DESIGN AND ANALYSIS OF VARIOUS HANDSET ANTENNAS WITH THE AID OF HFSS

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C E R T I F I C A T E

This is to certify that the thesis entitled ***"DESIGN AND ANALYSIS OF VARIOUS HANDSET ANTENNAS WITH THE AID OF HFSS"*** *by* ***Mr.Girijala Ravichandran****, submitted to the National Institute of Technology, Rourkela for the award of Master of Technology in Electrical Engineering, is a record of bonafide research work carried out by him in the Department of Electrical Engineering , under my supervision. I believe that this thesis fulfills the requirements for the award of degree of Master of Technology.The results embodied in the thesis have not been submitted for the award of any other degree elsewhere.*

Prof.K. R. Subhashini

Place:Rourkela

Date:

To My Loving parents and Inspiring GUIDE

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I would like to dedicate this thesis to my amazingly loving and supportive parents who have always been with me, no matter where I am.

GIRIJALA RAVICHANDRAN

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Contents

Abstract

In this thesis, an attempt is made to present the design of handset antennas, the proposed handset acts as a thin wire model that represents the backbone of the final antenna. The designed antenna parameters are subjected to optimization to fit into the desired frequency bands. Different antenna types are used, such as wire antennas and planar antennas designed using the HFSS.The design of basic antennas for handset applications, experimented with a simple monopole and dipole in a 3-D form. The monopole and dipole used in handset antennas provides multi-band and broadband properties that cover the desired frequency bands in the handset antennas.

The design experiment and analysis of a continuous and unbroken metal rimmed antenna with a monopole which is directly fed with a patch acts as a loop antenna in smart phone applications is proposed. The antenna proposed here provides a straight forward and a good multi-band antenna result for an protected metal rimmed smart phone. The protected rim and two no-ground portions are set on the both the top and bottom sides of the system circuit board, respectively. The system ground is surrounded between the two no ground portions which are connected to the metal rim with a small grounded patch which divides the unbroken metal rim into two strips. Atlast the dual-loop antenna is formed by adjusting the ground plane and the microstrip in a proper way. The design antenna is operated on several number of GSM bands.

The second design is study of a balanced antenna with folded architecture for mobile handset applications with dual-frequency performance (2.40 GHz and 5.00 GHz) for WLAN applications are discussed. The thin-strip planar dipole is used as an antenna with folded architecture and two arms on each monopole. The folded architectures one on the left and other on the right acts as a dipole and are capable of providing the multiple bands .The antenna performance is featured by using the antenna radiation pattern,return loss, power gain and surface current distribution of the antenna. The parametric studies are carried out by varying the antenna height and width of 1 mm each, the parameters are optimized for steered impedance matching within the range of frequency bands for both the WLAN and short distance communication systems.

The third design is focused on the frequency band (1.8 GHz to 2.45 GHz) in which the balanced antenna for applications of mobile handsets with a bandwidth of highly improved performance. The slot planar dipole is used an antenna here with folded architecture and is having a dual arm on both the sides of the ground plane. The S-parameter method is used to find the antenna impedance. In order to obtain the power gain measurement in the antenna.The balanced feed from an unbalanced source is supported by planar balun which is of wide bandwidth to get the desired gain. The results measured provides a good agreement and also provides good wide-band characteristics.

List of Figures

List of Abbreviations

Abbreviation	Description
WLAN	Wireless Local Area Networks
GSM	Global System For Mobile Communications
RF	Radio Frequency
FEM	Finite Element Method
WiMAX	World Interoperability for Microwave Access
VSWR	Voltage Standing Wave Ratio
IMTS	International Mobile Telecommunication
PCS	Personal Communication System
UMTS	Universal Mobile Telecommunications System
DCS	Digital Communication System
FDTD	Finite-Difference Time Domain
HFSS	High Frequency Structure Simulator
HPBW	Half-Power Beamwidth

Chapter 1

INTRODUCTION

1.1 Introduction

Mobile communications, wireless interconnects, wireless local networks (WLANs) and phone advances make one in every out of the first rapidly developing in markets today. Actually, these applications need antennas. what's extra the mobile handsets are demanding that those are little, light-weight and minimal. These requests are dry spell an on the improvement of low-profile inner antenna with unrivaled execution. This being the situation, transportable antenna innovation has completely developed along the edge of mobile and cell advancements. it is critical to have the legitimate antenna for a gadget. the best possible antenna will enhance transmission and gathering, lessen power utilization, last more and enhance the attractiveness of the communication gadget. On the other hand, designing an inward antenna is actually testing as a consequence of the constrained antenna volume and impact of the instance of the mobile handset terminal. As mobile communications area unit growing rapidly new frequency bands are get into the picture. At the same time the service suppliers try to equip end users with new terminals that bring extra advantages from operating at more than one band. first commercial handheld portable terminals that may operate at 2 bands have also appeared on the market. nevertheless the dual band handset antennas still presents a challenge for each antenna design engineers and antenna manufacturers. In general, relatively simple dual band handset antennas are often divided into single feed and dual feed structures, whereas additional difficult solutions are supported adaptive array techniques. most often used external antennas i.e., monopoles and dipole antennas are used. one in all the foremost common antenna design for mobile handset operational inside the worldwide system for mobile communication (GSM, 890-960 MHz) and digital communication system (DCS, 1710-1880 MHz) band is planar monopole design, that the benefits include low-profile and easy fabrication. Besides the aforesaid basic operation, different major operational bands for wireless communication systems like personal communication system (PCS) covering bands from 1850 MHz-1990 MHz and wireless local area network (WLAN)covering bands from 2400 MHz -2484 MHz for IEEE 802.11b/g are commonly included.

1.2 Literature Review

Wireless communications have advanced very quickly in the past years, and plenty of mobile units are becoming shrinked. To fulfill the miniaturisation demand, compact antennas are needed. planar printed antennas have the active features of low profile, shrink size and corresponding to mounting hosts. theyŕe very promising candidates for satisfying the on top of applications. For this reason,both the broad band and compact based design techniques for planar antennas have appeal to more attention from antenna researchers. Very recently, especially after the 21st century, many novel planar antenna designs to satisfy specific bandwidth specifications of present-day mobile cellular communication systems, as well as the GSM band 890-960 MHz, ,PCS band 1850-1990 MHz and DCS band 1710 MHz -1880 MHz and therefore the UMTS band 1920 MHz -2170 MHz.In communication devices the planar antennas are also very attractive for applications in wireless local area network (WLAN) systems within the 2.4 GHz (2400-2485 MHz) and 5.2 GHz (5150-5450 MHz) bands.

Heejun Yoon et al. given the design of a multi-band internal antenna for mobile phone applications. Two antenna components are formed on both bottom and top of the same substrate and bring together by metallic pin to get the multi band characteristics.

A Multi-band FPMA has been proposed for mobile handset by Shun-Yun Maya Lin .Here designed an folded planar monopole antenna, that includes a very low profile of about one twentieth of the wavelength of the lowest in operation frequency. The result is successfully bring out by using a bent radiating patch which is in rectangular shape and an inverted l-shaped ground plane.

A novel compact antenna operating at DCS,GSM, PCS and IMT2000 bands has been conferred by Peng Sun et al. With a sensitively coupled ground branch, the antenna proposed here covers all 2G and 3G wireless communication bands. Best conferred a multiband round shape monopole antenna. The monopole which is in round shape exhibits broader impedance bandwidth and improved pattern performance. Kundukulam et al conferred a dual-frequency antenna arrived from a compact microstrip antenna by loading a pair of narrow slots near its radiating edges. The two operating frequencies exhibit parallel polarization planes and similar radiation characteristics.

Hao Chun Tung et al. proposed a printed dual band monopole antenna for 2.4/5.2GHz WLAN access point. The trident monopole antenna comprises a central arm for the 2.4 GHz band (2.42.484GHz) operation and two side arms for the 5.2 GHz band (5.155.35GHz) operation.

A double wide-band CPW-fed altered Koch fractal printed opening antenna, suitable for WLAN and WiMAX operations is proposed by Krishna et al.Here the working recurrence of a triangular space antenna is brought down by the Koch cycle strategy bringing about a minimized reception apparatus.

Koch fractal space reception apparatus has an impedance transmission capacity from 2.38-3.95GHz and 4.956.05GHz covering 2.4/5.2/5.8GHz WLAN groups and the 2.5/3.5/5.5 GHz WiMAX groups.

A minimized double band planar antenna has been proposed by Gijo Augustin et al. It is a Finite Ground CPW fed, double band monopole setup. The double band operation is accomplished by stacking the flared monopole recieving wire with a ”V”-molded sleeve.

Deepu et al. exhibited a smaller uniplanar antenna for WLAN applications. The dual band antenna is acquired by adjusting one of the parallel portions of an opening line, consequently creating two diverse current ways. The antenna reverberates with two groups from 2.20 to 2.50 GHz and from 5.00 to 10.00 GHz with great coordinating, great radiation attributes and moderate gain.

An inside GSM/DCS antenna supported by a step molded ground plane for a PDA Phone was proposed by K.L. Wong et al. The antenna has two emanating strips intended to work at around 900 and 1800MHz for GSM/DCS operation, and is upheld by a step molded ground plane.

Jeun-Wen Wu et al. proposed a planar meander line antenna wire comprising of three expanded strips for low-profile either DCS or PCS or GSM or WLAN triple-band operation of cellphones. The branch strips are intended to work as quarter-wavelength structures at 900 and 1800 MHz, individually, and covering GSM/DCS/PCS/GSM and WLAN groups.

Zhong, Jiangwei, Kang-Kang Chen, and Xiaowei Sun[x1] The built in slot is kept in between the metal frame and the metal ground of the handset antenna is taken as a part of the handset antenna, and the other part slot is engraved at metal strengthen plate, expecting to cover the liquid crystal display in mobile phone. S. Wang and Z. W. Du, antenna proposed here occupies a very small area on chip. The compact antenna is having a driven arm connected with a ground arm and by adjusting the antenna, which are to be printed in both the bottom layer and the top layer of a chip.

M. Zheng, H. Y. Wang, and Y. Hao, a fold monopole or dipole or loop antenna wire offers special preferences more than a routine Planar Inverted-F Antenna (PIFA) and monopole antenna for a portable cell gadget. The proposed antenna has four resonances in which three of them are 0.5 , 1 and 1.5 modes. The antenna proposed here is folded dipole which is in 2 mode, which has not been accounted for in this way, is excited and used.

