes antenna very promising for application in mobile phones as an internal antenna. The antenna comprises an outer loop strip and an inner inverted-L strip connected to and enclosed by the outer loop strip. The antenna occupies a compact area of 15×50 mm^2 only, yet generating three resonant modes to form two wide bands at about 900 and 1800 MHz for the global system for mobile communication/digital communication system operation. When a shielding metal case is placed close to the antenna, small effects on the antenna's impedance matching are seen, allowing compact integration of the antenna with nearby conducting elements or electronic components. The antenna is also found to result in small excited surface current distributions on the system ground plane of the mobile phone.

A paper published in June 2009(Wong and Chen, 2009) introduced a modification for the antenna mentioned in (Chi and Wong, 2007) to be penta band mobile phone applications instead of dual band with keeping the same area. The antenna is very suitable to be directly printed on the system circuit board of the mobile phone, making it easy to fabricate at low cost and generally showing no thickness above the circuit board; the latter is very attractive for thin profile mobile phone applications. In addition, the proposed loop antenna is very suitable to be printed at the bottom position of the mobile phone.

Research report was performed by (Wei-Yu Li and Kin-Lu Wong, 2007) to develop an internal printed loop type mobile phone antenna for penta-band operation. An internal printed loop-type antenna comprising a driven monopole and a coupled strip for application in GSM850/GSM900/DCS/PCS/UMTS penta-band operation is presented. The antenna is suitable to be printed on the system circuit board of the mobile phone and short-circuited to the system ground plane to form as a loop type structure. The antenna provides two wide bands at about 900 and 1900 MHz to cover to GSM850/ 900 and DCS/PCS/UMTS bands, respectively. The lower band is generated by the driven monopole and coupled strip operated together as a half-wavelength loop resonant structure. The upper band is formed by two resonant modes: the first one is the driven monopole operated alone as a quarter-wavelength monopole and the second one is contributed from the driven monopole and coupled strip operated together as a one-wavelength loop resonant structure.

In all of the reported works mentioned previously the feeding technique used to excite the antenna either microstrip line or coaxial cable. In January 2009 a research report was published by (Wei-Yu Li and Kin-Lu Wong, 2009) to use a capacitive coupled feed to excite their antenna. The presence of the capacitively coupled feed leads to a new loop path, whose length is slightly less than that of the original loop strip. The 0.5, 1.0, and 1.5-wavelength modes of the new loop path are also excited with good impedance matching. The two 0.5-wavelength modes of the new loop path and original loop strip form a wide bandwidth of 310 MHz for the antenna's lower band to cover GSM850/900 operation. The other modes of the two loops form a very wide bandwidth of larger than 1 GHz for the antenna's upper band to cover GSM1800/1900/UMTS/WLAN/WiMAX operation. With seven-band operation achieved, the proposed loop antenna only occupies a small volume of

$60 \times 10 \times 3$ mm^3, and owing to its thin thickness of 3 mm only, and the antenna is very promising for thin mobile phone applications.

1.4 Organization of the thesis

This thesis consists of four chapters; the first chapter includes the introduction part of the thesis, the challenges of handset antenna design, microstrip antenna, feeding techniques, and previous studies explain how to design compact and broadband microstrip antenna. Chapter two represents the importance and objectives of the study, High frequency simulation structure (HFSS) and advantages of printed loop antenna. Chapter three considers the simulation result and the discussion of the return loss, excited surface current density, antenna gain, antenna efficiency and radiation pattern. Chapter four presents the conclusions that were reached during this study.

Chapter Two

Importance and Objectives of the Study

The increasing use of wireless communication systems demand antennas for different systems and standards with properties like compact, broadband, multiple resonant frequencies. Because of many attractive features, microstrip patch antennas have received considerable attention for mobile communication handset terminals. In wireless communications, for different systems and standards different frequency bands are allocated such as: DVB-H [470-860 MHz], GSM850 [824-894MHz], GSM900 [890-960MHz], GPS [1575±10MHz], DCS [1710-1880MHz], PCS [1850-1990MHz], UMTS [1920-2170], WiBro [2300-2390 MHz], Wireless local area network[Bluetooth 2400MHz and IEEE802.11a 5200MHz] and 2.5GHz band [2500-2690MHz] for worldwide interoperability for microwave access (WiMax) operation.

Applications in present-day mobile communication systems usually require smaller antenna size in order to meet the miniaturization requirements of mobile units. Thus, size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas, also the challenge is to design multi-band operation antenna. Accordingly; studies to achieve these requirements for microstrip antennas greatly increased.

A novel printed loop antenna with a perpendicular feed for penta band mobile phone application is reported in (Wong and Huang, 2008) will be chosen as the basis structure to adjust it, where a printed loop antenna is described which can be mounted to the circuit board of the mobile phone for penta-band operation. The antenna comprises a loop pattern printed on a thin FR4 substrate of small size 10×60 mm^2 and a perpendicular feeding portion printed on the narrow top ungrounded region of the system circuit board. The antenna occupies a small volume inside the mobile phone housing and is suitable to operate as an internal antenna. In addition, the antenna generates two wide operating bands centered at about 900 and 1900 MHz to cover GSM850/900 and DCS/PCS/UMTS operations, respectively. The configuration of this reference antenna is shown in Fig. 2.1(Wong and Huang, 2008).

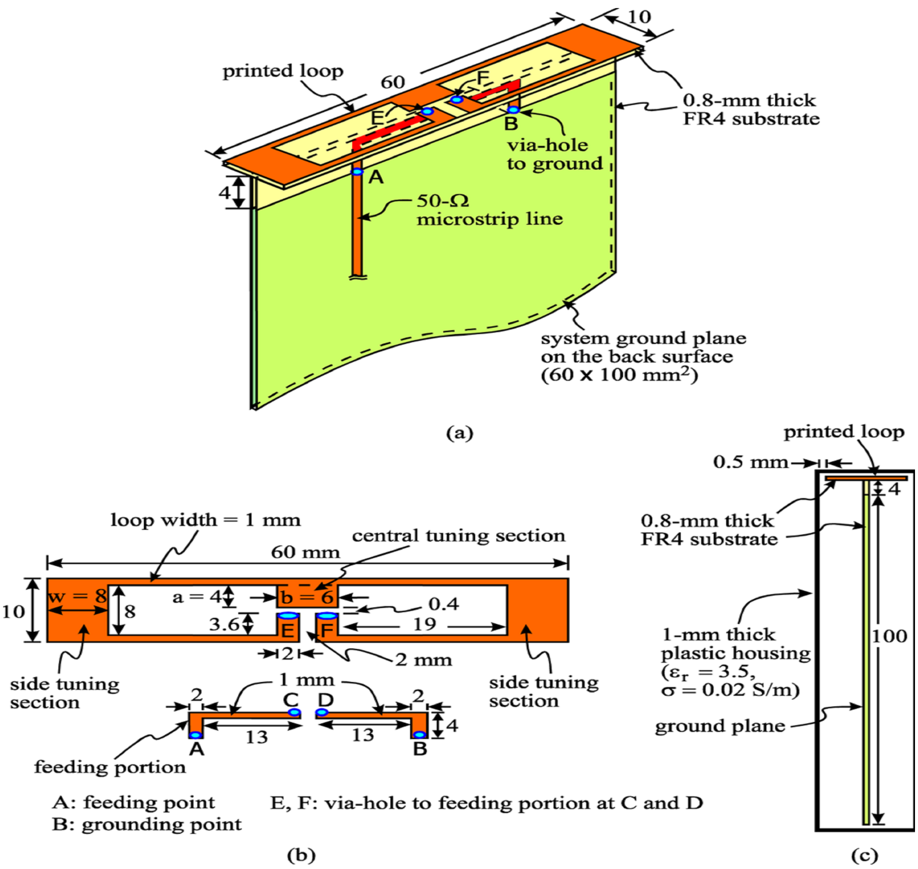
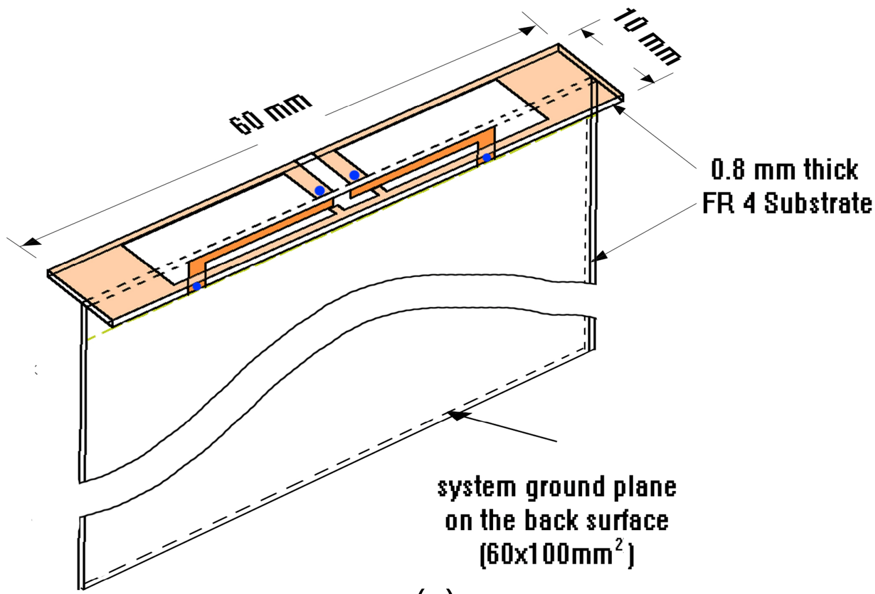


Figure 2.1 (a) Configuration of the printed loop antenna with a perpendicular feed for mobile phone application. (b) Dimensions of the loop pattern and the perpendicular feeding portion. (c) The printed loop antenna enclosed by a 1 mm thick mobile phone plastic housing.

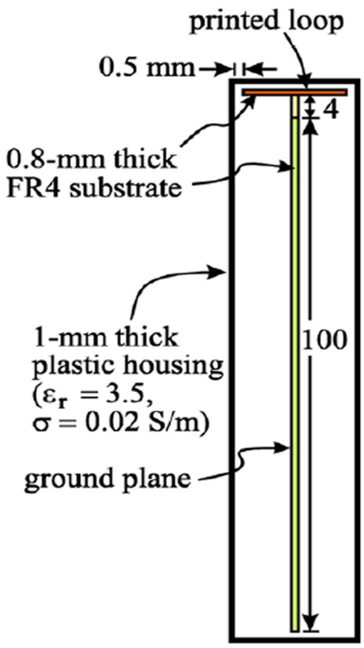
In this study, we will adopt an enhancement for the antenna proposed in (Wong and Huang, 2008), while maintaining the same size of the antenna proposed in (Wong and Huang, 2008); by increasing the operating bands to include three bands cover WiBro, Bluetooth and Wimax to become proposed antenna for eight band wireless applications. By changing the location of perpendicular feeding portion, adjusting the dimensions of the central tuning section, and feeding portion in Fig. 2.1. A parametric study will be performed for the proposed antenna in order to choose best dimensions of the antenna.

The configuration of the proposed printed loop antenna with a perpendicular feed is shown in Fig. 2.2. The loop pattern is printed on a 0.8-mm thick FR4 substrate of size 10×60mm^2; the printed loop pattern is then mounted in perpendicular to the top edge of the system circuit board (a 0.8mm thick FR4 substrate of size 60×104 mm^2 used here). The dimensions of the loop pattern are shown in Fig. 2.2 (c) and (d). Through the via-holes at points E and F, the loop pattern is connected to the feeding portion at points C and D printed on the top ungrounded region (size 60×4mm^2) of the system circuit board. A ground plane of width 60 mm and length 100 mm (L) is printed on the back side of the system circuit board as the system ground plane. The FR4 substrate used here has a relative permittivity of 4.4 and a loss tangent of 0.0245, and the selected sizes of the system ground plane and circuit board are for the possible applications of the proposed antenna in the general PDA phone or smart phone.

One end of the feeding portion is the feeding point (point A) of the antenna, which is connected to the 50 Ω microstrip feed line printed on the system circuit board. The other end (point B) of the feeding portion is grounded to the top edge of the ground plane through a via-hole in the system circuit board. From point A, through points C, E, F, and D, then to point B. Fig. 2.2(b) shows the printed loop antenna enclosed by housing of the mobile phone. The mobile phone housing is fabricated using a 1-mm thick acrylonitrile butadiene styrene (ABS) plate with relative permittivity of 3.5 and a conductivity of 0.02 S/m in this study. The ABS is a practical material for the housing of general mobile phones. The housing can avoid direct contact of the user's hand with the antenna and the system ground plane (Wong and Huang, 2008).


