

**INVESTIGATION OF MICROSTRIP PATCH ANTENNA USING
DEFECTED GROUND STRUCTURE FOR WIRELESS APPLICATIONS**

*A thesis submitted in partial fulfilment of the requirements
for the award of degree of*

MASTER OF ENGINEERING
In
Wireless Communication Engineering

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CERTIFICATE

I hereby declare that the work which is being presented in the thesis entitled, "Investigation of Microstrip Patch Antenna using Defected Ground Structure for Wireless Applications" in partial fulfilment of the requirement for the award of degree of M.E in Wireless Communication Engineering submitted in Electronics and Communication Engineering Department of Thapar University, Patiala is an authentic record of my own work carried out under the supervision of Ms. Jaswinder Kaur, Lecturer, ECED, Thapar University, Patiala.

The matter presented in this thesis has not been submitted in any other University/Institute for the award of degree.

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(Gurbaz Singh)

ABSTRACT

Wireless communications have been developed widely and rapidly in the modern world especially during the last two decades. The future development of the personal communication devices will aim to provide image, speech and data communications at any time, and anywhere around the world. This indicates that the future communication terminal antennas must meet the requirements of multi-band or wideband to sufficiently cover the possible operating bands. However, the difficulty of antenna design increases when the number of operating frequency bands increases. However, in order to transmit and receive more information large bandwidths are required, and bandwidth enhancement is currently a popular research area.

In this work presented, transmission line model is used to simulate rectangular microstrip patch antenna using microstrip feed line. The aim is to study defected ground structure and to analyze on their antenna performance. The conducting patch can take any shape rectangular, circular etc but here rectangular shaped MPA is preferred. The parametric study of the designed antenna is studied and the physical parameters examined in this study include the substrates and their dielectric constants and optimized parameter. Designed with the help of computer simulation technology microwave studio version 10.0 (CST MWS V 10.0). The microstrip patch antenna with a H-shape slot in ground plane at resonating at 1.89 GHz, providing 193MHz bandwidth and using GSM application. The antenna parameters like operating frequency, VSWR, bandwidth, return loss, directivity and gain are determined for each antenna configuration. The operating frequency, VSWR, bandwidth, return loss, directivity and gain of the single band antenna designed are 1.89 GHz, 1.9, 193 MHz, -20.2631, 2.42 dBi and 12.6 dB respectively.

The operating frequency, VSWR, Bandwidth, Return loss, directivity and gain of the Dual band antenna designed are 2.7GHz and 4.6 GHz, 1.2 and 1.3, 590 MHz and 241MHz, -28 and -17, 3.48 dBi and 3.52 dBi and gain is 3.23 dB and 2.75 dB respectively. The multiband antenna having slots in reduced ground plan resonates at 3.5 GHz, 5.4 GHz and 7.1 GHz and provides a wide bandwidth of 1267 MHz, 1150 MHz and 290 MHz. The directivity of the antenna 3.77 dBi, 3.68 dBi and 5.67 dBi, and return loss is -34dB, -31dB and -31dB respectively. The fabrication of the multiband is also done as well as the testing is done using VNA model no: E5071C. The testing results along with the comparison between testing results and simulated results are also show.

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LIST OF ABBREVIATIONS

MPA	Microstrip Patch Antenna
WLAN	Wireless Local Area Network
WiMAX	Worldwide interoperability for microwave Access
CST	Computer Simulation Technology
DGS	Defected Ground Structure
VNA	Vector Network Analyser
IMT	International Mobile Telecommunications
ISM	Industrial, Scientific and Medical

CHAPTER 1

INTRODUCTION

1.1 Introduction:

Communication between humans was first by the noise through voice. With the desire for slightly more distance communication, there came devices like drums, some visual methods like, burn signals and signal flags were used. The optical communication devices, utilized the light portion of the electromagnetic field. With the advancement of the technology, now the electromagnetic field, outside the visible region, has been employed for communication, through the use of radio. One of the human kind's greatest natural sources is the electromagnetic field and antenna is key factor for utilizing this source.

1.2 Wireless Communication:

The wireless communications supporting information exchange between people or devices is the communications frontier of the next few decades and much of it already exists in some form. The term "Wireless" came into public use to refer to a radio receiver or transceiver (can be used both as transmitter and receiver) establishing its use in wireless communication such as in cellular network and wireless broadband internet. It is also used to refer to any type of operation that is implemented without use of wires. It encompasses various types of fixed, mobile and portable two way radios, cellular telephones. Other examples are satellite television, wireless computer mice, keyboards and headsets, broadcast television [1].

Wireless operation permits services, such as long range communications, that are impossible or impractical to implement with the use of wires. The most common use of wireless networks is to connect the laptop/mobile data communication users who travel from location to location. Another important use is for mobile networks that connect through antennas, via satellite communications.

1.3 Role of antennas:

In any wireless communication system, the antenna plays a vital role in the reliability and performance of the system. An antenna is a "a metallic (usually) device used for radiating or receiving electromagnetic waves which acts as the transition region between free space and guiding structure like a transmission line in order to

communicate even in a longer distance. An antenna consists of two parts; Transmitter and Receiver. A transmitting antenna takes waves that are generated by electrical signals inside a device such as a radio and converts them to waves that can travel in an open space. The receiving antenna takes free-space waves and converts them into guided waves (electrical signals) that are compatible for cables or wires [2].