B. Yuan et al. The antenna here gives an answer for planar unbroken metal-rimmed handsets and can be worked in five wireless communication bands . Kingsley, S., here they described how dielectrics can be used to improve the performance of electrically small antennas, as well as describes techniques to integrate the antenna, with the radio to create an antenna module. T. Sasamori, T. Tobana, and Y. Isota, here they had measured the input impedance for the balanced Antenna by using return loss (s-parameter)method

Collins, B. S., S. P. Kingsley, J. M. Ide, S. A. Saario, R. W. Schlub, and S. G. O'Keefe, characterize the another multi band antenna consolidating an adjusted feed system which indicates significant resistance from the typical ground plane impacts and focuses the best approach to novel based antenna designs which can be moved between stages with almost no adjustment.

1.3 Objectives

The fundamental intention of this thesis is to design a handset antenna with multiple number of bands suitable for mobile handsets. By utilizing a monopole and dipole antenna, the space interest of the antenna as a major aspect of a mobile handset can be minimized, along these lines diminishing the prominence of the handset's appearance.

This thesis has three essential targets:

- Select and design an low profile,productive and realizable antenna able to operating at a frequency of the following frequency bands (900 MHz, 1.8 GHz and 2.0 GHz).

- Verify the operation of the antenna at the prescribed frequencies in terms of s-parameters,radiation pattern and gain using the antenna design software ANSYS HFSS.

- Examine the impacts of conformality on the antenna regarding execution.So as to accomplish the first target as set out over, a thorough writing is needed to get an antenna that requires insignificant alteration to suit the necessities of this theory. As the procedure of improving an antenna's measurements to meet an arrangement of determinations is exceptionally thorough, discovering an antenna that works proficiently at the three obliged frequencies, too being minimized and having a low profile, is very much desired

1.4 Thesis Organization

The thesis work has been organized as follows:

- In chapter 2, a brief introduction of small antenna theory and background is presented.Further discussed the dielectric loading,resonant frequency and concept of an unbalanced and balanced antenna.

- Chapter 3 In chapter 3, the design and analysis of metal rimmed mobile antenna has been discussed.The analysis is carried out by taking the return loss,radiation pattern and the field varying patterns

- In Chapter 4,the design and analysis of Wideband balanced folded dipole antenna with a dual arm monopole structure for mobile handsets is discussed with the help of the results like antenna return loss and some parametric variation

- Chapter 5, the design and analysis of compact compact dual band balanced handset antenna for wlan applications.simulations done on the design to obtain the results of various performance parameters are discussed. The return loss characteristics, gain plot, VSWR plot patterns and parametric variations are presented in this chapter.

- Chapter 6,This chapter gives the conclusion to this thesis and the future work continued antenna design by using a different structure configuration.

Chapter 2

SMALL ANTENNA THEORY AND BACKGROUND

Mobile device communications have become an important part of the telecommunication industry. Starting with the paging services, there are new applications emerging every day including tagging, wireless computer links, wireless microphones, remote control, wireless multimedia links, satellite mobile phones, wireless internet so its just about everything goes mobile. The significance of mobile phones has increased rapidly in last few years, it has become a necessity to a human life. Moreover, the rapid growth in mobile communication systems has led to a great demand for the development of internal antennas with the multiband and broadband operations. Handset platforms can have different designs like bar, clamshell, slider, swing and flip. In the case of a clamshell, slider and flip, the connection points for two parts can have influence on the antenna performance[1]. There is a need to make a self resonant and self immune antenna, as there might be some impact on antenna performance because of the style and its geometry and the presence of other antennas for GPS or for MIMO functionality. It has lead to an increase in the complexity of the antenna along with the commercial pressures to make cheaper models that occupy less volume in the handset. The two big challenges in designing a handset antenna are: how to use a single antenna to cover all the useful frequency bands and then how to make the antenna size small enough so that multiple antennas can be deployed in a handset. So one can see the pressure to design small, lightweight and user friendly mobile handsets devices creating a need for the optimal antennas for mobile applications. The antenna is a device which is used to transform a guided wave to a radiated wave or the other way around. According to the wave propagation theory the radiation capability of an antenna depends on its wavelength for the designed frequency. So the size of an antenna is much more important in determining how well and for which frequencies this transformation will be satisfactory. For an efficient antenna the size should be of the order of half a wavelength or larger. By miniaturizing the size of an antenna, it will influence its radiation characteristics, bandwidth, gain and efficiency. Moreover, it is not always easy to feed a small antenna efficiently.

2.1 Dielectric Loading

Dielectric materials available today were originally designed for dielectric resonator filters putting stringent requirements on the material parameters. Thus, todays antenna designers can make use of available low losses and wide range permittivity (up to 100) materials. Antennas can be loaded by a dielectric material. The permittivity and shape of the material determines the effective wavelength. As the wavelength is shorter in a high permittivity material, the antenna size can be reduced. This is due to the concentration of the electric field in high permittivity materials, which makes the adaptive launching of a guided wave into free space more difficult. High permittivity materials usually have higher dielectric losses. If the material is loss free, higher permittivity increases the Q-factor at a given frequency and thereby reduces the available bandwidth. The added losses, on the other hand, increases the bandwidth, but, on the expense of radiation efficiency. Aside from size diminishment, another motivation to utilize dielectric antennas is that they are more impervious to detuning when set to different items like the human body on account of the handset antennas. On the off chance that the dielectric material is utilized as a part of the antenna where the electric fields or streams are high, it makes the antenna more proficient than its all metal counterpart.

2.2 Resonant frequency

Another parameter associated to the antenna design is the frequency of operation or the resonant frequency. There is a range of frequencies over which the antenna can be operational, giving the bandwidth of an antenna. The antenna can be considered as a tuned circuit containing inductance and capacitance. It has a resonant frequency at which the capacitive and inductive reactances cancel each other. At the resonance it has purely resistive impedance, which is a combination of loss resistance (Rloss) and radiation resistance (Rr). These capacitances and inductances of an antenna are determined by the physical geometry of the antenna and its environment.

2.3 Input Impedance of an antenna

Antenna impedance is defined as the real (R) and reactive part (X) seen at the port of the antenna. It is a function of frequency (ω). If no losses are included in the antenna model, then the real part impedance seen at the port is purely radiation resistance.

$$Z(\omega)=R(\omega)+jX(\omega)$$

2.4 Lumped component matching

Antennas with a size smaller than half a wavelength show a strong reactive input impedance and very low resistance. This reactive impedance can be compensated by loading the antenna with lumped components. This might be a simple way to make the antenna smaller, at the lower resonant frequency. This can be illustrated by the example of a simple loop. Its input impedance is highly inductive and can be matched with a capacitor. As the radiation resistance of a loop antenna is much small, any losses caused by the matching circuit or the antenna structure itself can reduce the . If there is less loss then it improves the Q, thus reducing the BW.

2.5 Radiation resistance

The radiation resistance is a measure of the antennas ability to radiate an applied signal into space or to receive a signal from space. The radiation resistance is not a dissipative resistance, rather its a measure of the power radiated into the free space for a given input current.As the size of an antenna decreases, its reactance increases but its radiation resistance decreases. Thus, large antennas have higher radiation resistances and higher radiation efficiencies.

2.6 Return loss

It is the distinction in the middle of forward and reflected power, in dB, by and large measured at the information to the coaxial link joined with the antenna. In the event that the power transmitted by the source is Pt and the power reflected back is Pr, then the return loss is given by Pr. For most extreme power exchange, the return loss ought to be as little as could be allowed. This implies that the proportion Pr/Pt ought to be as little as conceivable, or communicated in dB, the return loss ought to be as substantial a negative number as could be allowed. Return Loss is resolved in dB as follows

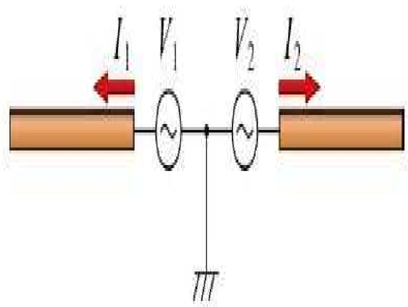
$$RL = -20log_{10}\,|\Gamma| \tag{2.1}$$

where $|\Gamma|$ is the reflection coeffiecient

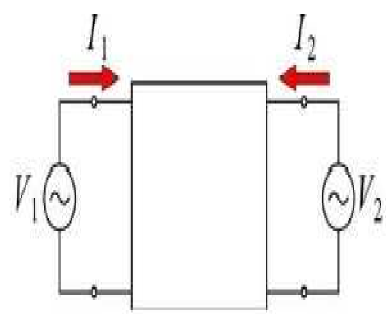
2.7 S-Parameter method

Figure 2.1 shows the dipole antenna, which is one of the balanced fed antennas. Using the impedance matrix of the two-port network as shown in figure below, the equation for the dipole antenna is given by

$$\left.\begin{aligned} V_1 = Z_{11}I_1 + Z_{12}I_2 \\ V_2 = Z_{21}I_1 + Z_{22}I_2 \end{aligned}\right\} \tag{2.2}$$



(a) dipole antenna



(b) two port network

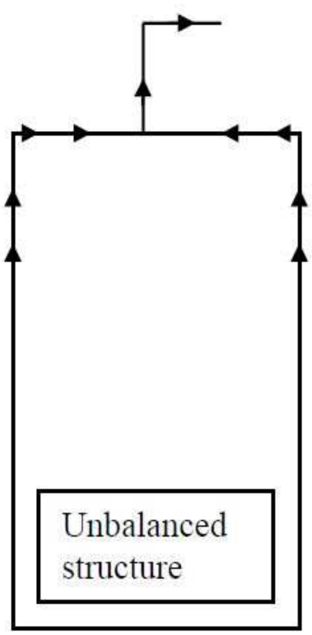
Figure 2.1: s-parameter method

$$Z_{in} = V_d/I = Z_{11} - Z_{12} - Z_{21} + Z_{22} = 2Z_0\frac{(1-S_{12})(1-S_{21}) - S_{11}S_{22}}{(1-S_{11})(1-S_{22}) - S_{12}S_{21}} \tag{2.3}$$

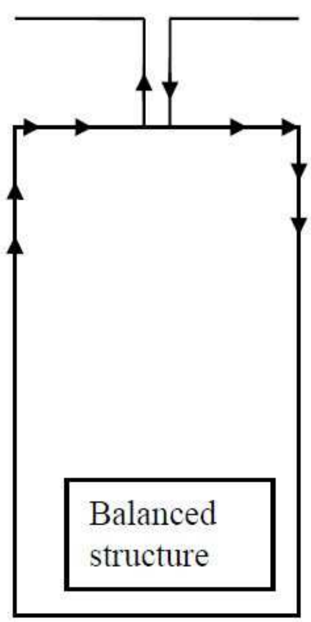
$$= \frac{1}{C}(A - D + AD + BC - 1) \tag{2.4}$$

2.8 Concept of an unbalanced and balanced antenna

Consider a simple monopole structure, i.e., a single ended structure. The length of the antenna is a quarter of a wavelength. To make this antenna work more efficiently and have large bandwidth, image theory is used which makes the ground plane as a part of the antenna and improving the radiation characteristics. Such structures or antennas that are depending on the ground characteristics are known as unbalanced antenna, where PIFA is a good example. The current towards the ground plane is not balanced in case of a monopole as compared to the balanced antennas and thus causing a radiation of electromagnetic field from the ground plane. For balanced (feed consists of two lines over ground) and self balanced (single feed, but still balanced ground currents) structures the ground plane does ideally not contribute to the radiation characteristics. A dipole antenna has a balanced structure. Figure demonstrates the flow of currents towards the ground plane for both cases.