60 mm
10 mm
0.8 mm thick
FR 4 Substrate
system ground plane
on the back surface
(60x100mm²)

(a)


printed loop
0.5 mm
4
0.8-mm thick
FR4 substrate
1-mm thick
plastic housing
(εr = 3.5,
σ = 0.02 S/m)
100
ground plane

(b)

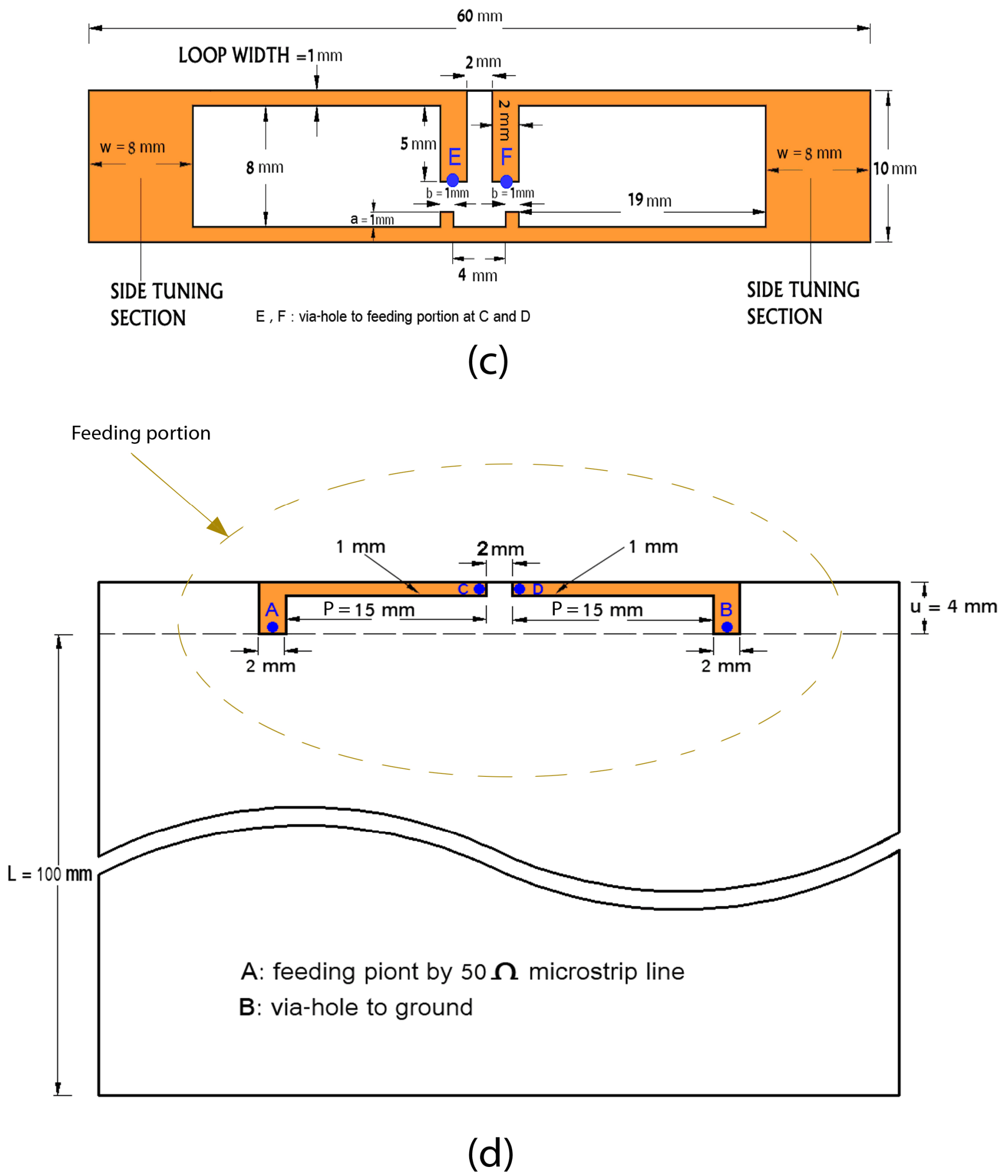


Figure2.2 The configuration of the proposed antenna (a) Three dimension for the proposed antenna. (b) Side view for the proposed antenna. (c) Top view for the proposed antenna. (d) Front view for the proposed antenna.

2.1 Advantages of the printed loop antenna

This type of printed loop antenna's has two features are mentioned and described below.

Effects of the ground plane size: The varying of ground plane length has a large effect for unbalanced mode on the impedance characteristics. For a decreased ground plane length, the excitation of the unbalanced mode quickly becomes degraded the impedance characteristics. But the printed loop antenna shows an attractive feature of performing as a balanced structure when operated at its one-wavelength resonant mode. This property can lead to smaller antenna performance degradation.

Research report was performed by (Wu and Wong, 2002) to present an experimental study of the impedance bandwidth of the PIFA for a UMTS mobile handset. Fig. 2.3 shows the configuration of the PIFA mounted on the top portion of a ground plane of length L and width W, which can be considered to be the ground plane of a mobile handset.

The PIFA shown in Fig. 2.3 with various ground-plane lengths and widths was experimentally studied. Fig. 2.4 shows the measured return loss against frequency for the PIFA with various ground-plane lengths of 65-90 mm. It is clearly seen that the measured return loss is significantly affected by the variation in the ground plane length.

It is observed that in Fig. 2.5, for L varying from 50 to 105 mm, the obtained impedance bandwidths vary from about 210 to 490 MHz, a variation of over 300%. The optimal impedance bandwidth occurs at about L=65 mm, which corresponds to be about 45% of the free-space wavelength at 2050MHz, As for the center operating frequency shown in Fig. 2.5(b), the variations in the ground-plane length also cause a variation of about 70MHz, from about 2045 to 2115 MHz. Fig. 2.6 shows the effects of various ground-plane widths on the measured impedance bandwidth and the center operating frequency. It is seen that both the impedance bandwidth and the center operating frequency are increased monotonically with decreasing ground-plane width.

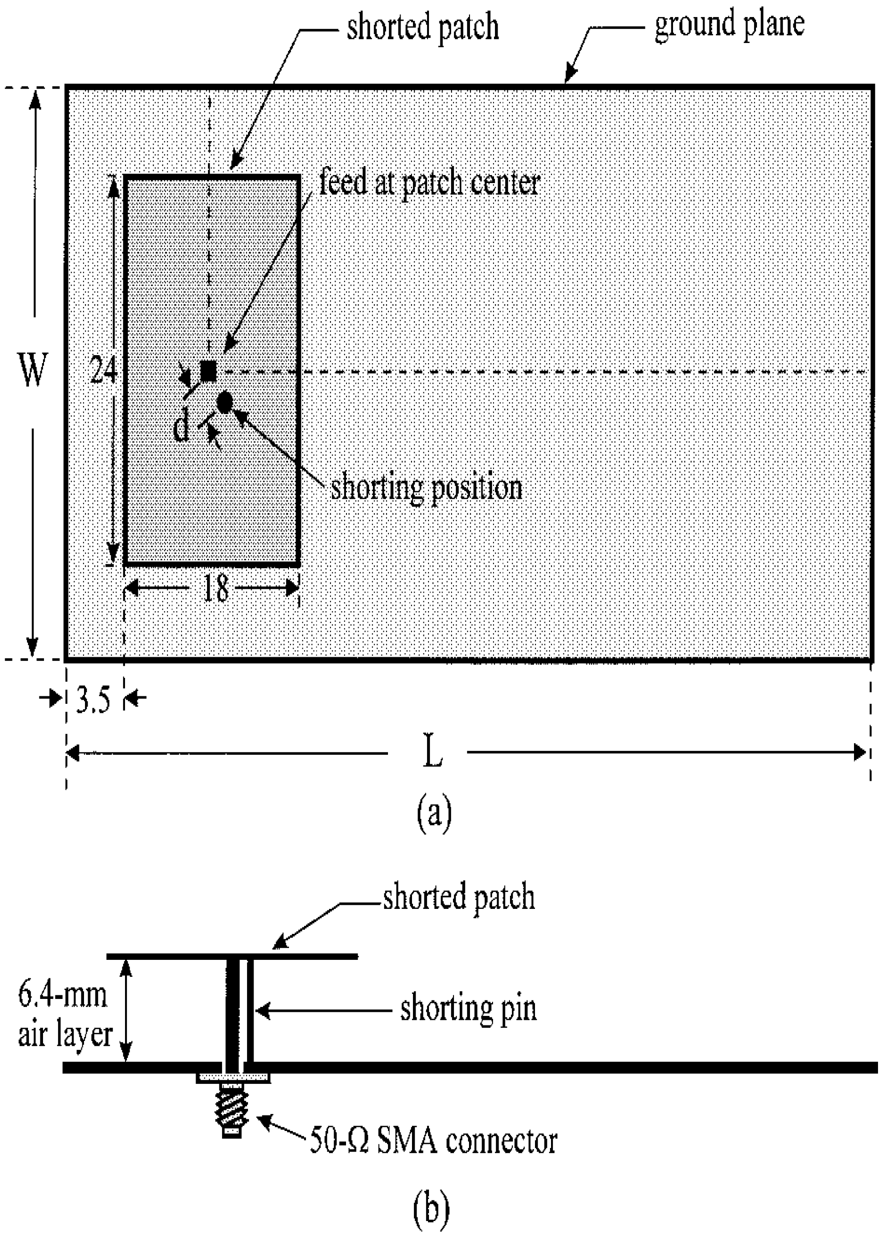


Figure 2.3 Geometry of a planar inverted-F antenna for a UMTS mobile handset (a)Top view (b) Side view

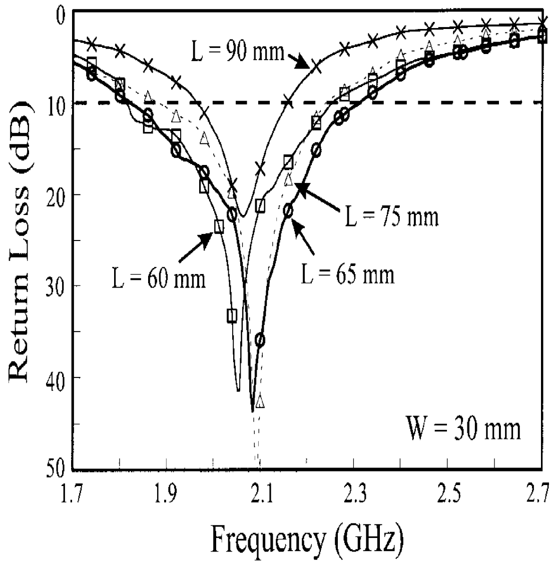


Figure 2.4 Measured return loss for the antenna shown in Fig. 2.3 with *W*=30 mm.

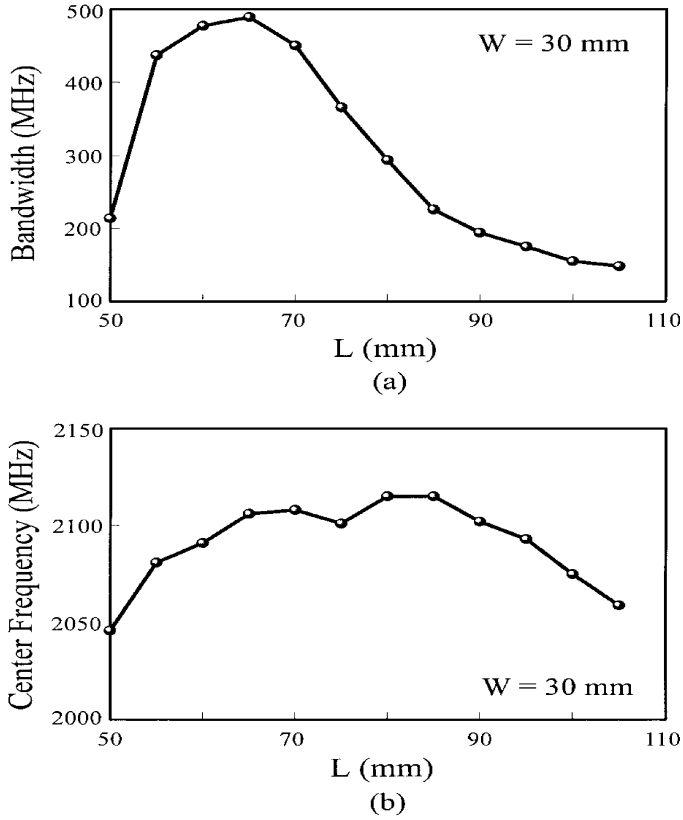


Figure 2.5 Measured (a) impedance bandwidth and (b)center operating frequency for the antenna shown in Fig.2.3 with *W*=30 mm

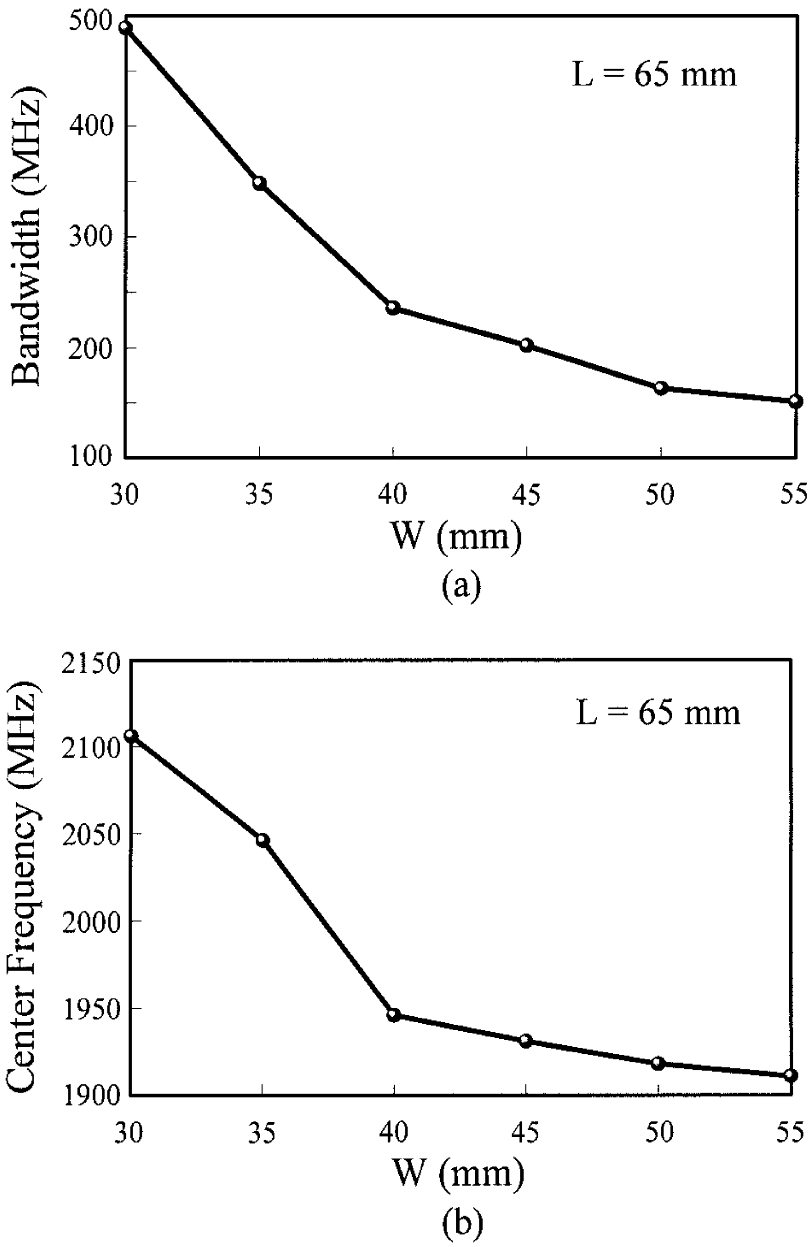


Figure2.6 Measured (a) impedance bandwidth and (b) center operating frequency for the antenna shown in Fig. 2.3with *L*=65 mm.