(a) monopole antenna



(b) dipole antenna

Figure 2.2: Unbalanced and Balanced structures of an antenna

Fig.2.2 the unblanced structure shows the currents towards antenna from the PCB, while in balanced structure the two opposite currents on PCB can be seen, which cancel each other, making the antenna structure independently resonant. PIFA antenna has an unbalanced structure. It is a popular internal multiband antenna. However, it suffers from poor efficiency and narrow bandwidth. PCB is added as an additional radiating element to the antenna, which improves the bandwidth. It can be seen from the monopole current distribution that it will lead to large excited surface currents on the system ground plane. The location of the antenna near the end of the PCB is important for proper coupling or to excite the supporting wavemode on the chassis[**?**] .This dependency then puts some limitations on the width and height of the antenna element with respect to the ground plane. In the case of a balanced antenna which is more independent of the ground plane, it seems natural that when the ground plane conditions are changed, the radiation characteristics of the antenna will be less affected. The balanced structure offers the advantage of reduced detuning and greater efficiency as compared to the single ended monopole antenna, when the mobile device is in normal use [2]. To meet the same bandwidth requirements, usually the size of a balanced antenna is twice as large as an unbalanced antenna, e.g., a monopole (quarter wavelength) and a dipole (half wavelength). In the low band of 900 MHz the antenna has to be unbalanced as the wavelength is in a region where the whole PCB is needed as the primary radiator. The size of the antenna is inside the Chu-Harrington limit[3], which means it will either be an inefficient radiator or lack sufficient bandwidth without the use of PCB as the main radiator. The balanced mode would typically be above 1.5GHz.

Chapter 3

Metal Rimmed Mobile Antenna

3.1 Introduction

In recent years, smartphones have entered into a rapid development period and have gradually become the main communication tools[4]. Furthermore, a smartphone with an unbroken metal rim has become an obvious trend. The metal rim can not only provide sufficient mechanical strength to extend the service life of the smartphone, but also can possess a wonderful appearance, which is very desirable for consumers.

Not surprisingly, the performance of the previous antennas designed for smartphones will be affected dramatically, if the metal rim, without any modification, is placed around the housing of the smartphone.In [5], it has presented a detailed explanation about how the unbroken metal rim influences the performance of the internal antenna. The unbroken metal rim sets up a bad feedback link to the internal antenna which introduces an undesired coupling between the unbroken metal rim and the internal antenna. The undesired coupling affects the performance of the internal antenna adversely which will increase the design difficulty for antenna designers to achieve multiband of an antenna. Recently, several promising solutions[5] have been demonstrated which can resolve the effects of the metal rim. For example, in , it has shown a method to reduce the effects of the metal rim by inserting three gaps and two grounded patches. Besides, by judiciously choosing the locations of the gaps and the grounded patches, this method can alleviate the effects of the metal rim. In [6], it has presented a compact slot antenna of 15.5×56.5 mm by adding several grounded patches between the bottom system ground and the unbroken metal rim. The two slots are fed by the same feeding strip, which can cover five WWAN bands of GSM850/900/DCS/PCS/UMTS2100 operation. Seen from the above discussion, both of them occupy too much space of the PCB and the width of the narrow edges of these two antennas is always more than 15 mm, which are not suitable for narrow-frame antenna designs[7][8]. In addition, another promising candidate for the metal-rimmed smartphone antenna is exciting and employing the different chassis' characteristic modes [6]. However, its biggest drawback is the narrow-band operations. In order to widen the impedance bandwidth, many effective techniques have been reported in [9]. The usual effective techniques of widening the impedance bandwidth include the matching network [10], coupled-fed and reconfigurable technique. In [9], it has introduced a novel antenna structure combining a nonself-resonant CCE and a self-resonant ILA antenna occupying only 750 mm . However, it needs a matching network which needs a correct selection of low-loss components. In [9], it has proposed a small antenna system using nonresonant planar elements for 2G, 3G, and 4G occupying about 700 mm . In [11], it has presented a coupled-fed dual-loop antenna capable of providing eight-band WWAN/LTE operations. This method indeed can widen the impedance matching but it will increase of antenna tuning in the final optimization process, because its performance is very sensitive to the coupled gaps between the feeding strip and shorting strip.The reconfigurable antenna is controlled by one p-i-n diode to choose the antenna mode between loop antenna mode and an inverted-F antenna mode. Unfortunately, the p-i-n diode will also introduce insertion loss. To alleviate these problems, a simple direct-fed dual-loop antenna capable of providing more numbers of bands for WWAN/LTE operation under surroundings of an unbroken metal rim in smartphone applicationsThe unbroken metal rim is directly fed by a coaxial feed line and then connected to the system ground by a small grounded patch. Thus the unbroken metal rim is partitioned into two stripes and a dual-loop antenna is shaped by consolidating the internal framework ground and two strips. The biggest merit of the proposed antenna is that it keeps the integrity of the metal rim and sufficient bandwidth to cover hepta-band WWAN/LTE operation. Hence, it is very promising for metal-rimmed smartphone applications.

3.2 Proposed Antenna Configuration

Figure demonstrates the geometry of the proposed dual-loop antenna shaped by an unbroken metal rim for WWAN/LTE smart phones, whose exact structure and optimized values are given in Fig.3.1. As represented in Fig.3.2, an 0.8-mm thick FR4 substrate of relative permittivity 4.4 and loss tangent 0.024 is utilized as the system circuit board. The system circuit board of 130×70 mm is embraced by an unbroken metal rim whose height is of 5 mm and thickness is of 0.3 mm. The distance between the system circuit board and the metal rim is 2 mm[6]. Two non-ground portions of 10×70 mm and 5×70 mm are set on the top edge and bottom edge of the system circuit board, respectively.In the middle of two different no-ground parts, there will be an system ground plane with the length of 115 mm and the width of 70 mm.Seen from fig 3.1 a mini coaxial feed line is employed to excite the antenna connected to the feeding point (point A) and the grounded point (point B). The distance between the feeding point and the base edge of the system circuit board is 25 mm. The unbroken metal rim directly fed by a mini coaxial feed line is connected to the system ground by a small grounded patch. The unbroken metal rim is divided into two stripes by the grounded patch. Finally, the dual-loop antenna is framed by joining the inner system ground and two strips. The distance between the grounded patch and the base edge of the system circuit board is 50 mm.

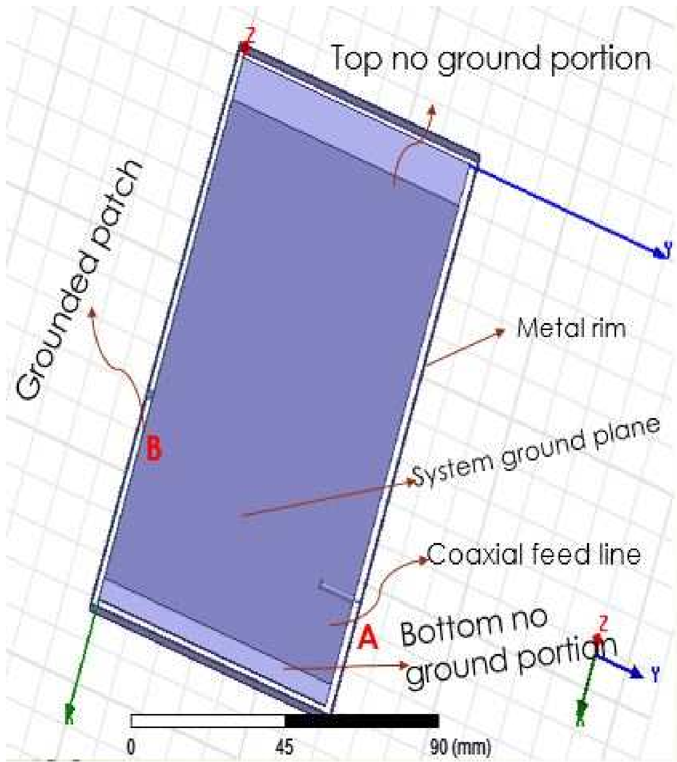


Figure 3.1: Geometry of metal rimmed mobile antenna

The length of the Loop 1 is about 260 mm which allows it to generate a loop mode (at 0.67 GHz) as the fundamental mode. The high-order resonant mode of Loop 1 such as and modes are also excited. The length of the Loop is about 156 mm (about at 1.13 GHz) which can provide two high-order resonant modes (and modes). The two fundamental modes of the Loop 1 and Loop 2 generate a wide bandwidth to cover the GSM850/900 operation. The desired band DCS/PCS/UMTS2100/LTE2300/2500 is provided by the high-order modes to operate both the loop1 and loop 2.

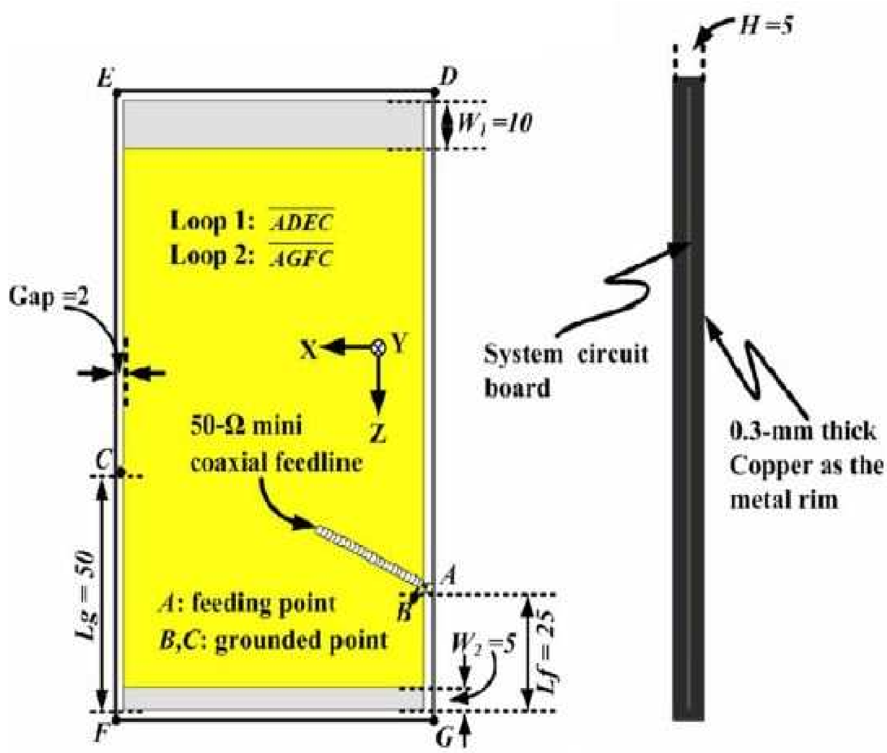


Figure 3.2: dimensions of metal rimmed antenna in detail

3.3 Results and discussion

3.3.1 Return loss for loop 1

The simulated antenna design resonates at 1.05 GHz, 1.2 GHz,1.7 GHz,2.00 GHz,2.1 GHz,2.3 GHz and 3.00 GHz and exhibit return loss of -10.54 dB,-15.217 dB,-14.619 dB,21.8134 dB,-17.574 dB,-19.249 dB and -16.782 dB. more negative is the return loss, more is the coupling and therefore more will be the directivity and gain of the proposed antenna.

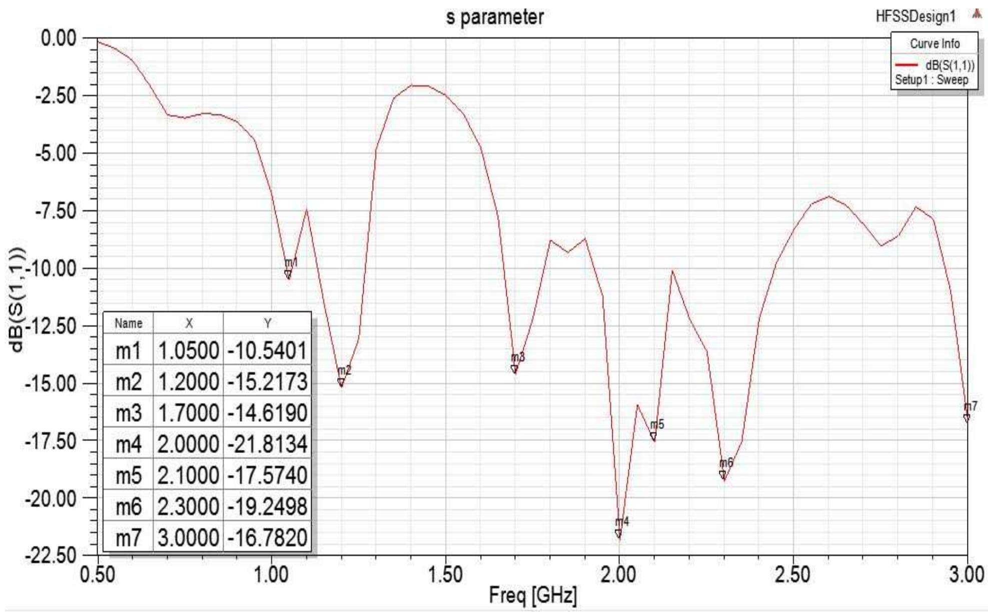


Figure 3.3: s-parameter of loop 1

3.3.2 Return loss for loop 2

The simulated antenna design resonates at 1.10 GHz, 1.35 GHz,1.7 GHz, 2.12 GHz, 2.26 GHz and 2.7 GHz GHz and exhibit return loss of -15.01 dB,-23.89 dB,-20.68 dB, 14.08 dB ,22.12 dB and 17 dB respectively.

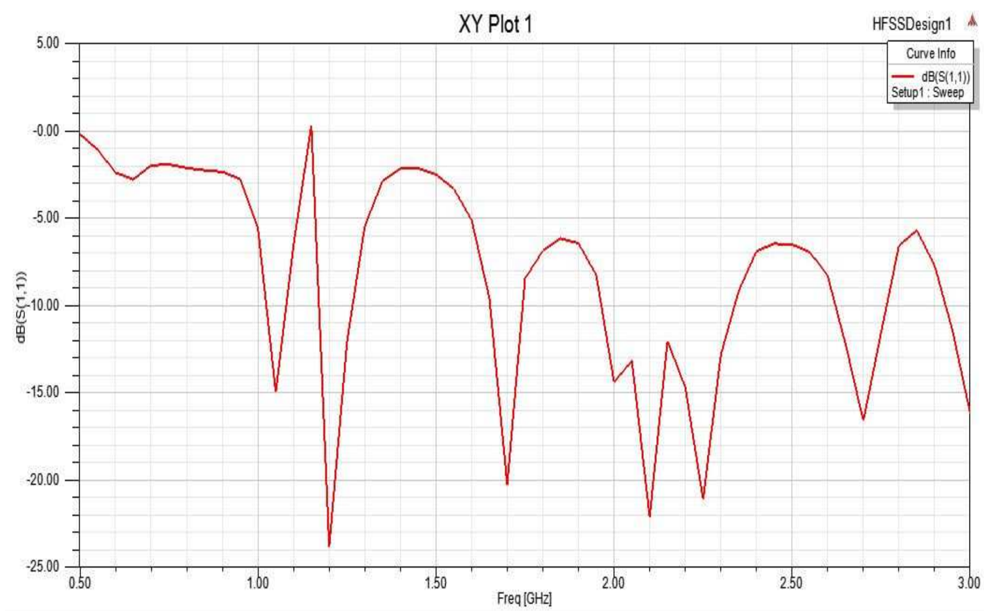


Figure 3.4: s-parameter of loop 2

3.3.3 VSWR of the antenna

This Voltage standing wave ratio is the ratio used for matching and tuning of the transmitting antennas. In practical applications the value of VSWR usually lies between 1 and 2.The voltage standing Wave ratio of the patch antenna in fig. 3.5 this plot show that the value of VSWR is less than 2 at resonating frequency 1.75 GHz, 2.00 GHz, 2.1 GHz and 2.30 GHz.

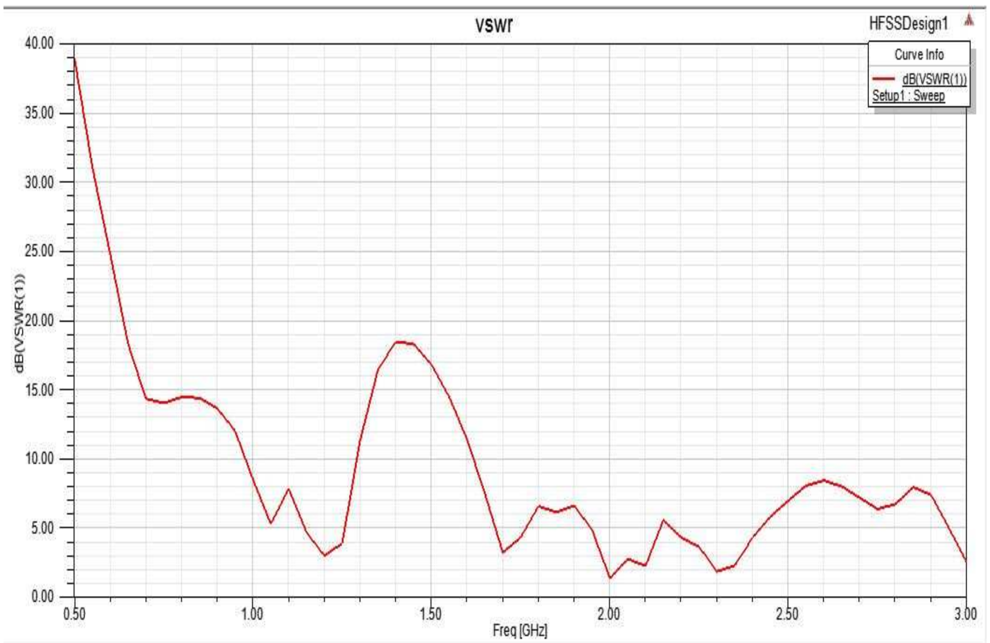


Figure 3.5: vswr of the metal rimmed antenna

3.3.4 parameteric study of the metal rimmed antenna

In the proposed antenna ,the two no ground portions plays a major role in impedance matching. The size of the two no ground portions effects the ground portion are analyzed, where the simulated results are included in Fig 3.6 and Fig.3.7 shows the influence on the antenna performance when varying the width $w_1$of the top no-ground portion.The lower band is mainly effected due to the impedance matching over the range of frequencies.when the length w_1 varied from 5 to 15 mm For w_1= 5 mm, the lower band impedance matching is not good. As increasing the width w_1 , the improved impedance matching of the lower-band is obtained. In this study, the width of the top no-ground portion is chosen as 10 mm for good impedance matching and minimizing the size of the top no-ground portion.