Effects of excited surface current density: Recently, it has been demonstrated in a scientific research that the loop antenna is very promising for achieving dual-band or multiband operation in the mobile phone. Although these loop antennas are mainly operated as half-wavelength and one-wavelength structures, unlike the conventional quarter-wavelength planar inverted-F antennas (PIFAs) for mobile phones, they still can be configured to occupy a compact volume inside the mobile phone for multiband operation. Such internal loop antennas also show an attractive feature of performing as a balanced structure when operated at its one-wavelength resonant mode. In this case, the excited surface currents on the system ground plane of the mobile phone will be greatly suppressed. This property can lead to smaller antenna performance degradation when the mobile phone is held by the user's hand / or attached to the user's head (Wong and Huang, 2008).

Hisashi Morishita, Yongho Kim and Kyohel Fujimoto (Morishita, et al., 2002)performed a study to compare between the antenna's performances for balanced loop antenna and unbalanced loop antenna by example. This study a small rectangular loop antenna, which has small and low profile, as shown in Fig. 2.7. An analysis has shown a remarkable reduction in the currents on the ground plane. This is shown in Fig. 2.8 where Fig. 2.8a and 2.8b show the current distributions on the ground plane and the antenna element in the balanced and the unbalanced system, respectively. The radiation patterns have also been analyzed, and are shown in Fig. 2.9. The patterns of both unbalanced and balanced systems are shown, for cases where the effects of both the human head and hand are included. In this analysis, the models of the human head and hand shown in Fig. 2.8 and Fig. 2.9 give evidence that the balanced system is more useful compared to the unbalanced system, because of the much lower current flowing on the ground plane, and because of smaller influences on the patterns due to the human head and hand models. This fact suggests that the human-body effect on the antenna's performance in small mobile terminals would be made very small, when an antenna system is made with a balanced structure.

Figure 2.7 (a) A balanced loop antennas for a handset

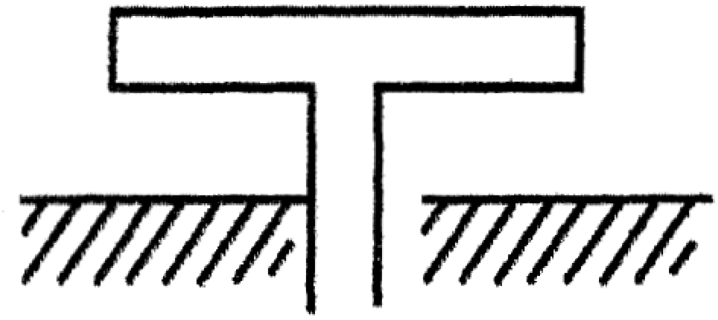


Figure 2.7 (b) An unbalanced feed for the loop of Figure 2.7 (a)

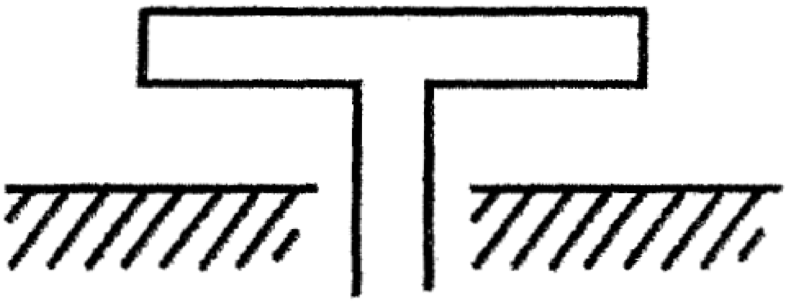


Figure 2.7 (c) A balanced feed for the loop of Figure 2.7 (a)

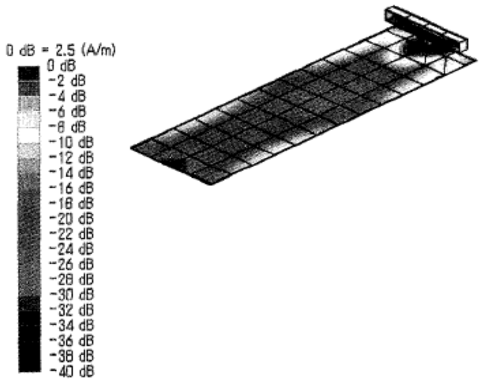


Figure 2.8 (a) The current distribution on the antenna system of Figure 2.7a for an unbalanced feed

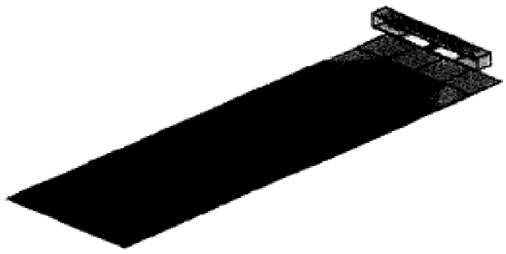


Figure 2.8 (b) The current distribution on the antenna system of Figure 2.7a for a balanced feed (The color scale is the same as shown in Fig. 2.7 a)

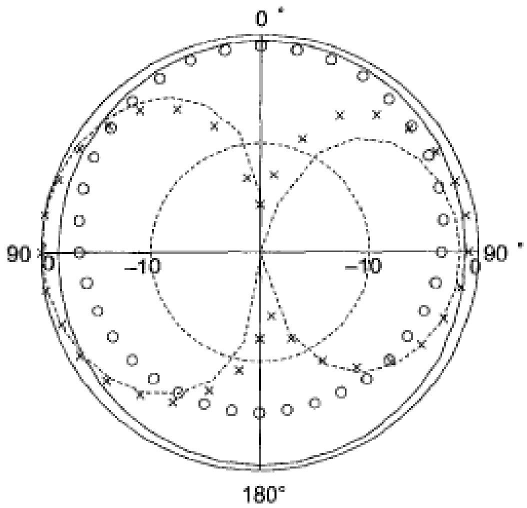


Figure 2.9 (a) The radiation pattern for the unbalanced system of Figure 2.7a without a human model: —E_ϕ (calculated); o E_ϕ (measured); …. E_Θ (calculated); x E_Θ (measured)

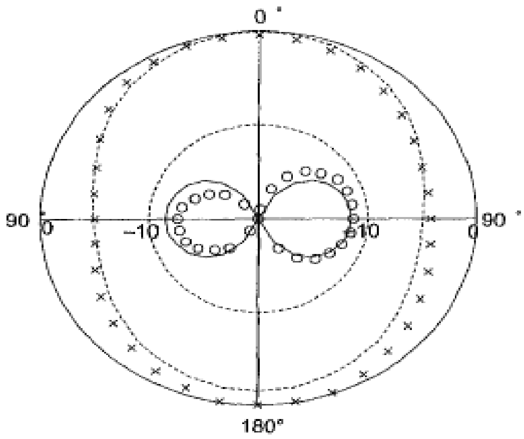


Figure 2.9 (b) The radiation pattern for the balanced system of Figure 2.7a without a human model.

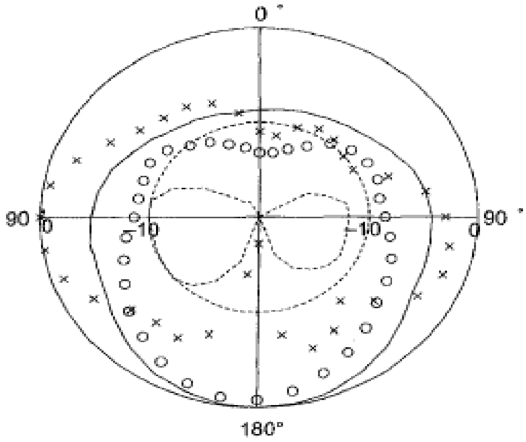


Figure 2.9 (c) The radiation pattern for the unbalanced system of Figure2.7a with a human head model.

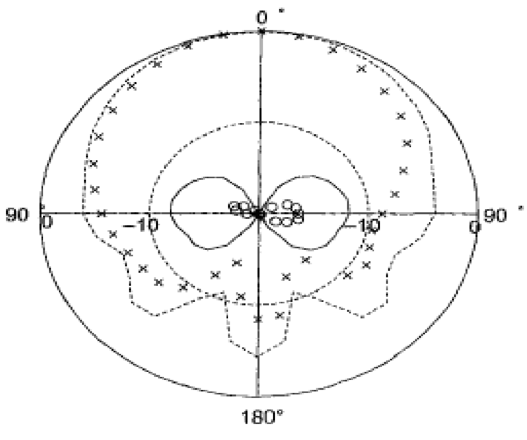


Figure 2.9 (d) The radiation pattern for the balanced system of Figure 2.7a with a human head model

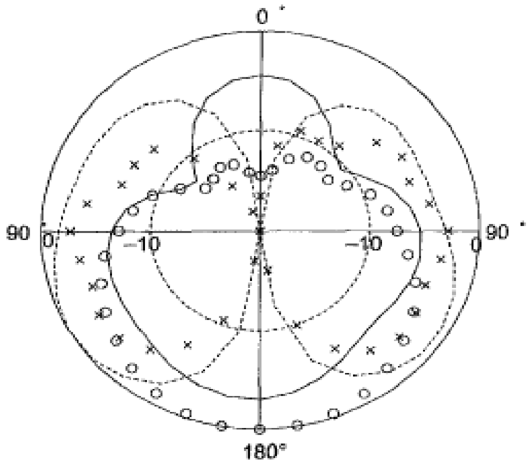


Figure 2.9 (e) The radiation pattern for the unbalanced system of Figure 2.7a with a human hand models

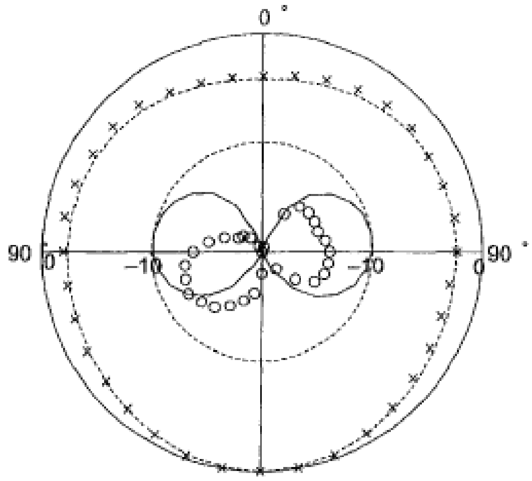


Figure 2.9 (f) The radiation pattern for the balanced system of Figure 2.7a with a human hand models

2.2 Objective of the Study and the HFSS

In particular, the study will focus on the antenna return loss, gain, and the excited surface current distribution on the system ground plane (to evaluate the effect of the near antenna by conducting elements, and the user's hand effect). Another study will consider the radiation pattern characteristics of the antenna, which is required to be "Monopole-like" pattern. To achieve this, an antenna design software package, called High Frequency Simulation Structure (HFSS) has been selected to develop and to simulate this proposed antenna. Nowadays, antenna engineers can rely on highly specialized full wave electromagnetic field solvers to develop and optimize their designs. Computer-aided analysis and optimization have been replaced the design process of the iterative experimental modifications of the initial design.

Ansoft *HFSS* is based on finite element method (FEM). Its first formulations were developed as matrix methods for structural mechanics (Vasylchenko, et al., 2009). This lead to the idea to approximate solids, and in 1942, Courant introduced an assembly of triangular elements and the minimum of potential energy to torsion problems. The first paper on the application of FEM to electrical problems appeared in 1968. The main concept of FEM is based on subdividing the geometrical domain of a boundary-value problem into smaller sub-domains, called the finite elements, and expressing the governing differential equation along with the associated boundary conditions as a set of linear equations that can be solved computationally using linear-algebra techniques. The matrices tend to be large, particularly

in three dimensions, but are very sparse, unlike the full matrices generated by Mom. Since for large problems, most of the computational time is consumed by the solution of the matrix equation, it is very important to use a technique that takes full advantage of the sparsely. In *HFSS,* the final elements are introduced as tetrahedrons: four-sided pyramids. Each element can contain a different material. Therefore, the interface between two different materials must coincide with element boundaries. This contributes the ability to treat geometrically very complex structures with inhomogeneous and anisotropic materials to FEM.

Two mesh operations can be manually controlled by the user in *HFSS (*Ansoft Corporation HFSS*)*:

- Length-based mesh refinement: refines the length of tetrahedral elements on a surface or within a volume until they are below a certain value.
- Skin-depth-based mesh refinement: refines the surface triangle length of all tetrahedral elements on a surface or volume to within a specified value.

Chapter Three

Simulation Results and Discussions

The configuration of the proposed antenna as shown in Fig.2.2 contains several variables. Changing these variables affect the antenna parameters performance (return loss, gain, radiation efficiency, radiation pattern). The main reason of this study is the design of an internal antenna for mobile phone to cover the largest possible number of operating bands. Therefore, the final dimensions of the proposed antenna shown in Fig.2.2 identified by using parametric study in order to cover eight operating bands GSM850/900, DCS/PCS/UMTS/WiBro, Bluetooth, and Wimax.

3.1 Parametric Study

I have used the HFSS to determine antenna parameter performance and the final dimension for the proposed antenna. The return loss used to determine the operating band(s) in which antenna can be utilized. The internal antennas of the mobile phones usually designed based on the bandwidth definition of 6 dB return loss (3:1 VSWR) (Wong and Huang, 2008). Results of the return loss variation as a function of the width **w** are presented in Fig.3.1. Small effect on the antenna's first, second and third resonant mode are seen, and large effects on the antenna's fourth resonant mode. In order to cover the DCS/PCS/UMTS/WiBro, Bluetooth, and Wimax, the width **w** is selected to be 8 mm. In addition, I study the effect of adjusting **a** and **b** on the return loss. From Fig.3.2, we notice that changing **a** and **b** significantly affect the fourth resonant mode. Thus, the preferred values of **a** and **b** to cover DCS/PCS/UMTS/WiBro, Bluetooth and Wimax is chosen to be **a** = 1mm and **b** =1 mm.

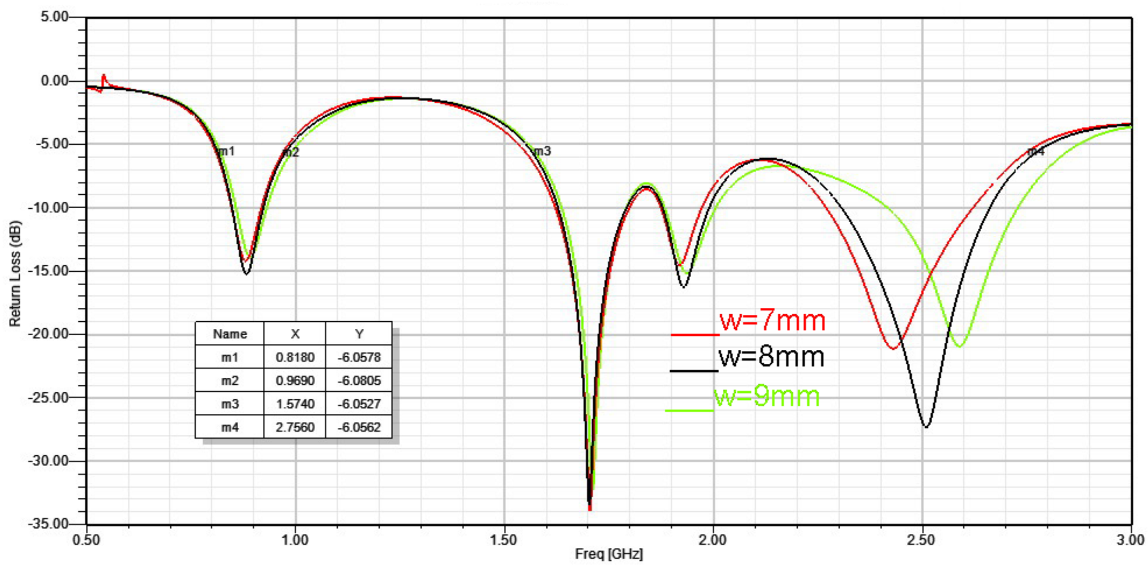


Figure3.1 Effects of adjusting of the width of the side tuning section **w** on the return loss

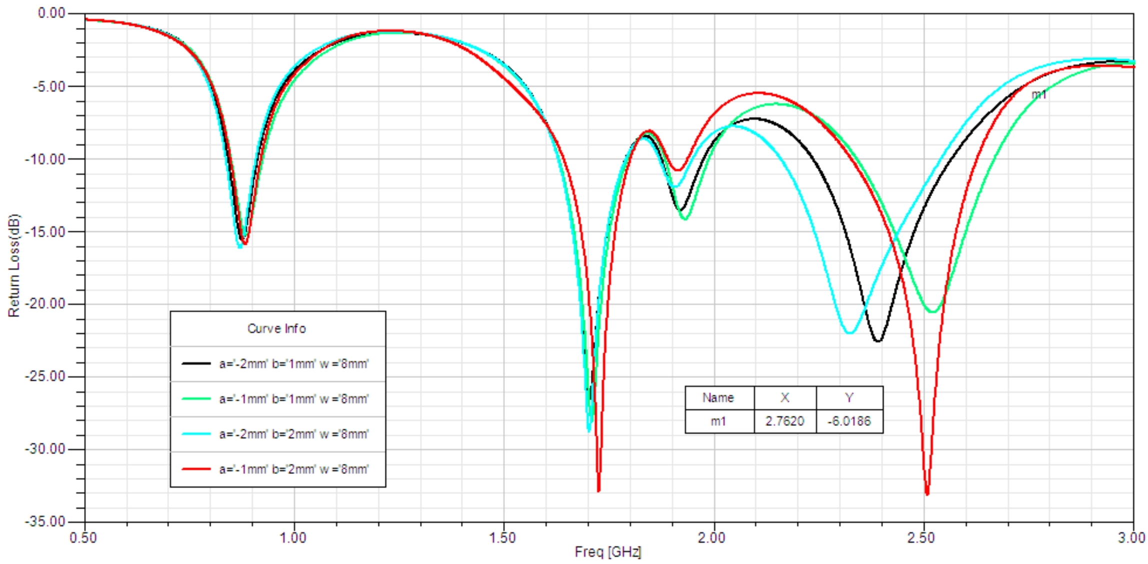


Figure3.2 Effects of the adjusting of "**a**" and "**b**" on the return loss

The variation of the return loss as a function of **P**, the length of feeding portion, is shown in Fig.3.3. Results indicate that the variable **P** affects the second, third and fourth resonant modes. Thus, the value of **P** is selected to be 15mm to cover DCS/PCS/UMTS/WiBro, Bluetooth, and Wimax.

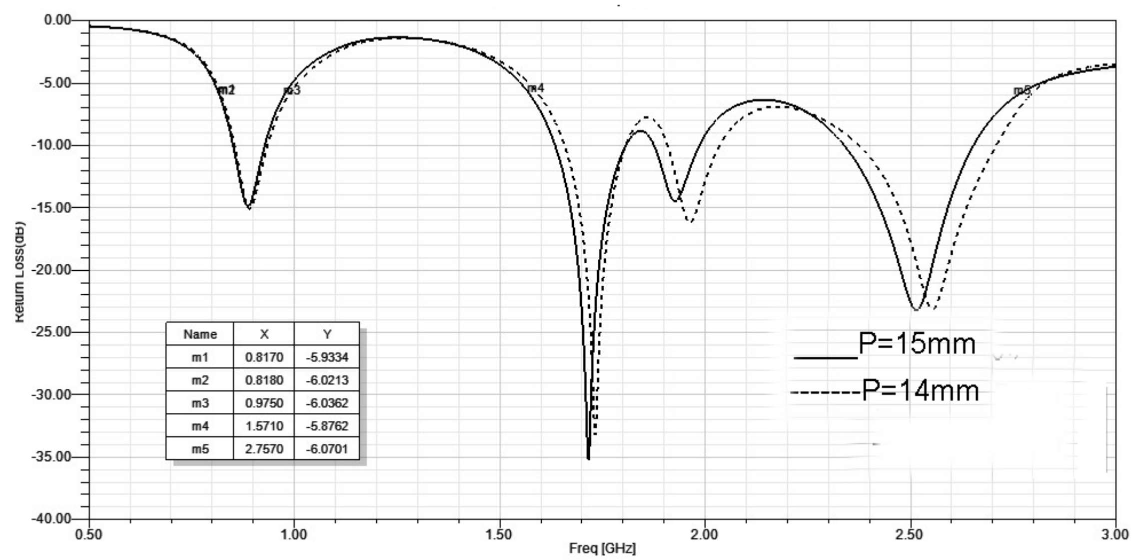


Figure3.3 The variation of the return loss as function of **P**, the length of the feeding portion

Finally, effect variation of **u**, top ungrounded region is demonstrated in Fig.3.4. When **u**= 5mm the third resonant mode is disappeared whereas when **u**=3mm third resonant mode is shifted to uncover DCS/PCS. Thus, the better value of **u** is selected to be 4mm to cover all applications in upper band.

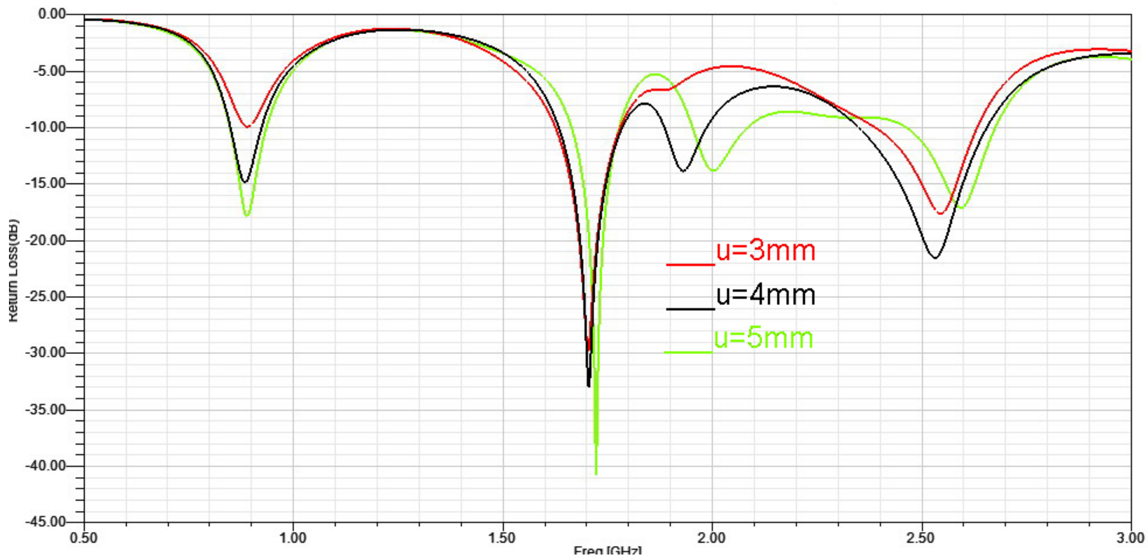


Figure3.4 The variation of the return loss as a function of **u**, the top ungrounded region

Accordingly, the final dimensions of the proposed antenna were adopted to be as shown in Fig.2.2. The variation of the return loss for the proposed antenna compared to that of (Wong and Huang, 2008)is shown in Fig.3.5. Using the 3:1 VSWR (6 dB return loss) as reference value, which is generally used for the internal mobile phone antenna design, the lower band shows a bandwidth of 151 MHz (818-969 MHz) centered at first resonant mode around 900MHz, allowing the antenna to cover GSM850/900 operation. While the second, third and fourth resonant modes occur at about 1700, 1936 and 2500 MHz, respectively. They are responsible for generate the upper band has a bandwidth of 1182 MHz (1574-2756 MHz) centered at around 2165 MHz, which satisfies the required bandwidth for DCS/PCS/UMTS/WiBro, Bluetooth and Wimax.

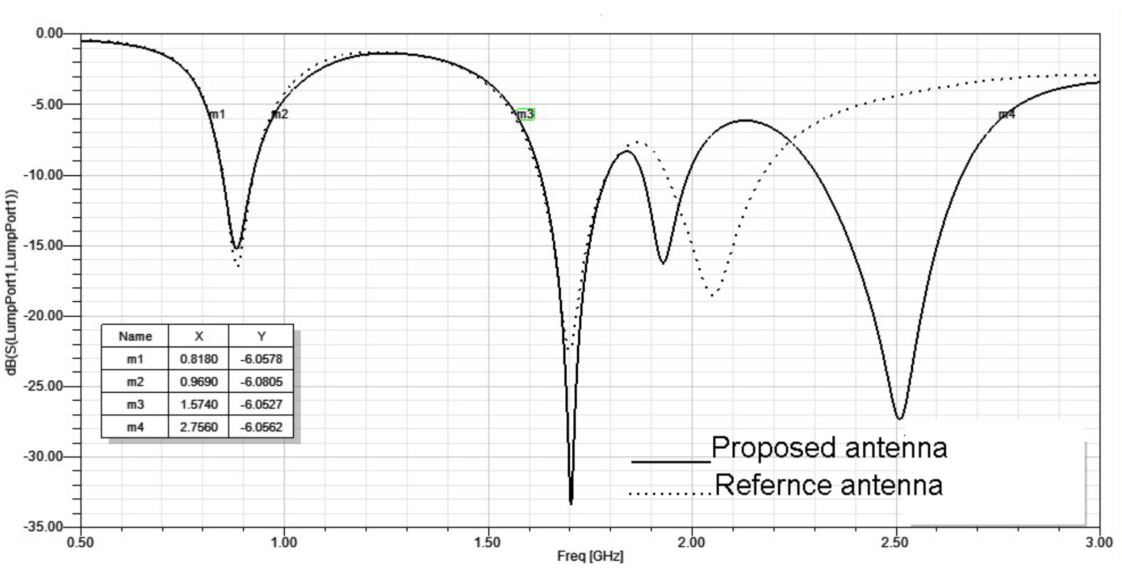
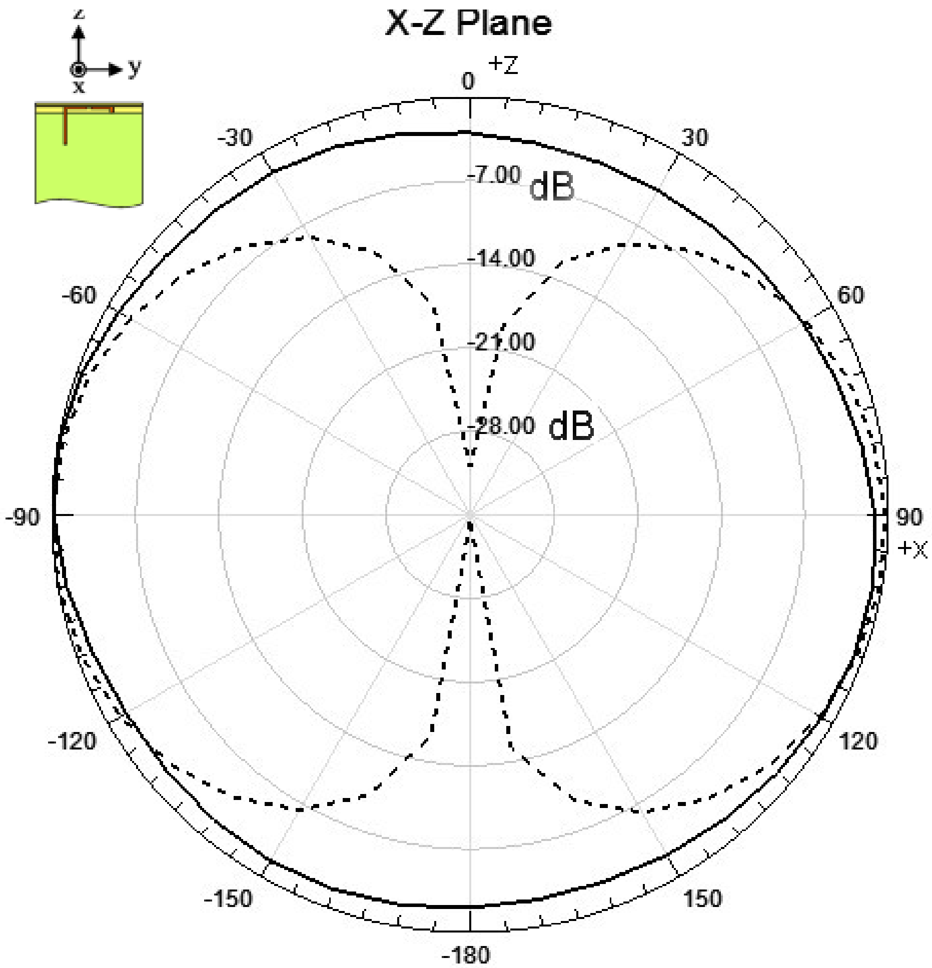