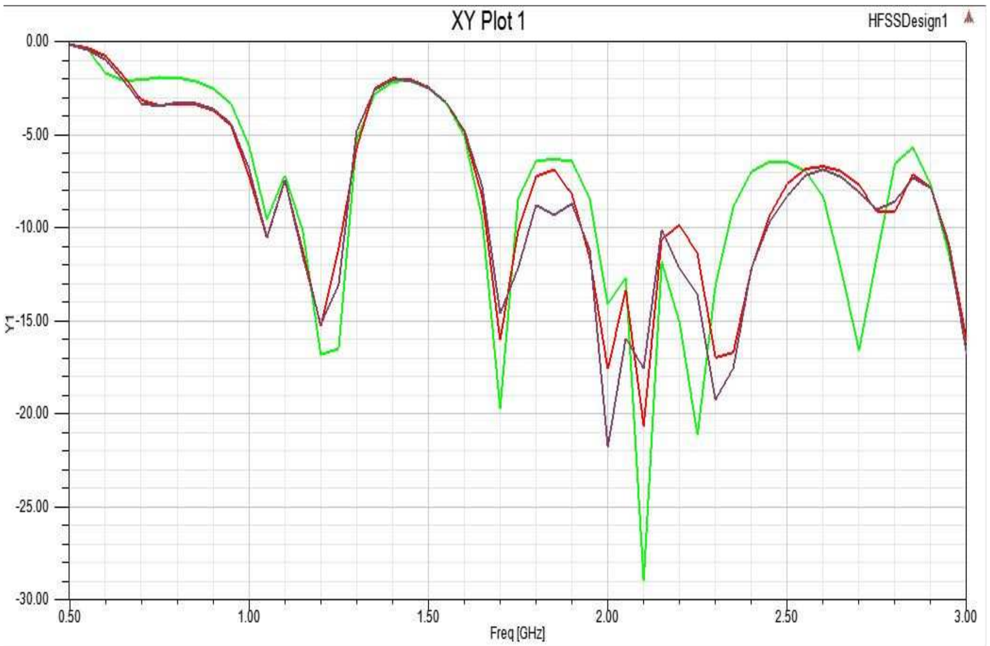


Figure 3.6: parametric study of w_1

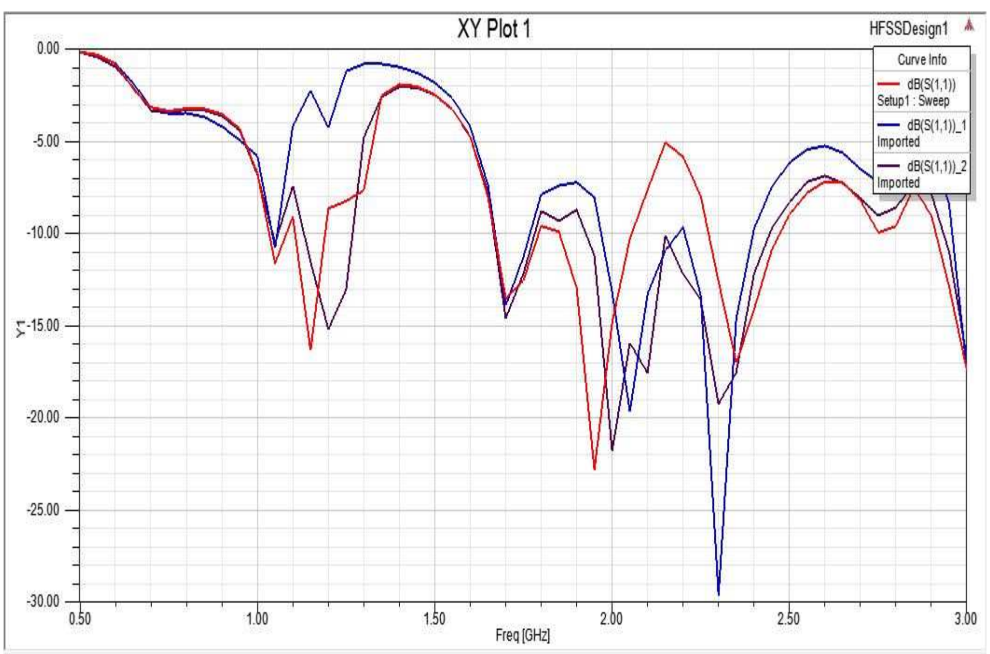


Figure 3.7: parametric study of w_2

From Fig. 3.7, the width w_2 of the bottom no-ground portion effects the impedance matching over both the lower-band and upper-band. The impedance matching is not likely good, if without the bottom no-ground portion. Taking into account both bandwidth and miniaturization of the proposed antenna, The width w_2 is varied from 0 mm to 10 mm.Here the width $w_2 = =5$ mm is a suitable choice for the bottom no-ground portion which provides good impedance matching.

3.4 Conclusion

A simple metal rimmed mobile antenna capable of providing multiple number of bands for WWAN/LTE operation under surroundings of an unbroken metal rim in smartphone applications is proposed and studied in this thesis. By combining the multi resonant character of the dual-loop antenna, the proposed antenna can provide two wide operating bands of 824960 MHz and 17102690 MHz, respectively. A prototype of the proposed unbroken metal-rimmed antenna has been successfully designed, and measured. The obtained measured results including S parameter, antenna peak gain, and total efficiency are presented, which can meet the requirements for smartphone systems.In addition, the greatest highlight is that the proposed antenna keeps the integrity of the metal rim very well, which is very promising for metal-rimmed smartphone applications.

Chapter 4

Wideband balanced folded dipole antenna for mobile handsets

4.1 Introduction

From the last 10 years, the requirement to extend antennas bandwidth in mobile hand-held devices can begin to be additional urgent, owing to the ever-growing data rates and for this reason spectrum requirements of mobile devices. The antenna designs implementation inflicting reduced coupling with the human head and hand, and hence reduced performance variations and SAR(specific observation rate), would be engaging to several customers, so growing the market value of devices using WBFD antennas. Traditionally, the unbalanced planar inverted-F antenna (PIFA) is one in all the foremost popular candidates for closely packed inbuilt mobile handset antennas. PIFAs utilize the bottom plane as the radiation ground, that allows an awfully compact antenna to realize adequate gain and bandwidth [12]. In the majority situations, the currents in the radiating are induced on the ground plane and therefore the element of antenna. In use, however, when held by users these WBFD antennas show poor performance . An excellent replacement may be a balanced antenna [13] containing a regular structure can be fed with balanced currents. The leading and commonly encountered balanced antennas are Dipoles and loops [14]. Balanced currents merely runs on the antenna element, so severely decreasing the current flow effect on the ground plane. As an outcome, balanced antennas might have good efficiency and, more significantly, sustain their performance when in use side by side to the human body. Balanced antennas may, nonetheless, have a few impediments, similar to size imperatives in low-frequency bands (e.g. GSM900) for mobile phones applications, since the wavelength is long then such that the antenna is not equipped for being obliged inside of the handset box. The balanced antenna techniques will be applied to bands higher than 1.5 GHz in higher bands [15]. In the open literature an antenna design is reported that of type multi-band balanced [16]. The narrow band nature of balanced antennas is another constraining variable for handset applications. Some novel strategies are anticipated for the upgrade of impedance bandwidth, for occasion, a genetic algorithm strategy has been upheld to improve the impedance bandwidth [17]; and a parametric study has been connected to the length and width of strip lines to acquire a more extensive bandwidth for the the folded loop antenna framework [14]. In this chapter, the attributes of an inbuilt balanced folded dipole antenna with a remarkable double arm structure, expected for mobile handsets is acquainted and examined so as with acknowledge multi-band operation, together with GSM1800, GSM1900, UMTS and Bluetooth LAN (2.4 GHz). Within the analysis, an electromagnetic (EM) test system taking into account the finite integration technique was connected to figure return loss and radiation patterns. A technique for the measuring of input impedance of the proposed antenna was self-tended to and a two-dimensional balun with corresponding wide transmission capacity for feeding the proposed antenna was portrayed in a feeding. At last, the simulated and measured results for the antenna are displayed, analyzed and specified.

4.2 Antenna design concept and structure

The antenna designed here is to attain the wideband operation for mobile handset applications. The balanced antenna with dual arm structure is shown in figure4.1 is placed at one end of a rectangular conductor plate (120×50 mm), which can be used as a ground plane of the mobile handset in practical situations. Planar monopole antennas have been used so far after that it is used for ultra wide-band((UWB) applications. [18], [19]. A dipole is configure with facilitate the assistance of a intergrating the paired monopole antennas and still we tend to get the wide bandwidth characteristics. In the majority the balanced folded antennas, the planar dipole antenna works very good in free space and tends to perform badly when placed within the section of different conductors (e.g. mobile phone ground plane). Thus, so as to mitigate the effects of the ground plane inflicting degradation of antenna performance.

A method was connected by embeddings wring on every one of the arms of the planar dipole is proportional back the outcomes of the instigated current on the framework ground plane. Therefore, a ground plane amid which the current is impelled could have less common effect on the collapsed dipole versatile antenna. After that the antenna may have the capacity to be put near to the ground plane of the handset (e.g. 1 mm away) with a specific end goal to accomplish an implicit low profile highlight, the two arms of the dipole antenna were obliged to be collapsed. The prior outline idea for adjusted portable antennas was connected and actualized in the creators' past work, as outlined in [20]. In this plan, a further change on the impedance transfer speed for the antenna was explored, keeping in mind the end goal to cover an extra band at 2.45 GHz for WLAN, since most cellular telephone offered inside of the business is having that kind of components . Hence, in order to fulfill and satisfy the versatile business requests, the planned portable antenna was recreated for multi band application.

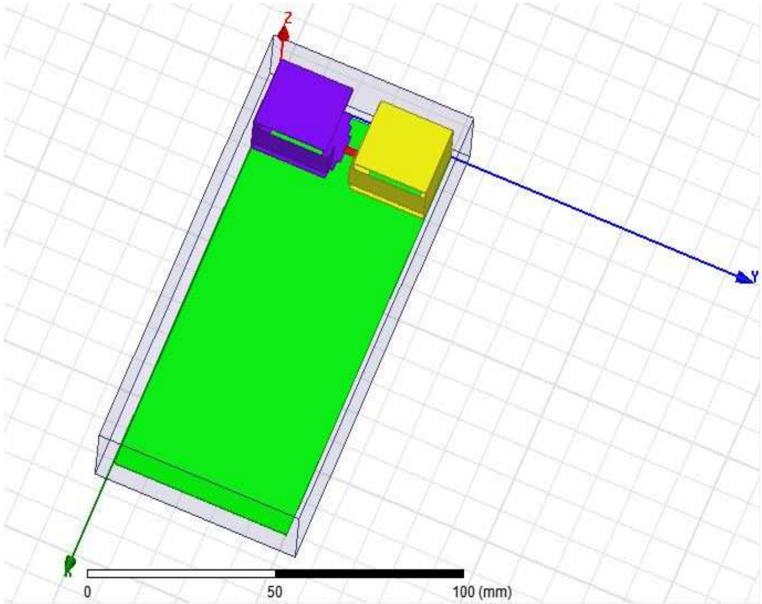
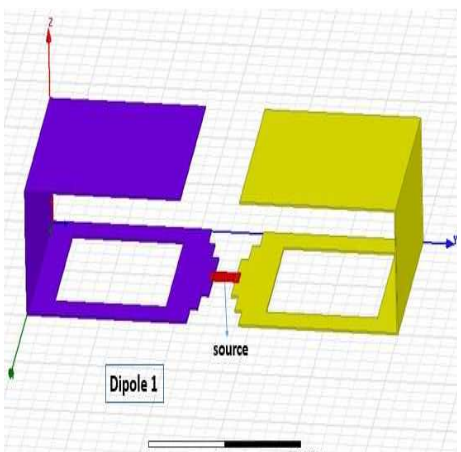
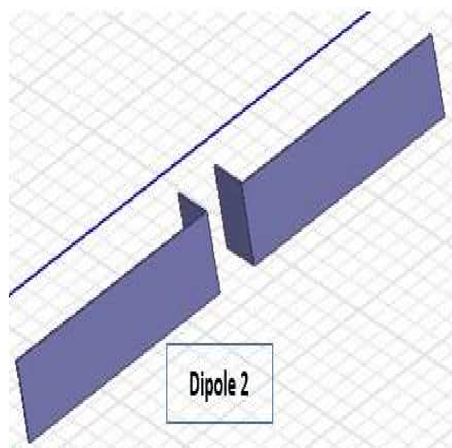


Figure 4.1: Balanced folded dipole antenna with conducting plate



(a) Dipole 1



(b) Dipole 2

Figure 4.2: proposed multi band antenna design

At first, an antenna (referring as 'dipole 1': see Fig.4.2a, working at around 2 GHz, was designed and optimized utilizing the HFSS. Likewise, another system was connected by embeddings an extra thin-strip arm (alluding as 'dipole 2': see Fig. 4.2b for each planar dipole arm to create another resonant frequency in the 2.45-GHz band. Utilizing this procedure, the balanced resonant antenna was adjusted and grew as a wideband double resonant variation for multi-band operation. It is striking that asymmetrically ventured structure was misused at the edges of the arms close to the food point, as indicated in Fig.4.1, supplanting the symmetrical triangle trimming structure as utilized as a part of [20]. This is on the grounds that the ventured design has better control of the impedance bandwidth, as found in the examination. The opening size including its area and length, likewise the area of extra arms for 'dipole 2', together with different parameters (see Fig.**??**) of the proposed antenna, were balanced and further advanced to guarantee that the design completely secured the obliged frequency bands (17102484 MHz) at which the VSWR at the input port is under 3 (it is proportional to return loss of 26 dB)

4.3 Results and discussion

4.3.1 Return loss of folded dipole antenna

The return loss is the loss occured due to the amount of power that is lost to the load and does not return as a reflection.The simulated antenna design resonates at 1.73 GHz and 2.6 GHz and exhibit return loss of -14.236, -20.43 respectively.If the return loss is more negative then the coupling is more therefore the directivity willl be more for the proposed antenna in that particular direction.

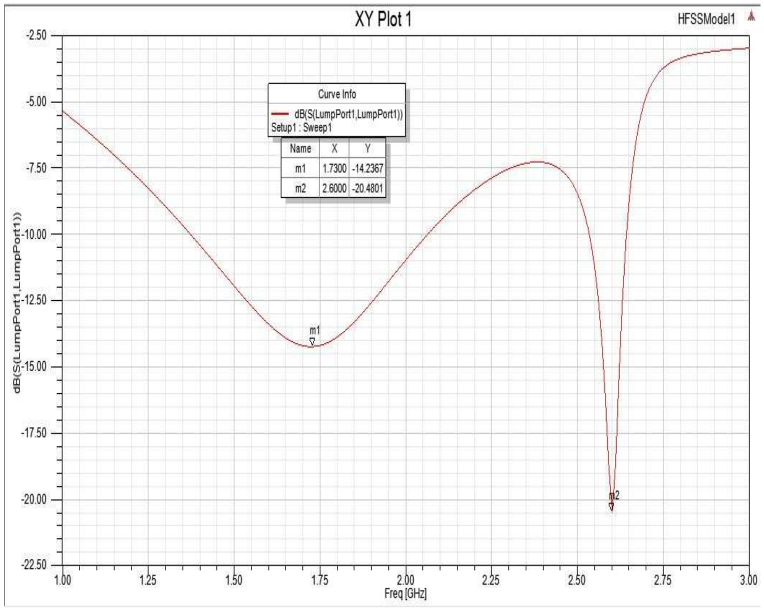


Figure 4.3: Return loss of the Balanced folded dipole antenna

4.3.2 voltage standing wave ratio

The voltage standing Wave ratio of the proposed antenna in figure 4.4 this plot show that the value of VSWR is less than 2 at resonating frequency 2.45 GHz.

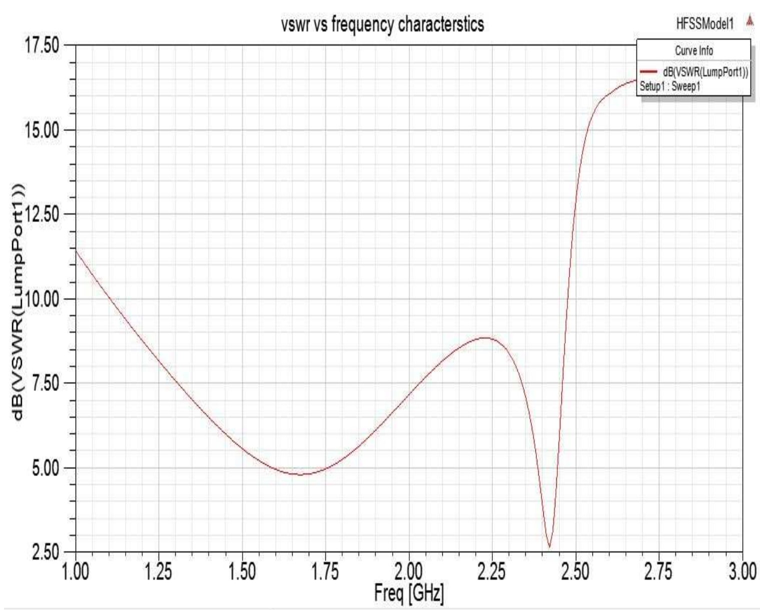


Figure 4.4: vswr of the proposed antenna

4.3.3 Parametric study of the antenna

In this section, the effect of the various physical parameters likes length,thin strip by varying the individual parameter and keeping all other parameters constant so that one can get optimized antenna for the desired applications.Here the parameter n is varied from 21 mm to 24 mm .By observing the return loss vs frequency plot it can be observed that at n=24 gives a return loss of -27.3 dB so it will be the optimum value gives the best results.

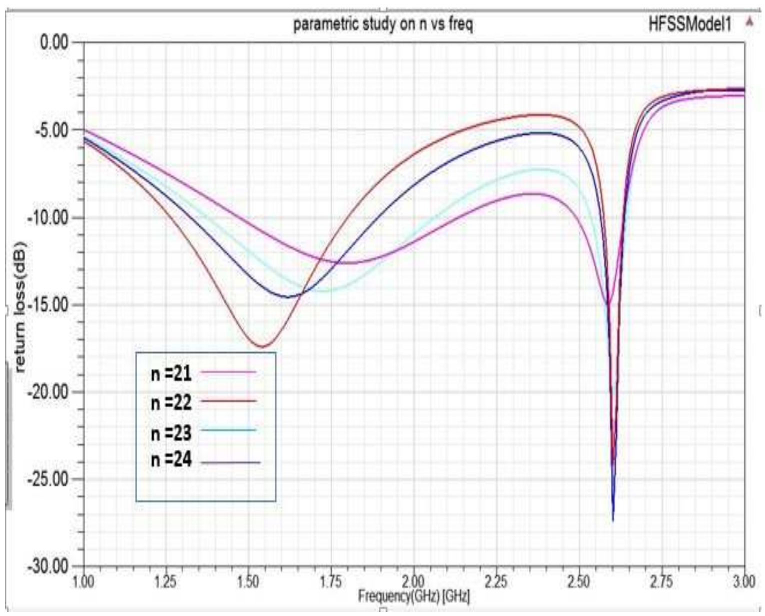


Figure 4.5: Parametric study on parameter n against operating frequency

The fig ??hows the effect of change in the parameter x_1 from 12 mm to 15 mm.By decreasing the value x_1 from 15 mm to 12 mm, the value of return loss decreases and the resonating frequency shifts towards lefts and there is a small decrease in return loss at the lower band but overall there is a good impedance matching and return loss.

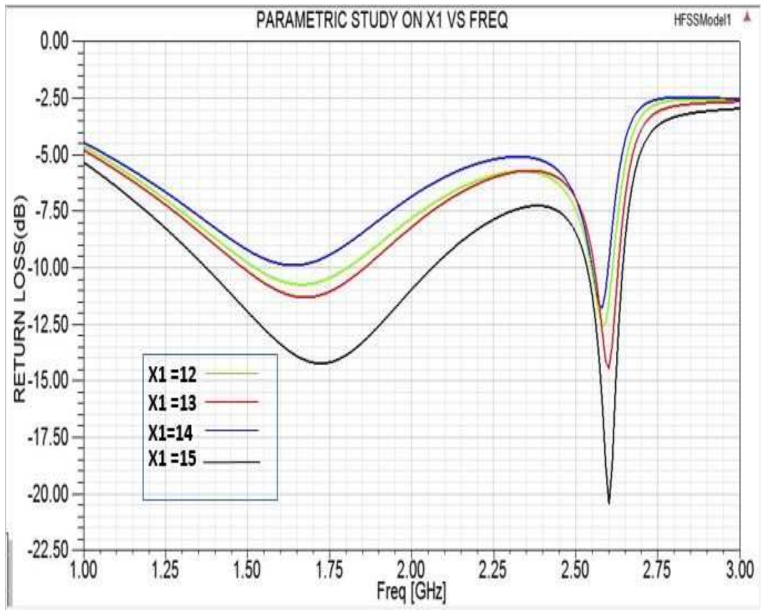


Figure 4.6: Parametric study on parameter $x_1$against operating frequency

The figure below shows the effect of change in the parameter thin strip e_2 from 2 mm to 6 mm.By decreasing the value e_2 from 2 mm to 6 mm, the value of return loss decreases and the resonating frequency shifts towards lefts and there is a small decrease in return loss at the lower band but overall there is a good impedance matching and return loss.