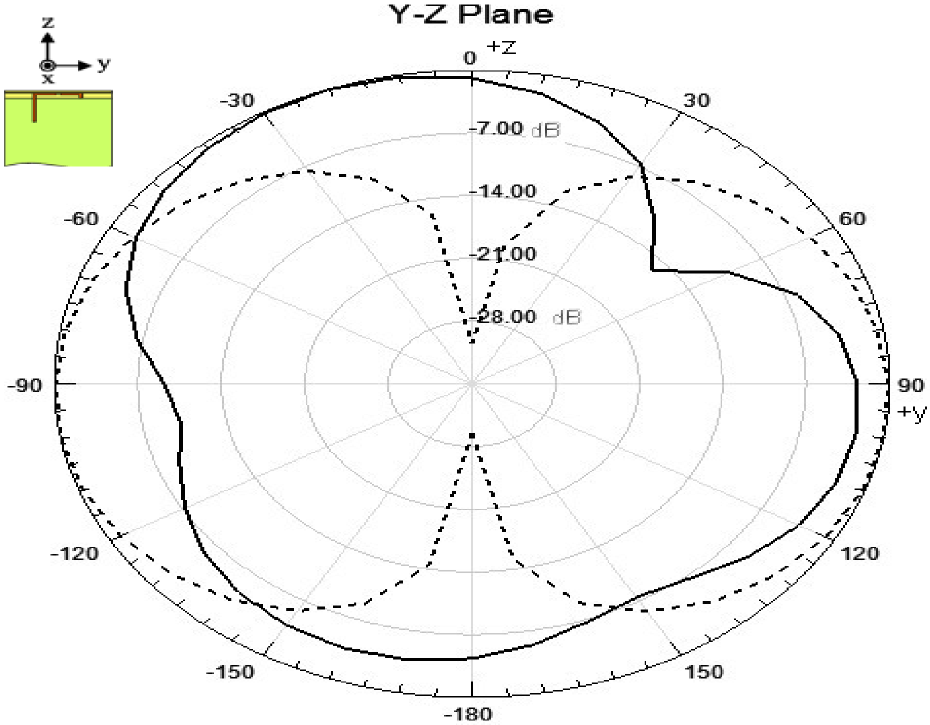
Figure3.5 The variation of the return loss for the proposed antenna and the reference antenna

3.2 The Antenna Parameters Performance

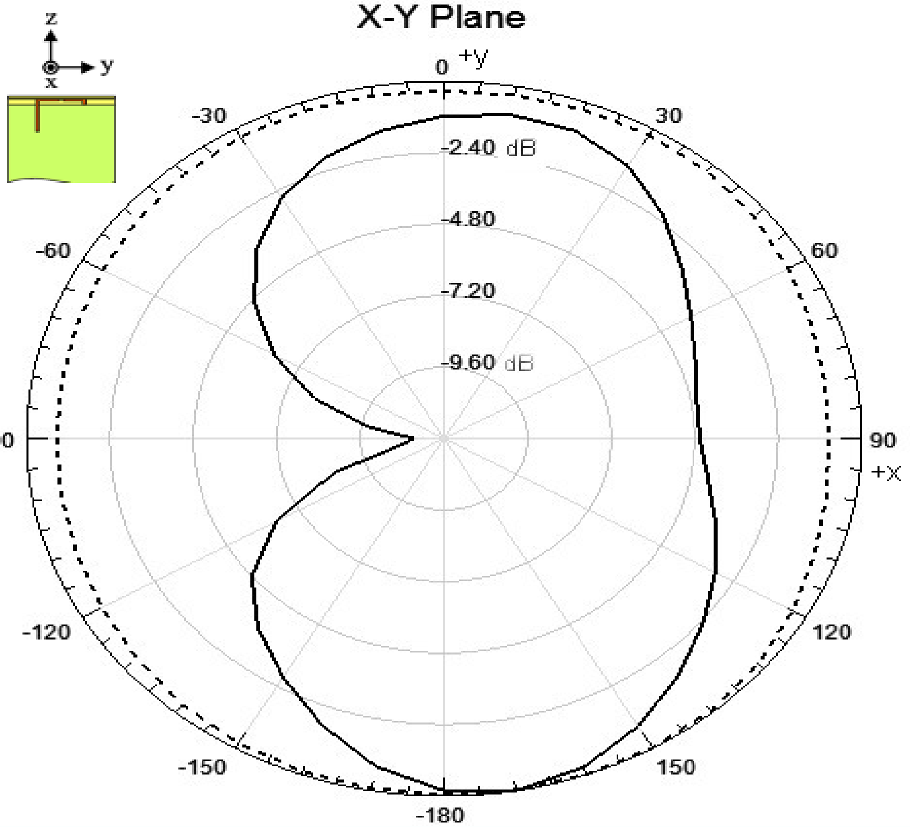
The simulated radiation pattern for all resonant modes are shown in Figs.3.6, 3.7, 3.8, and 3.9 which seem to be similar to that of monopole antenna with nulls occurring at some angels such as 0°, 90°,-90°, 180°,-180°. The antenna gain and radiation efficiency, the radiation efficiency is the ratio of the radiated power to the accepted power, for reference antenna in (Wong and Huang, 2008)and proposed antenna, are presented in Fig.3.10 and 3.11, respectively. The reference antenna gain for lower band varies from 1.14 to 1.59 dBi whereas the lower band gain for proposed antenna varies from 1 to 1.58 to dBi. The radiation efficiency of reference antenna in (Wong and Huang, 2008) for the lower band varied from 60 to 85 % whereas the radiation efficiency of proposed antenna for the lower band varied from 71.8 to 79.8 %.



(a)

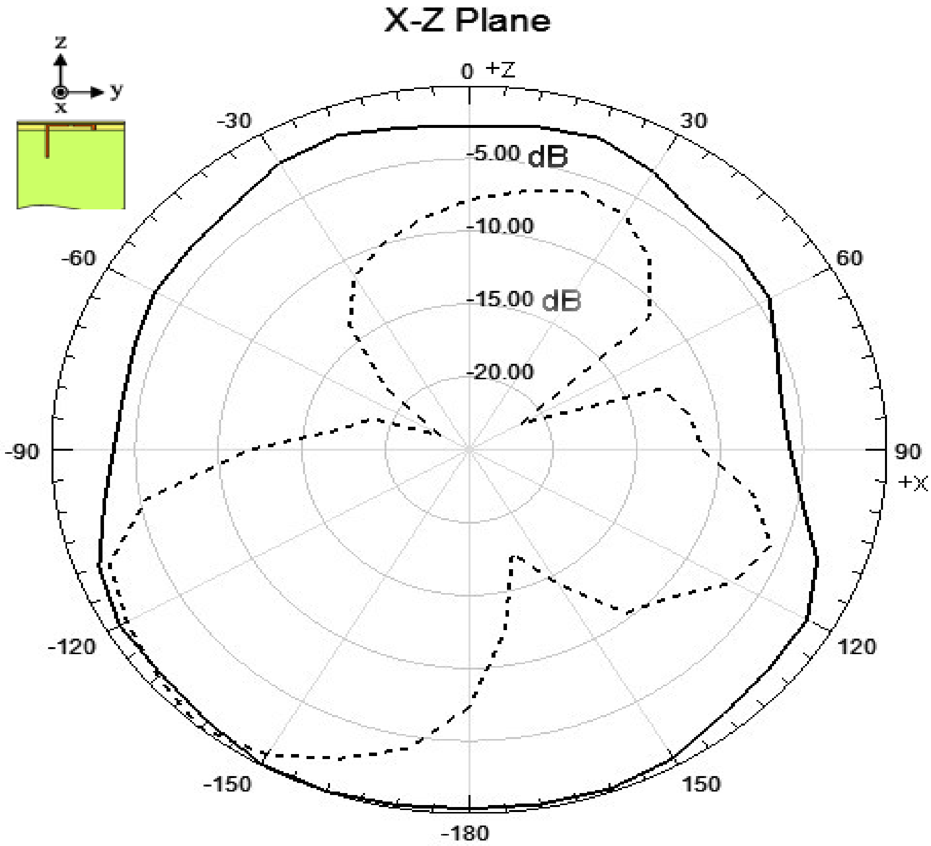


(b)

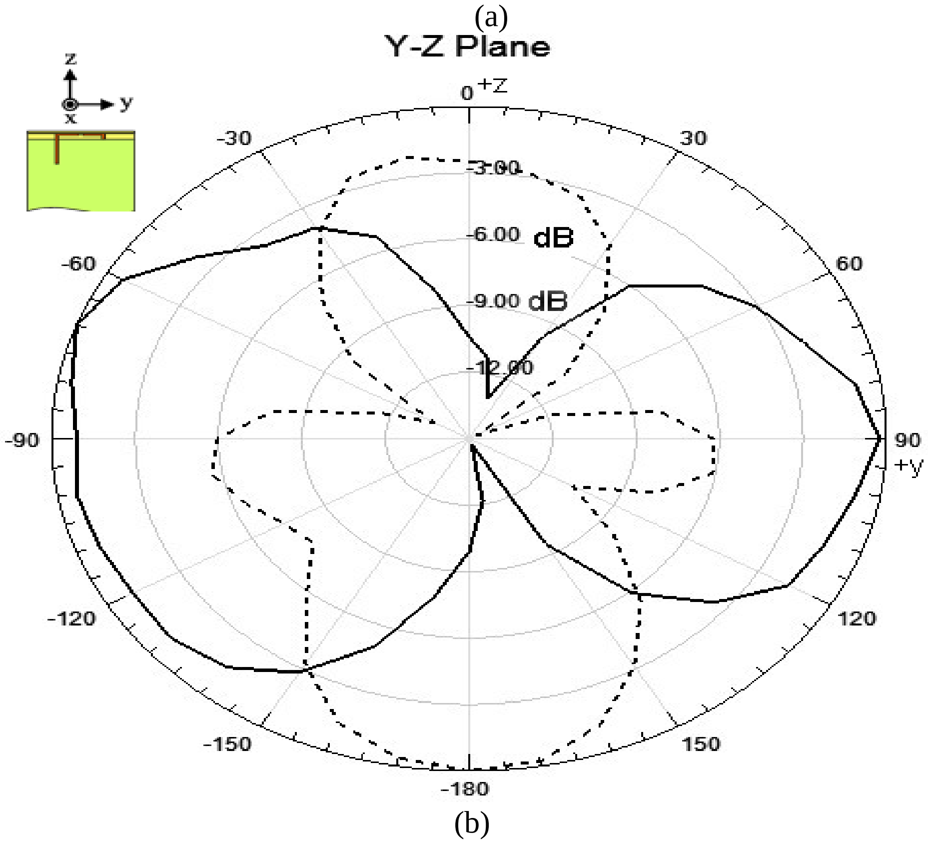


(c)

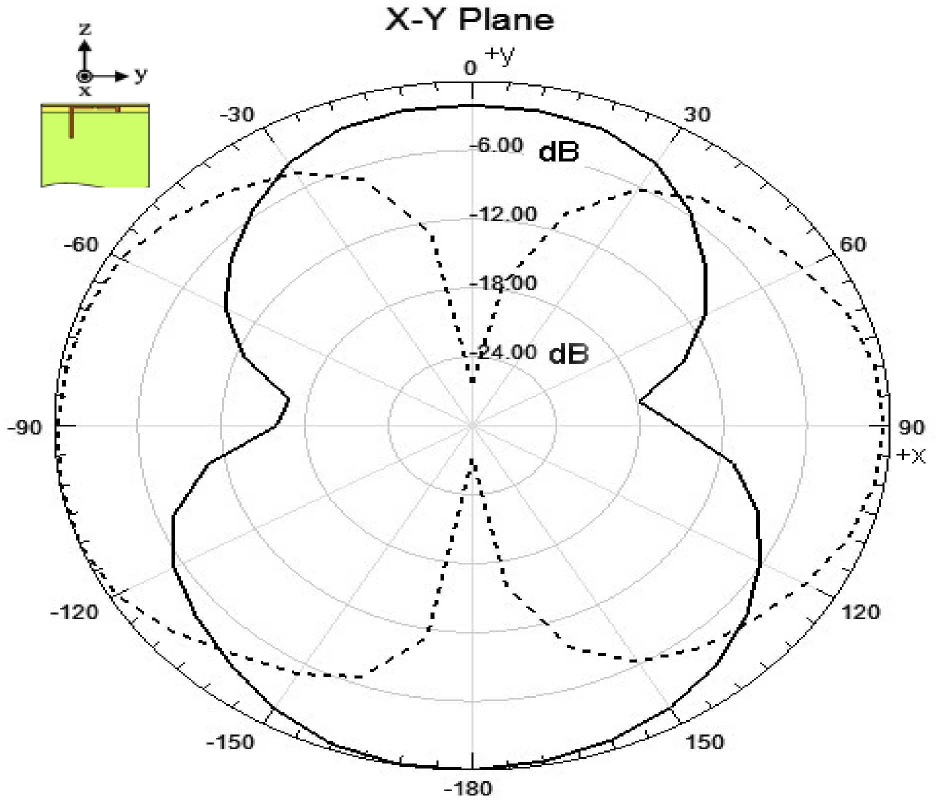
Figure3.6 Radiation pattern for f = 900 MHz for the proposed antenna —E_{ϕ}, ----E_{Θ}.