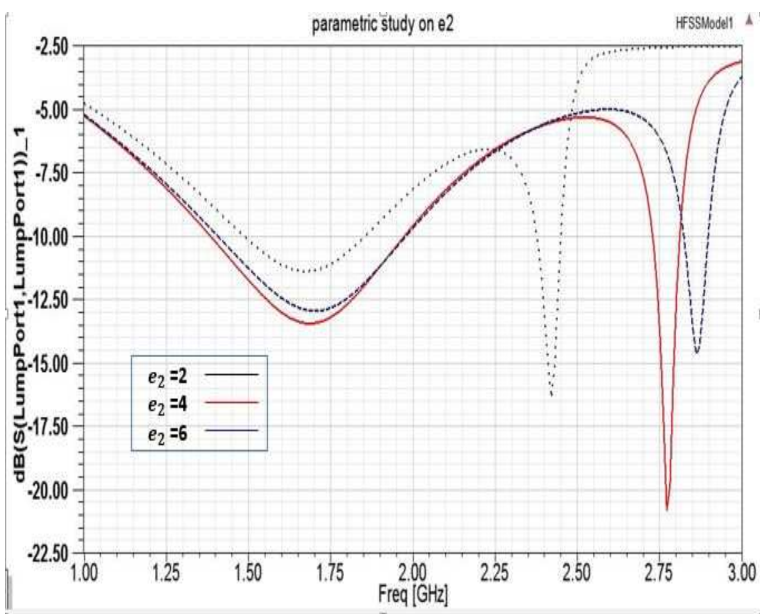
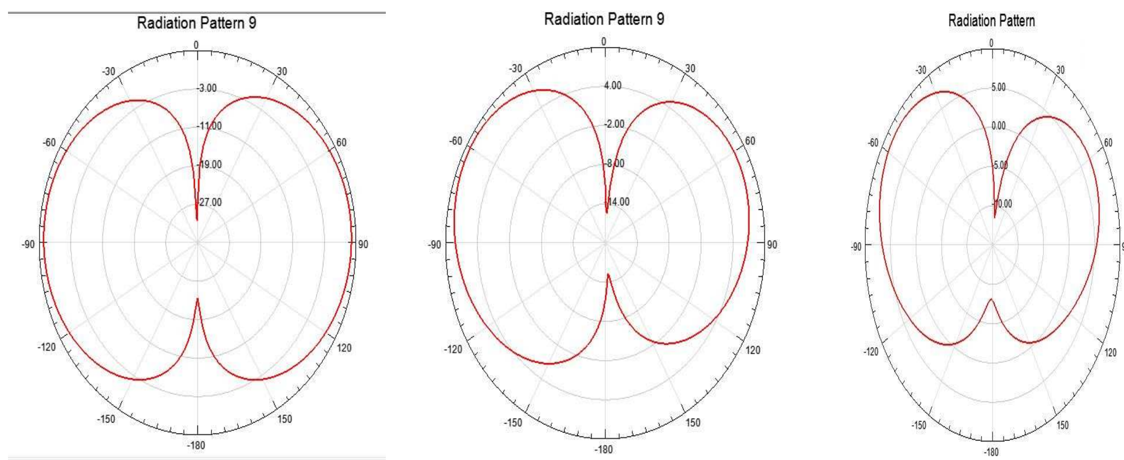


Figure 4.7: Parametric study on parameter e_2 against operating frequency

4.3.4 Radiation Pattern

The Radiation pattern of the balanced dipole antenna at different frequencies i.e., at 1.94 GHz, 2.04 GHz and 2.45 GHz



(a) at 1.94 GHz (b) at 2.04 GHz (c) at 2.45 GHz

Figure 4.8: Radiation pattern

4.4 Conclusion

A wideband balanced folded dipole antenna, together with its feeding network working over the GSM1800, GSM 1900, UMTS and 2.45-GHz bands, has been exhibited and investigated. Examination of return loss and far-field radiation designs estimations demonstrated a decent assention with recreations utilizing HFSS. The execution of the model balanced antenna additionally demonstrated that there was insignificant communication with the ground plane, with the outcome that the attributes were autonomous to the length of ground plane and communication with the group of the client would be minimized, this makes it an appealing applicant for mobile handset applications.

Chapter 5

Compact Dual-band Balanced Handset Antenna

5.1 Introduction

wireless communication has been portrayed of the new current move to make the mobile hand- sets little and lightweight as would be prudent; while not trading off usefulness. To scale down in accordance with shopper needs and yearning and hold multiband usefulness, mobile handsets advancement ought to be portrayed by making every single physical part as little as physically potential. The key issues thought-about here on the design of antenna frameworks for little handsets identifies with keeping the antenna execution unaltered or enhanced, regardless of the fact that the antenna size turns out to be little and lessens the corruption of antenna execution brought on by the administrator's adjoining effect[13]. A balanced structure may be a genuine choice to evade the said debasement of the antenna execution when held by clients [21] since balanced streams just flow on the antenna component amid this kind of antenna, along these lines significantly decreasing the consequence of current flow on the base plane.

Accordingly, balanced antennas ought to have a brilliant strength and a considerable measure of essential to deal with their execution once being used neighboring the human body[20]. Lately, numerous novel mobile antennas designed with the balanced procedure have incontestable the enhanced stability of antenna execution, contrasted with the unbalanced sort, once the telephone is just about put by the caput and/or hand [16]. An implicit planar metal plate antenna for mobile handsets with the balanced operation is exhibited in this paper. The antenna was designed by folding a meager strip planar dipole with an additional arm on an extra monopole. The antenna elements balanced operation is to diminish this flow on the directing surface of the handset body. The antenna design model expects to cover 2.4 GHz furthermore the 5 GHz LAN applications. So, this paper exhibits and explores another design of an implicit double frequency balanced antenna for LAN and short-go remote interchanges. The attributes of this balanced collapsed antenna with a novel double arm structure for mobile handsets ar investigated, and additionally ascertaining the return loss and the radiation patterns for comparisons.

5.2 Antenna design

The balanced antenna structure proposed here is shown in Fig.5.2 The antenna was constructed from a copper sheet with thickness of 0.15 mm. Fig.5.1 shows one side of the folded dipole antenna, in which the cooper plate was folded up to become a folded dipole antenna. The proposed antenna is achieved by using two tier processes in order to generate another resonant frequency. Firstly, it was begun by folding the monopole arm and having an opening inside each monopole with a cut on the base side, as demonstrated Fig.5.1. Also, an extra thin-strip arm was embedded into every arm of the planar dipole. This collapsed component of the proposed antenna was designed to work at 2.4 GHz with a solitary arm to produce the second resonant frequency for 5 GHz frequency band[16]. Keeping in mind the end goal to accomplish a low- profile collapsed (i.e., lower d) balanced antenna, while keep up the adequate impedance bandwidth needed at the two WLAN groups, a long opening is presented on the each collapsed arm of the dipole antenna. Along these lines, the comparable wavelength of the surface current at 2.4 GHz is expanded, contrasted with the case without the long opening. Accordingly, the collapsed antenna height (d) can be lessened by 50% and the low-profile design is thusly figured it out. The optimized dimensions of the proposed antenna to operate at required bands are: a = 18.5 mm, b = 8 mm, d = 5 mm, c = 11.5 mm, w = 3 mm, h = 4 mm, t = 1.5 mm, f = 2 mm, g = 10.5 mm. The antenna is mounted 1mm above the ground plane with dimension of 90× 40 mm. Parametric study has been done to streamline the impedance matching bandwidth for the proposed antenna to accomplish the obliged impedance matching covering the frequencies bands of intrigued at 2.4 GHz and 5 GHz bands for WLAN and short range communication systems.

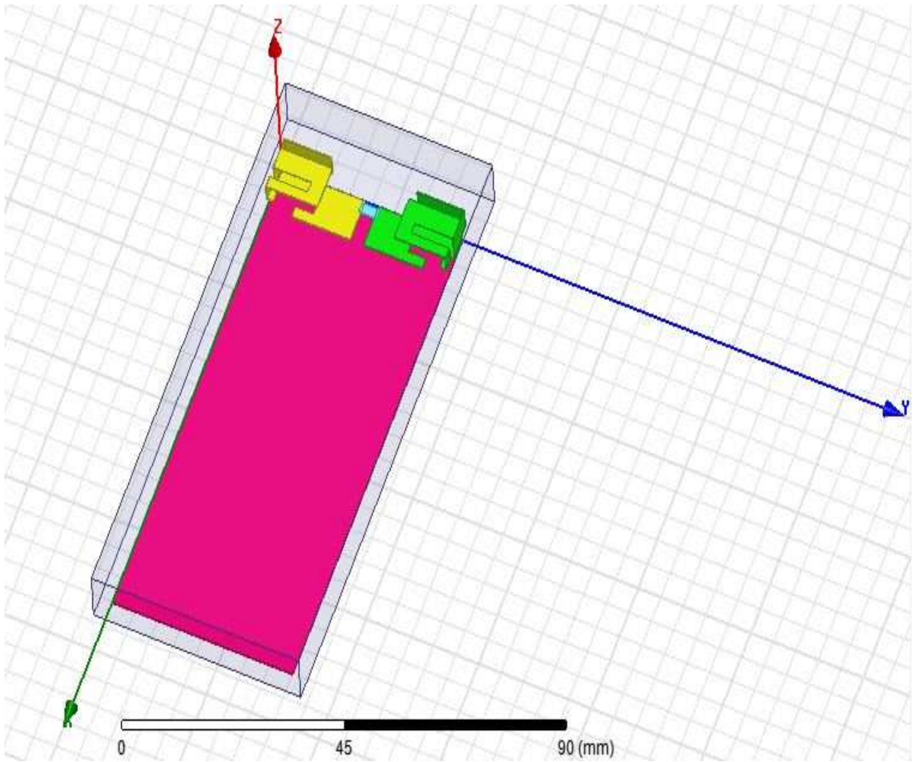
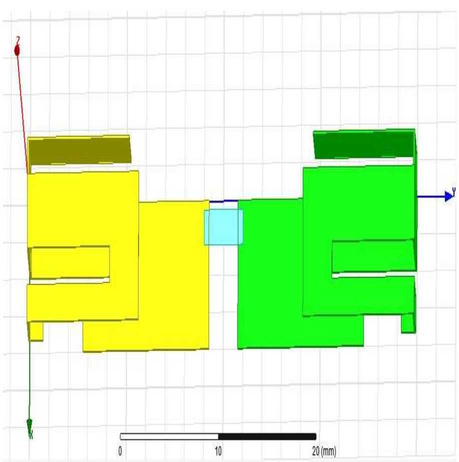
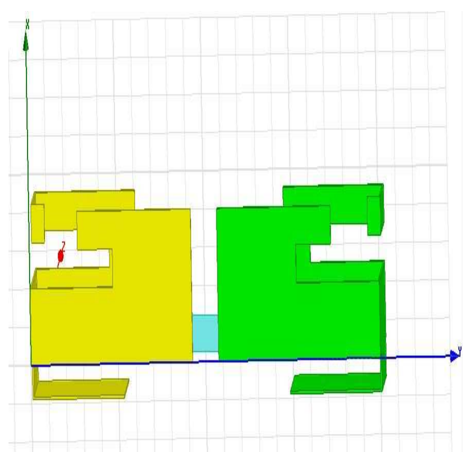


Figure 5.1: proposed balanced antenna design



(a) Top view



(b) Bottom view

Figure 5.2: Balanced mobile antenna

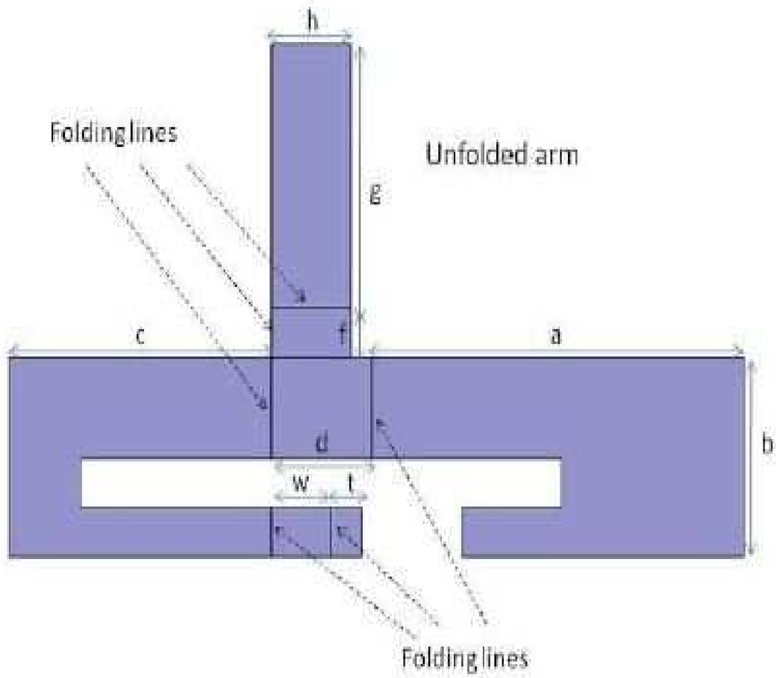


Figure 5.3: unfolded structure with important parameters

The antenna height (h and w) were thought to be the most touchy parameters to control the impedance bandwidth of the proposed antenna for meeting the design objectives. The parameter h was fluctuated from 2 mm to 5 mm with 1 mm every stride and w parameter was differed from 1 to 4 mm with likewise 1 mm step. To completely comprehend, the impact of these parameters taking into account its impedance bandwidth, the parametric study will be done here with stand out parameter are shifting at once, while others keep steady with the expect ideal quality. The ideal estimation of h and w were discovered to be 4 mm and 3 mm as indicated in Fig.5.6 and Fig.?? separately. By altering the length and area of the extra arm of the proposed antenna, it was able to let the antenna covers the required two frequency bands at acceptable return loss 10 dB. The proposed antenna features of the compact design used, has the size dimensions of $(l = 38) \times (w = 10) \times (h = 4)$.

5.3 Results and discussion

5.3.1 Return loss of the compact balanced handset antenna

The simulated antenna design resonates at 2.7 GHz, 5.05 GHz and 7.00 GHz exhibit return loss of -21.361, -10.955 and -9.9474 respectively.

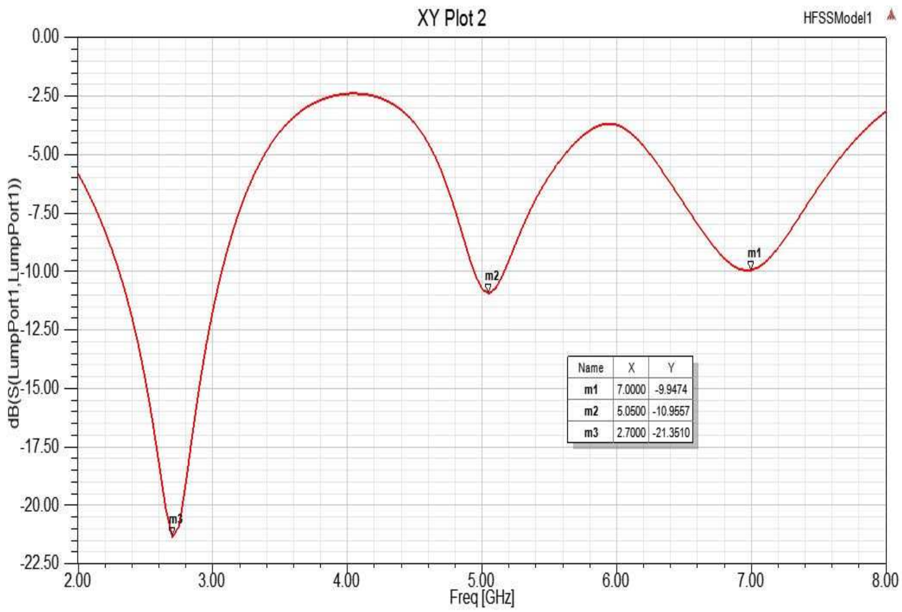


Figure 5.4: s parameter of the balanced antenna design

5.3.2 Parametric variations of the compact balanced handset antenna

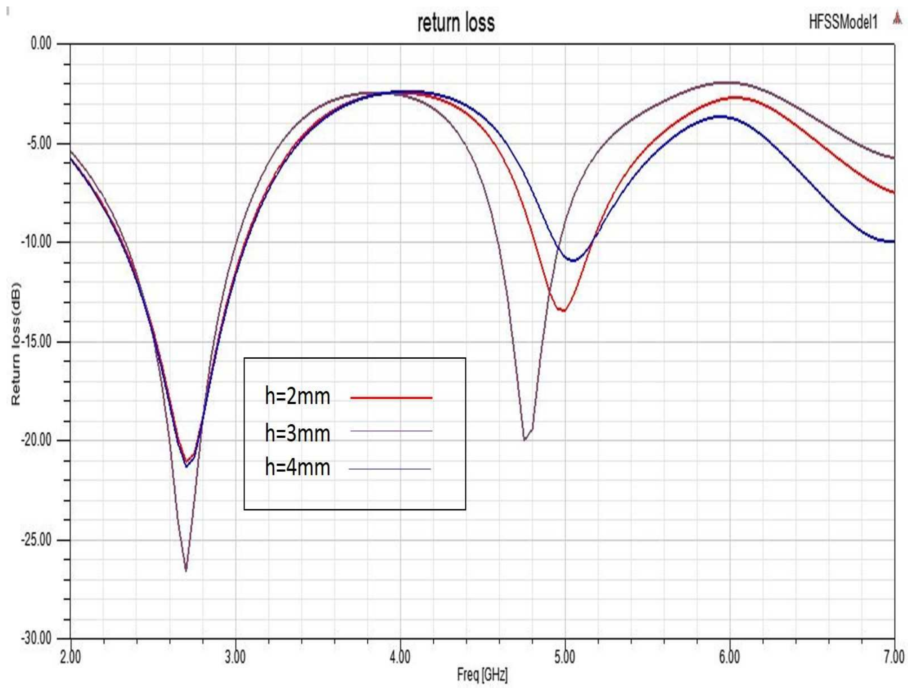


Figure 5.5: parameter variation of w

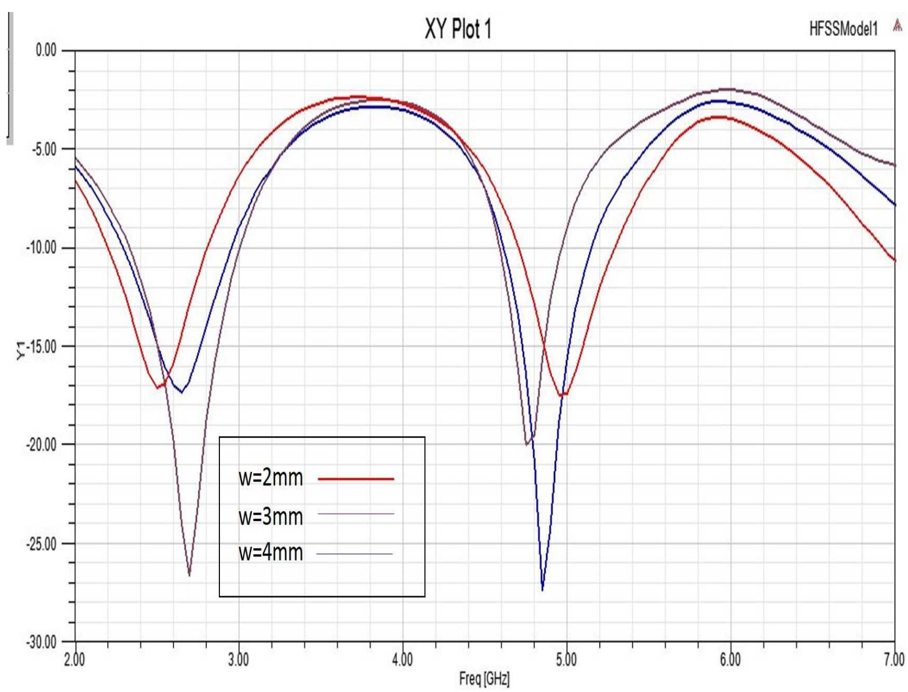


Figure 5.6: parameter variation of h of the folded arm

5.4 Conclusion

A novel minimized double balanced handset antenna for mobile gadgets has been displayed. The proposed antenna model was designed and measured to confirm the design idea. The qualities of proposed balanced antenna were broke down regarding antenna return loss, VSWR and antenna gain. The reproduced results show great concurrence with the deliberate one and in this way show that the proposed design can be suggested as a promising competitor mobile-antenna solution for WLAN applications.

Chapter 6

Conclusion and Future Scope

6.1 Conclusions

During the last decade, the mobile phone communications industry has grew at such fast rate. This phenomenon has not only seen a large increase in mobile phone users all over the world but also produced more wireless communication systems. Due to these reasons the demand for multi-band antennas increases. With the advancement of technology, wireless communication devices such as mobile phones have now become smaller and more compact, thus the antenna to be used in such devices should be small, low profile and should support more services. Therefore, the objective of the work done is to design a multi-band antenna for use in handheld devices, which provides support to several cellular and non-cellular technologies. The main purpose of this thesis is to achieve a new antenna design that supports various frequency bands such as 2G, 3G, 4G, GPS, Bluetooth and WLAN. And the designed antenna can be integrated with any handheld device because of its low profile, small size features. However, this is done through very complex and time consuming process where problems were faced and dealt with constantly. Nevertheless, many interesting characteristics of the PIFA antenna have been uncovered and good results are achieved.

- The designed multi-band antenna,is very sensitive to any changes to the dimensions of the structure including the ground plane.

- Ground plane of the antenna can also be used as a radiator resulting in overall size reduction and improvement in operating bandwidth.

- PIFA generally have two very good characteristics, which is small in size and having omnidirectional radiation pattern.

6.2 Future Scope

Taking into account the conclusions are drawn and limitions of the work exhibited, future work can be
done in the accompanying areas:

- Further, the antenna prototype developed can be used to study the performance of the antenna with human interaction and investigate the Specific Absorption Rate (SAR) value by employing human model testing.

- The antenna structure can be placed inside a handheld device casing and it can be analyzed using an Anechoic chamber.

- The outline proposed in this thesis can be stretched out for supporting MIMO applications for
  the gadgets which support LTE and WiMAX technologies.

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Authors Biography

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