X-Z Plane
0 +Z
30
60
90
+X
120
150
-180
-150
-120
-90
-60
-30
-5.00 dB
-10.00
-15.00 dB
-20.00

(a)

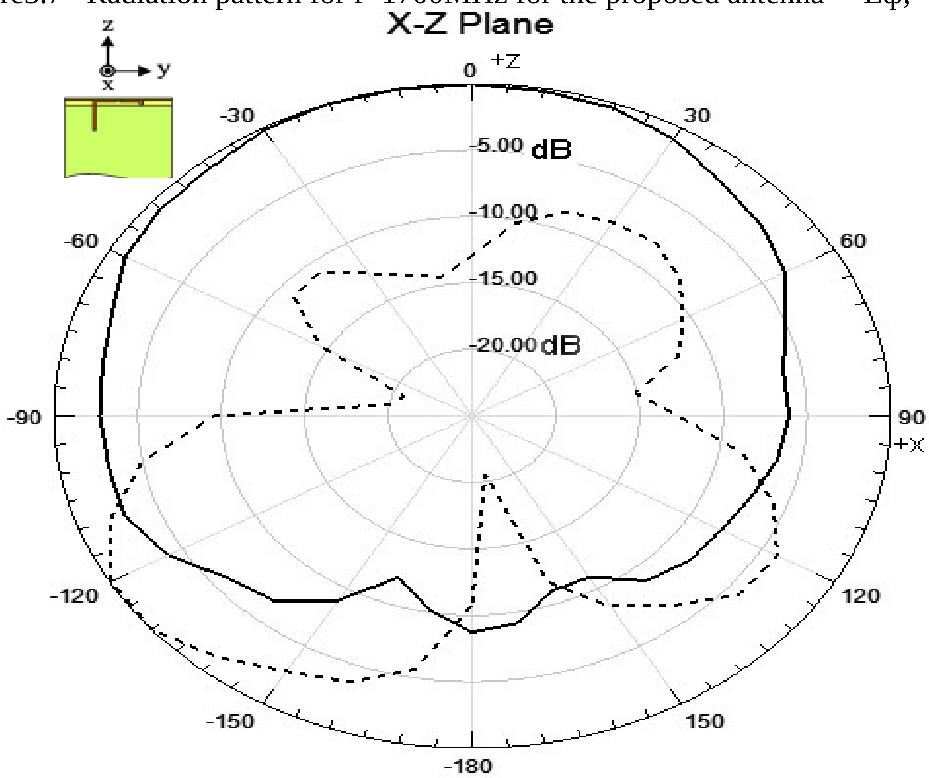

Y-Z Plane
0 +Z
30
60
90
+y
120
150
-180
-150
-120
-90
-60
-30
-3.00
-6.00 dB
-9.00 dB
-12.00

(b)

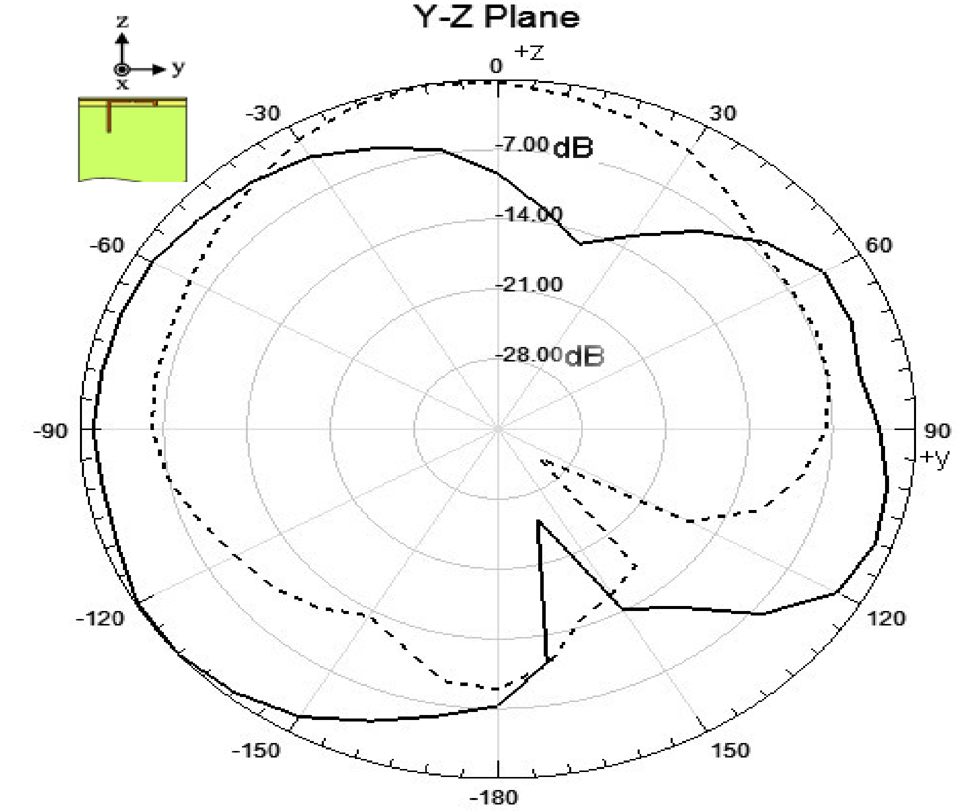


(c)

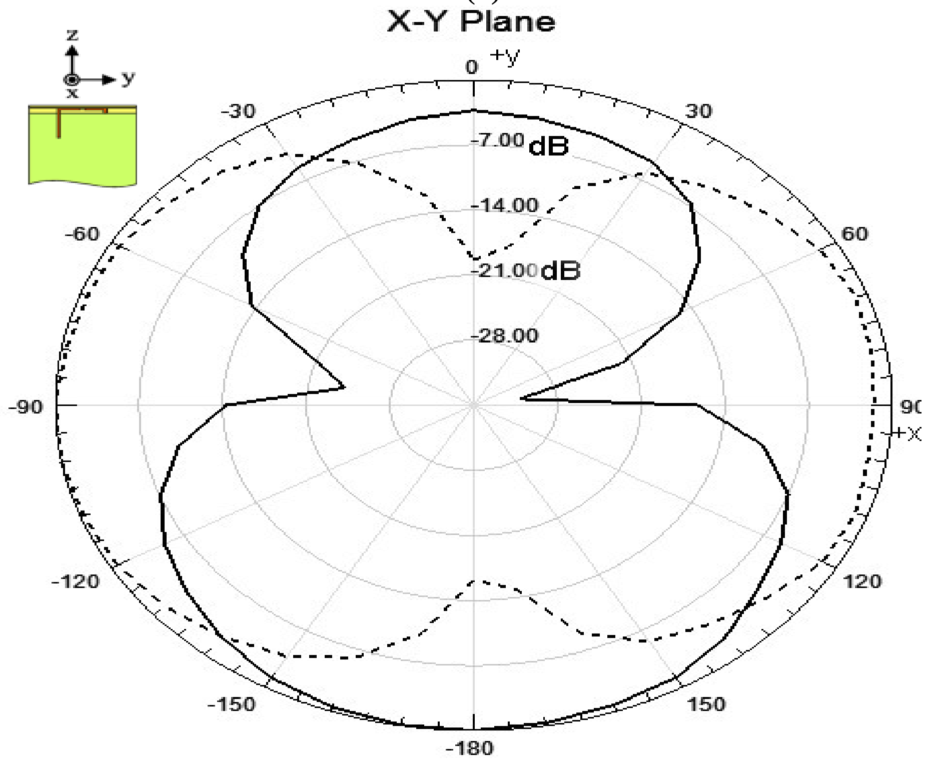
Figure3.7 Radiation pattern for f=1700MHz for the proposed antenna —Eφ, ----EΘ



(a)

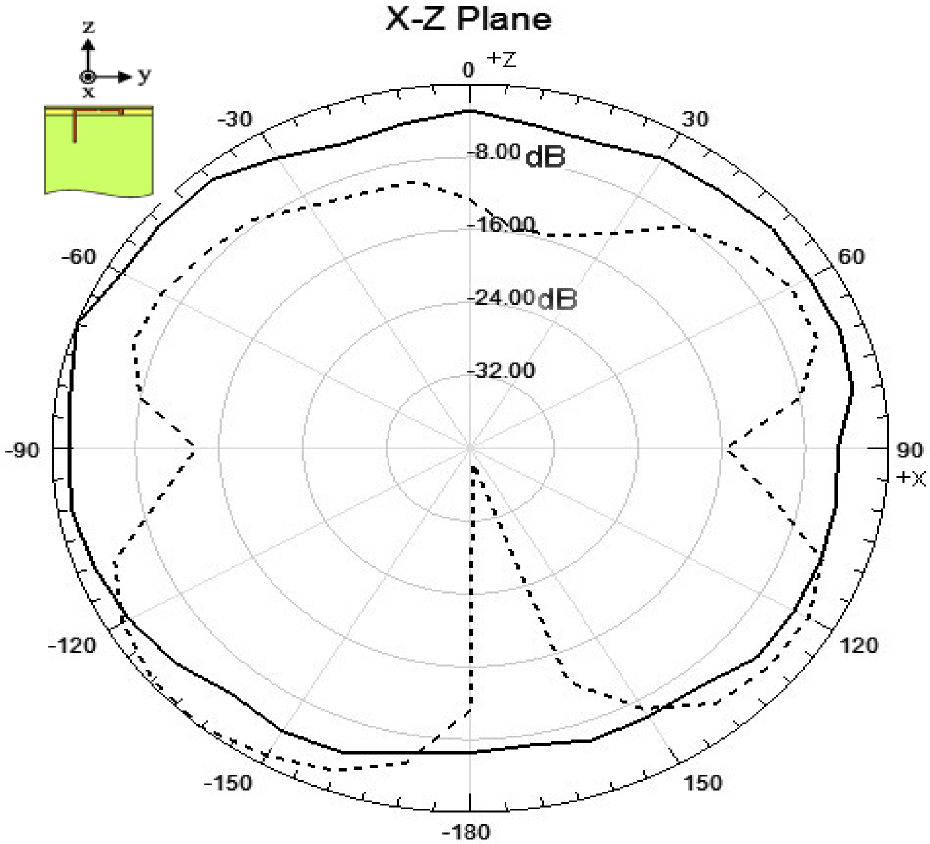


(b)

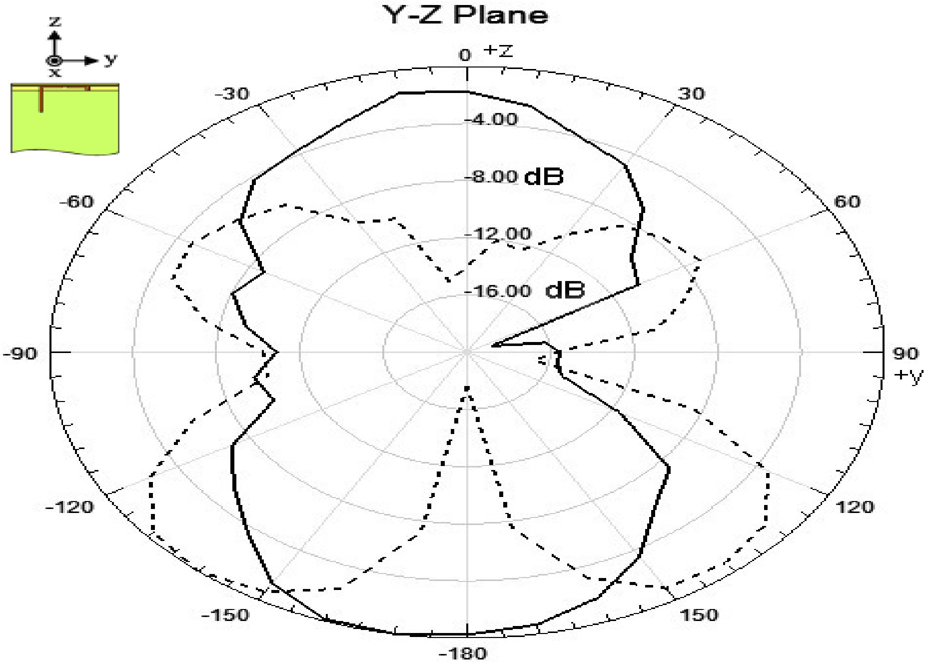


(c)

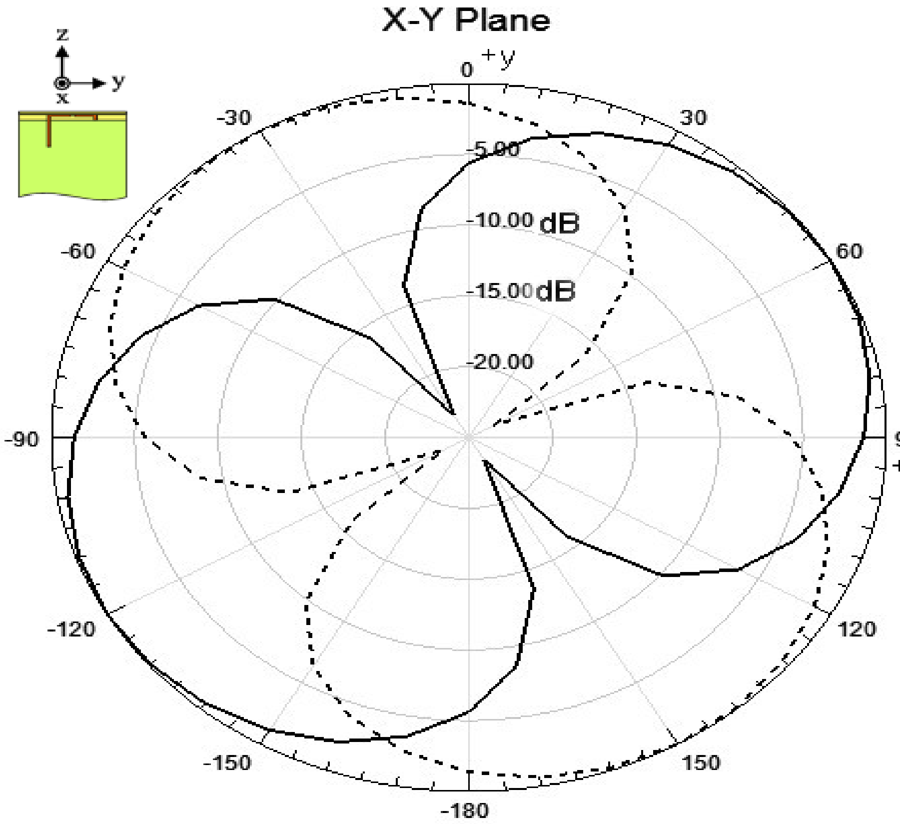
Figure3.8 Radiation pattern for f = 1936 MHz for the proposed antenna —E_ϕ, ----E_Θ.


X-Z Plane
z
y
x
0
+Z
30
60
90
+X
120
150
-180
-150
-120
-90
-60
-30
-8.00 dB
-16.00
-24.00 dB
-32.00

(a)


Y-Z Plane
z
y
x
0
+Z
30
60
90
+y
120
150
-180
-150
-120
-90
-60
-30
-4.00
-8.00 dB
-12.00
-16.00 dB

(b)



(c)

Figure3.9 Radiation pattern for f=2500MHz for the proposed antenna —E_ϕ, ----E_Θ

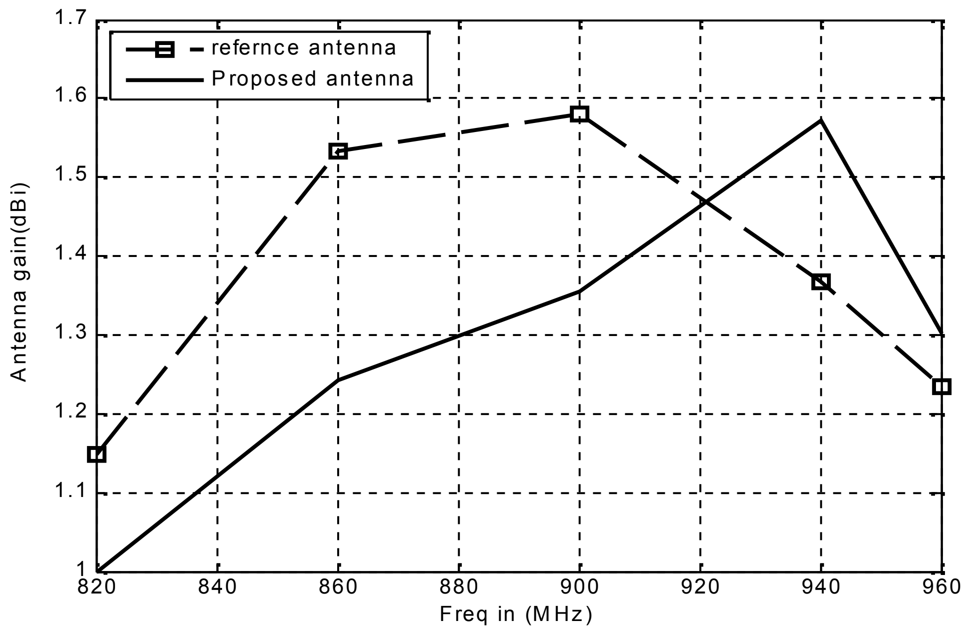


Figure3.10 The variation of the antenna gain for the lower band

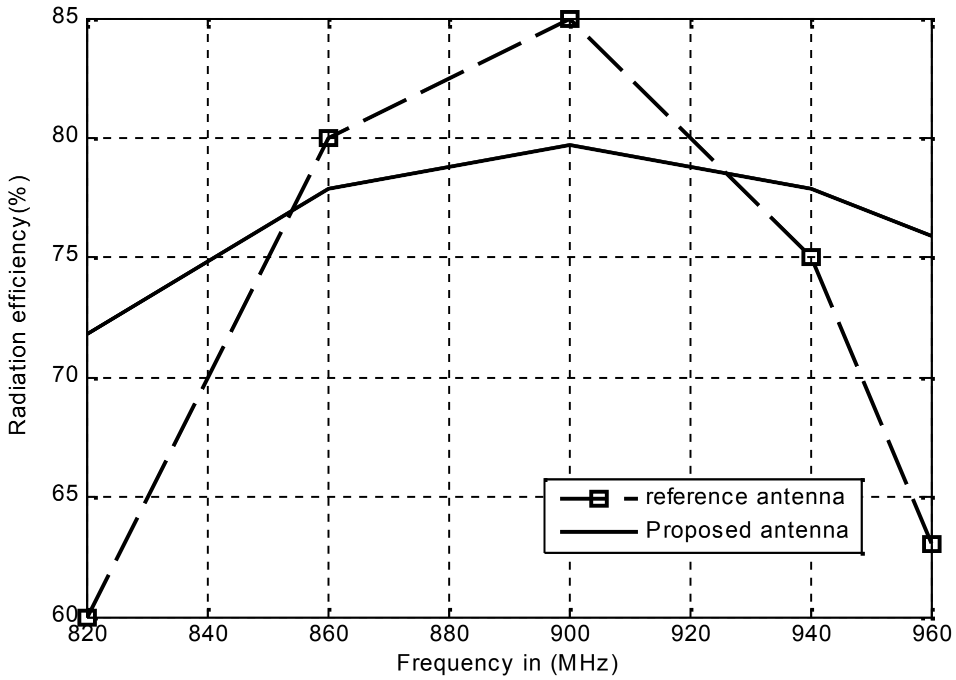


Figure3.11 The variation of the radiation efficiency for the lower band

The variation of the antenna gain and radiation efficiency for the reference antenna (Wong and Huang, 2008) and proposed antenna, for the upper band, is shown in Figs.3.12 and 3.13, respectively. The reference antenna gain for upper band varied from 1.5 to 3.6 dBi whereas the lower band gain for proposed antenna varied from 2.3 to 5 dBi. The radiation efficiency of reference antenna in (Wong and Huang, 2008) for the upper band varied from 66 to 77 % whereas the radiation efficiency of proposed antenna for the lower band varied from 63 to 75 %.

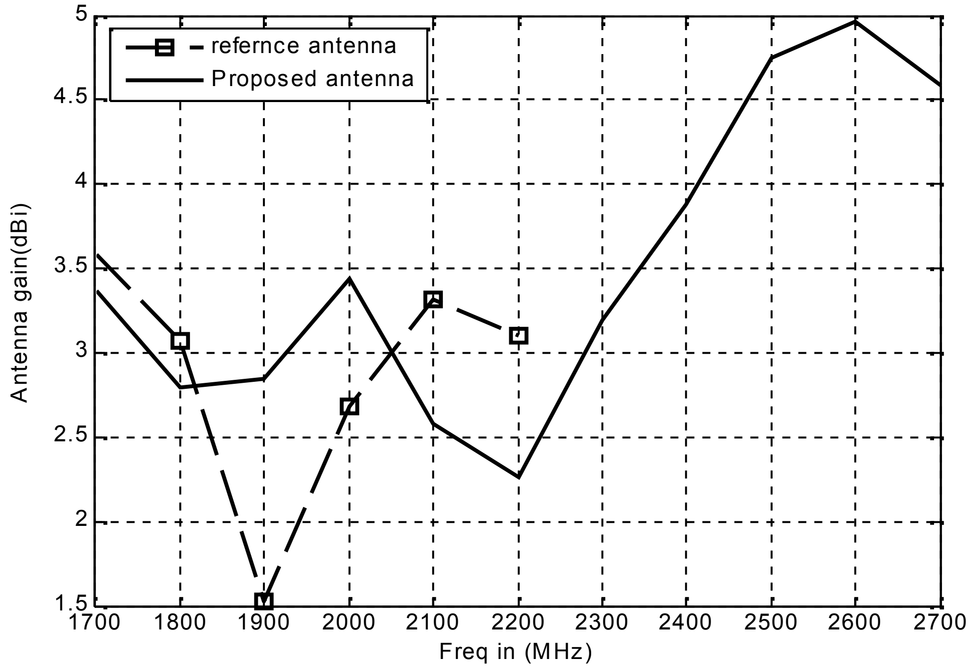


Figure3.12 The variation of the antenna gain for the upper band

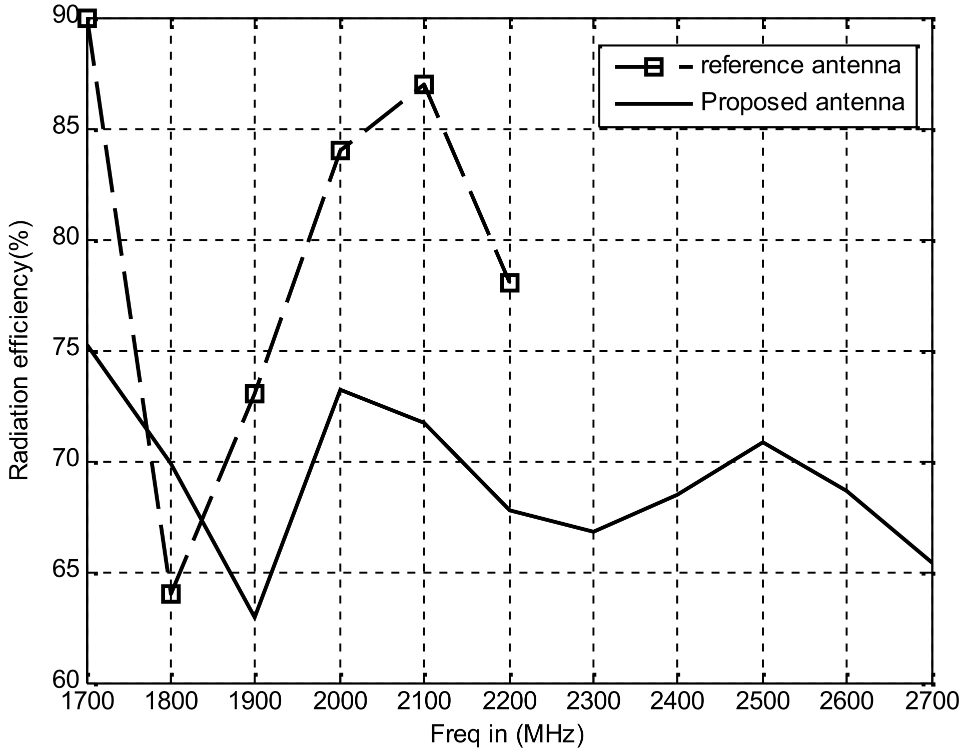


Figure3.13 The variation of the radiation efficiency for the upper band

3.3 Effect of the Ground Plane Size

The variation of the return loss for different values of the length of the ground plane L (from 30 to 100 mm) is shown in Fig. 3.14. For the antenna's second and third resonant modes, only some slight frequency shifting is observed; which indicate that the decreased ground plane length shows small effects on the excitation of the balanced mode. Nevertheless, the first and fourth resonant mode has large effects, which is an unbalanced mode. This behavior is very similar to PIFA's internal antenna mobile phone mentioned in the previous chapter. This phenomenon results from the excited surface currents density on the system ground plane of the mobile phone at balanced modes are weaker than at unbalanced modes.

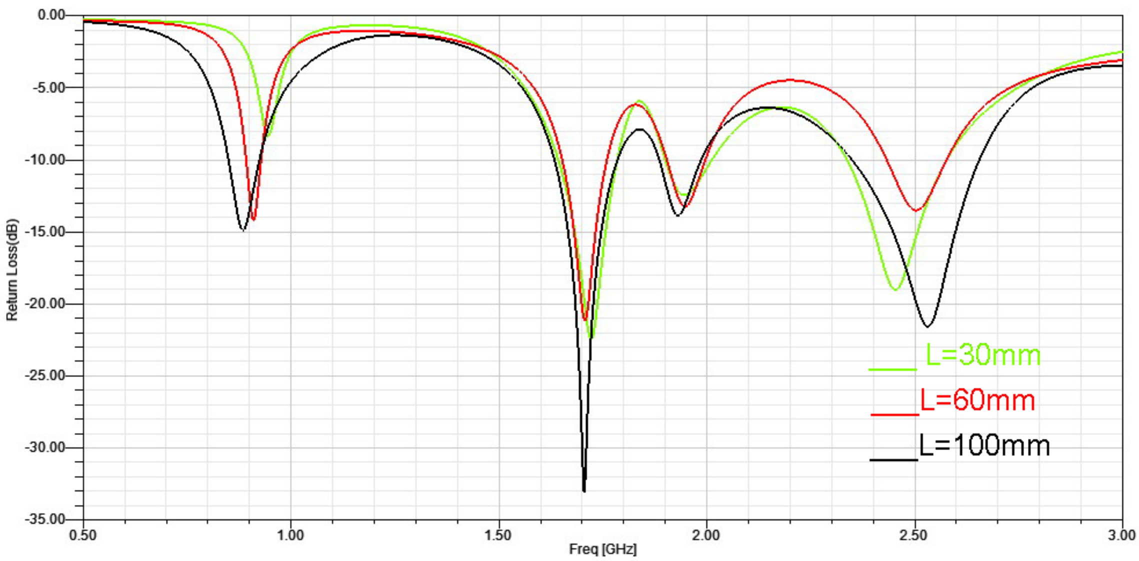


Figure3.14 Simulated return loss as a function of L, the length of system ground plane.

Chapter Four

Conclusion

In this study, I adopt the reference antenna in (Wong and Huang, 2008) as basis structure. The reference antenna presents a novel printed loop antenna on a thin FR4 substrate that can be mounted perpendicular to the top edge of the system circuit board with small size 10×60 mm^2 to occupy a small volume inside the mobile phone housing. The reference antenna capable of generating three resonant modes, first resonant mode occur at 900MHz, it's responsible for generating the first wide operating band centered at about 900MHz to cover GSM850/900 MHz operations, while the second, and third resonant mode occur at 1700,2050MHz. They responsible for generating the second wide operating bands centered at about 1900 MHz to cover DCS/PCS/UMTS operations.

All reported research tries to get the largest possible number of operating bands with smallest size without significantly affecting the antenna parameter performance. In my thesis, I worked to modify the structure of reference antenna while keeping the same size to cover the largest possible number of applications. I used the HFSS in order to achieve this modification. There are several variables in the basis structure. These variables can be controlled by using parametric study to reach the final dimensions of the proposed antenna. The modification of proposed antenna consist of changing the location of perpendicular feeding portion, adjusting the dimensions of the central tuning section, and length of feeding portion for the reference antenna in (Wong and Huang, 2008) . The proposed antenna capable of generating four resonant modes, the first resonant mode occur at 900MHz, it's responsible for generating the first wide operating band centered at around

900 MHz to cover GSM850/900 operations, while the second, third, and fourth resonant mode occur at 1700,1936,2500MHz, respectively. They responsible for generating the second wide operating band centered around 2165MHz to cover DCS/PCS/UMTS/WiBro/Bluetooth/Wimax operations. In the lower band, the gain and radiation efficiency for the proposed antenna more than the gain and radiation efficiency for the reference antenna from 820-850 MHz and 930-960MHz, while the gain and radiation efficiency for the proposed antenna less than gain and radiation efficiency for the reference antenna from 850-930 MHz. In the upper band, the gain for the proposed antenna less than the gain for the reference antenna from 1700-1800 MHz and 2050-2200 MHz, while the gain for the proposed antenna more than the gain for the reference antenna from 1800-2050MHz and 2200-2700MHz.The radiation efficiency of the proposed antenna less than the radiation efficiency of the reference antenna from 1700-2700MHz. In addition, the proposed antenna has small-excited surface current density on the system ground plane. This feature can lead to smaller antenna performance degradation when the mobile phone is held by the user’s hand/or attached to the user’s head.

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Appendix A

HFSS is a high performance full wave electromagnetic field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the finite element method, adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. HFSS is an interactive software package for calculating the electromagnetic behavior of a structure (Ansoft Corporation HFSS).Using HFSS, you can compute:

- Basic electromagnetic field quantities and, for open boundary problems, radiated near and far fields.
- Characteristic port impedances and propagation constants.
- Generalized S-parameters and S-parameters renormalized to specific port impedances.
- The eigenmodes, or resonances, of a structure.

The steps that have been followed to create, simulate, and analyze a proposed antenna in this thesis:

- *Launching Ansoft HFSS*

To access Ansoft HFSS, click the Microsoft Start button, select Programs, and select the Ansoft, HFSS 10 program group. Click HFSS 10

- Setting Tool Options

To set the tool options:

1. Select the menu item Tools > Options > HFSS Options

2. HFSS Options Window:

   a. Click the General tab

      - Use Wizards for data entry when creating new boundaries: √Checked
      - Duplicate boundaries with geometry:√ Checked

   b. Click the OK button

3. Select the menu item Tools > Options > 3D Modeler Options.

4. 3D Modeler Options Window:

   a. Click the Operation tab

      - Automatically cover closed polylines: √Checked

2. Click the Drawing tab

      - Edit property of new primitives: √Checked

3. Click the OK button

- Opening a New Project

To open a new project:

1. In an Ansoft HFSS window, select the menu item File > New.

2. From the Project menu, select Insert HFSS Design.

- Set Solution Type

To set the solution type:

1. Select the menu item HFSS > Solution Type

2. Solution Type Window:

   a. Choose Driven Modal

   b. Click the OK button

Creating the 3D Model

❖ Set Model Units

To set the units:

1. Select the menu item 3D Modeler > Units

2. Set Model Units:

   a. Select Units: mm

   b. Click the OK button`

❖ Set Default Material

To set the default material:

1. Using the 3D Modeler Materials toolbar, choose Select

2. Select Definition Window:

   a. Type FR4 in the Search by Name field

   b. Click the OK button

❖ Creating Box#1

1. Select the menu item Draw>Box.

2. Using the coordinate entry fields, enter the Box position

   X:0 Y:0 Z:0

3. Using the coordinate entry fields, enter the opposite corner of the box:

   dX:10 dY:60 dZ:0.8

4.To set the name:

   a. Select the Attribute tab from the Properties window.

   b. For the Value of Name type: horizontalsubstrate

   c. Click the OK button

- ❖ Creating Box#2

1. Select the menu item Draw>Box.
2. Using the coordinate entry fields, enter the Box position

   X:5.4 Y:0 Z:0

3. Using the coordinate entry fields, enter the opposite corner of the box:

   dX:0.8 dY:60 dZ:-104

4.To set the name:

a. Select the Attribute tab from the Properties window.

b. For the Value of Name type: verticalsubstrate

c. Click the OK button

- ❖ Set Default Material

To set the default material:

1. Using the 3D Modeler Materials toolbar, choose Select

2. Select Definition Window:

a. Type copper in the Search by Name field

b. Click the OK button.

- ❖ Creating rectangles

➢ Create side tuning left

1. Select the menu item Draw>rectangle.

2. Using the coordinate entry fields, enter the rectangle position

X:0 Y:0 Z:0

3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

dX:10 dY:8 dZ:0

4.To set the name:

a. Select the Attribute tab from the Properties window.

b. For the Value of Name type: sidetuningleft

c. Click the OK button

- Create Loopwidth#1

1. Select the menu item Draw>rectangle.

2. Using the coordinate entry fields, enter the rectangle position

X:0 Y:8 Z:0

3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

dX:1 dY:19 dZ:0

4.To set the name:

a. Select the Attribute tab from the Properties window.

b. For the Value of Name type: Loopwidth1

c. Click the OK button

- Create Feedleft

1. Select the menu item Draw>rectangle.

2. Using the coordinate entry fields, enter the rectangle position

X:0 Y:27 Z:0

3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

dX:6 dY:2 dZ:0

4.To set the name:

a. Select the Attribute tab from the Properties window.

b. For the Value of Name type:Feedleft

c. Click the OK button

- Create FeedRight

1. Select the menu item Draw>rectangle.

2. Using the coordinate entry fields, enter the rectangle position

X:0 Y:31 Z:0

3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

dX:6 dY:2 dZ:0

4.To set the name:

a. Select the Attribute tab from the Properties window.

b. For the Value of Name type:FeedRight

c. Click the OK button

- Create Loopwidth#2

1. Select the menu item Draw>rectangle.

2. Using the coordinate entry fields, enter the rectangle position

X:0 Y:33 Z:0

3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

dX:1 dY:19 dZ:0

4.To set the name:

a. Select the Attribute tab from the Properties window.

b. For the Value of Name type: Loopwidth2

c. Click the OK button

- Create side tuning right

  1. Select the menu item Draw>rectangle.

  2. Using the coordinate entry fields, enter the rectangle position

     X:0 Y:52 Z:0

  3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

     dX:10 dY:8 dZ:0

  4.To set the name:

  a. Select the Attribute tab from the Properties window.

  b. For the Value of Name type: sidetuningright

  c. Click the OK button

- Create Loopwidth#3

  1. Select the menu item Draw>rectangle.

  2. Using the coordinate entry fields, enter the rectangle position

     X:10 Y:52 Z:0

  3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

     dX:-1 dY:-42 dZ:0

  4.To set the name:

  a. Select the Attribute tab from the Properties window.

  b. For the Value of Name type: Loopwidth3

  c. Click the OK button

- Create groundplane

  1. Select the menu item Draw>rectangle.

2. Using the coordinate entry fields, enter the rectangle position

X:5.4 Y:0 Z:-4

3.Using the coordinate entry fields, enter the opposite corner of the rectangle:

dX:0 dY:60 dZ:100

4.To set the name:

a. Select the Attribute tab from the Properties window.

b. For the Value of Name type: groundplane

c. Click the OK button

- Group Conductors

  - To group the conductors:

    1. Select the menu item Edit>select>Byname
    2. Select Object Dialog:

a. select the object named:sidetuningleft,Loopwidth1,Feedleft, Feedright, Loopwidth2, sidetuningright, Loopwidth3

Note: use the ctrl+left mouse button to select multiple objects

b. Click the OK button

3.Select the menu item, 3D Modeler> Boolean>Unite

- Create the Lumped port

To create a rectangle that represents the port:

1. Select the menu item Draw > Rectangle
2. Using the coordinate entry fields, enter the rectangle position

X: 4.6, Y: 14.25, Z: -104, Press the Enter key

3. Using the coordinate entry fields, enter the opposite corner of rectangle:

dX: 0.8, dY: 1.5, dZ: -104, Press the Enter key

To set the name:

1. Select the Attribute tab from the Properties window.
2. For the Value of Name type: port
3. Click the OK button

Create Lumped Port Excitation

To select the object port:

1. Select the menu item Edit > Select > By Name
2. Select Object Dialog,
   a. Select the objects named: port
   b. Click the OK button

To assign wave port excitation

1. Select the menu item HFSS > Excitations > Assign > Lumped Port
2. Lumped Port : General
   a. Name: p1,
   b. Click the Next button
3. Lumped Port : Terminals
   a. Number of Terminals: 1,
   b. For T1, click the Undefined column and select New Line
   c. Using the coordinate entry fields, enter the vector position

      X: 4.6, Y: 15, Z: -104, Press the Enter key

   d. Using the coordinate entry fields, enter the vertex dX: 0.8, dY: 0.0, dZ: 0.0, Press the Enter key

e. Click the Next button

5. Wave Port : Post Processing

Reference Impedance: 50

6. Click the Finish button

- Analysis Setup

  - Creating an Analysis Setup

To create an analysis setup:

1. Select the menu item HFSS > Analysis Setup > Add Solution Setup

2. Solution Setup Window:

   a. Click the General tab:

      Solution Frequency: 0.9 GHz

      Maximum Number of Passes: 20

      Maximum Delta S per Pass: 0.02

   b. Click the OK button

- Adding a Frequency Sweep

  To add a frequency sweep:

1. Select the menu item HFSS > Analysis Setup > Add Sweep

   a. Select Solution Setup: Setup1

   b. Click the OK button

2. Edit Sweep Window:

   a. Sweep Type: Fast

   b. Frequency Setup Type: Linear Step

      Start: 0.5GHz

Stop: 3GHz

Stop size: 1MHz

Save Fields: √ Checked

c. Click the OK button

- Save Project

To save the project:

1. In an Ansoft HFSS window, select the menu item File > Save As.
2. From the Save As window, type the Filename: Proposedantenna
3. Click the Save button

- Analyze

- Model Validation

To validate the model:

1. Select the menu item HFSS > Validation Check
2. Click the Close button

Note: To view any errors or warning messages, use the Message Manager.

- Analyze

To start the solution process:

- Select the menu item HFSS > Analyze All

تصميم هوائي حلقي شريطي يعمل بنطاق عريض وعند نطاقات عدة للاتصالات اللاسلكية

اعداد
اياد علي ابراهيم ابوالحاج

المشرف
الأستاذ الدكتور محمد كامل عبدالعزيز

ملخص

تم في هذه الأطروحة تقديم هوائي حلقي شريطي له مساحة 10× 60 مم^2 قادر على توليد اربع ترددات رنين لتشكيل نطاقين عريضين يعملان عند 900 و 2165 ميغاهيرتز ليغطيا ثماني نطاقات تشملGSM850 وGSM900 وDCS وPCS وUMTS وWiBro و Bluetooth و Wimax. يتكون هذا الهوائي من حلقة مطبوعة على لوح مادة عازلة FR4 رقيقة ذات حجم صغير و تغذية عمودية مطبوعة على منطقة عليا ضيقة غير مؤرضة من لوح الدارة الكهربائية.يعمل الهوائي المقترح كهوائي داخلي لانه يحتل حجما صغيرا داخل الهاتف الخلوي.تقدم هذه الأطروحة تصميم ودراسة باراميترية ونتائج محاكاة حاسوبية للهوائي المقترح. تركز هذه الدراسة على المعامل المرتد والكسب وكفاءة الهوائي وكثافة التيار السطحي المثار و المخطط الاشعاعي للهوائي. لتحقيق ذلك يتم استخدام برمجية HFSS. تقدم هذه الأطروحة ايضا مراجعة سريعة للمواضيع التالية: الهوائيات الحلقية الشريطية وخصائصها وطرق تغذيتها والدراسات السابقة لكيفية عمل هوائيات حلقية شريطية صغيرة وعريضة النطاق.