1.4 Introduction to Microstrip Patch Antennas (MPAs):

In its most basic form, microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure (1.1). The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

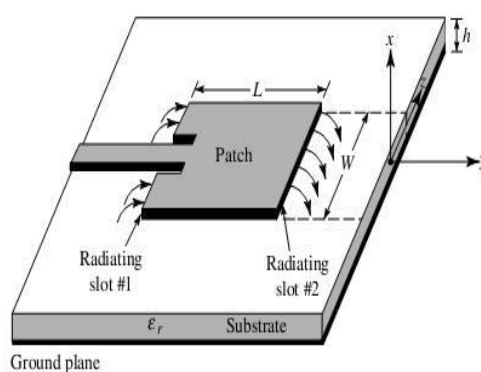


Figure 1.1: Structure of a MPA [2]

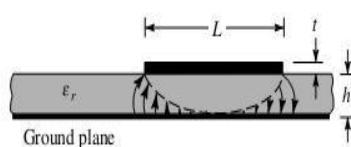


Figure 1.2: Side View of a MPA [2]

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular and elliptical or some other common shape. The thickness of the dielectric substrate 'h' is usually $0.003\lambda \leq h \leq 0.05\lambda$ and the thickness of patch 't' above the substrate is much less than λ (where λ is the free space wavelength). The microstrip antenna radiates relatively broad beam broadside to the plane of the substrate. End-fire radiation can also be accomplished by judicious mode selection. For a rectangular patch, the length L of the element is usually $\lambda/3 < L < \lambda/2$ and the dielectric constants of the substrates are usually in the range of $2.2 \leq \epsilon \leq 12$ [2]. MPA radiate primarily because of the fringing

fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact microstrip patch antenna, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a compromise must be reached between antenna dimensions and antenna performance [3].

1.4.1 Analysis of MPA Operation:

The preferred models for the analysis of microstrip patch antennas are the radiation mechanism, cavity model, and full wave model (which include primarily integral equations/moment method). Basically the radiation mechanism represents the microstrip antenna by two slots, separated by a low-impedance Z_c transmission line of length L .

(A) Fringing Effects

The dimensions of the patch are finite along the length and width; the fields at the edges of the patch undergo fringing. The amount of fringing is a function of the dimensions of the patch and the height of the substrate. For the principal E-plane (xy-plane) fringing is a function of the ratio of the length of the patch L to the height h of the substrate (L/h) and the dielectric constant of the substrate. Since for microstrip antennas $L/h \gg 1$, fringing is reduced; however, it must be taken into account because it influences the resonant frequency of the antenna. The same applies for the width. Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ϵ_{reff} is introduced to account for fringing and the wave propagation in the line. For a line with air above the substrate, the effective dielectric constant has values in the range of $1 \ll \epsilon_{\text{reff}} < \epsilon_r$. For most applications where the dielectric constant of the substrate is much greater than unity ($\epsilon_r \gg 1$), the value of will be closer to the value of the actual dielectric constant of the substrate. The effective dielectric constant is also a function of frequency.

———— ———— [—]

(B) Effective Length, Resonant Frequency and Effective Width:

Because of the fringing effects, electrically the patch of the MPA looks greater than its physical dimensions. Where the dimensions of the patch along its length have been extended on each end by a distance ΔL , which is a function of the effective dielectric constant and the width-to-height ratio (W/h). A very popular and practical approximate relation for the normalized extension of the length is

$$\frac{\Delta L}{L} = \frac{1}{2} \left(\frac{1}{\epsilon_{eff}} - 1 \right) \left(\frac{W}{h} \right)^{-1}$$

Since the length of the patch has been extended by ΔL on each side, the effective length of the patch is now $L_{eff} = L + 2\Delta L$ for dominant mode with no fringing)

For the dominant mode, the resonant frequency of the microstrip antenna is the function of length. Usually it is given by:

$$L_{eff} = \frac{L}{\sqrt{\epsilon_{eff}}}$$

Where c is the speed of the light in free space.

(C) Design: In the typical design procedure of rectangular microstrip patch antenna, three essential parameters are:

Frequency of operation (f_r): The resonate frequency of the antenna must be selected appropriately. The antenna designed should be useful for the wireless communication system. The frequency range is approximately 890MHz to 5.85 GHz.

Dielectric constant of the substrate (ϵ_r): The dielectric constant of substrate (ϵ_r) material plays an impotent role in the patch antenna design. A substrate with a high dielectric constant reduces the dimensions of the antenna but it also affects the antenna performance. So, there is a trade-off between size and performance of patch antenna.

Height of dielectric substrate (h): For the microstrip patch antenna to be used in communication systems, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate should be less. After the proper selection of above three parameters, the next step is to calculate the radiating patch width and length mathematically.

Step 1: Calculation of Width (W):

For an efficient radiator, practical width that leads to good radiation efficiencies is [2].

Step 2: Calculation of Effective Dielectric Coefficient (ε_{eff}):

The effective dielectric constant is given by:

Step 3: Calculation of Effective Length (L_{eff}):

The effective length is given by:

Step 4: Calculation of Length Extension (ΔL):

Before calculation of “ΔL”, will be calculated by:

$$\Delta L = \frac{L_{eff} - L}{2}$$

Step 5: Calculation of Actual Length of Patch (L):

Thus, the actual length of radiating patch is obtained by

Step 6: Calculation of Ground Dimensions (W_g, L_g):

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been the similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

)

1.4.2 Feeding Techniques:

There are many configurations that can be used to feed microstrip antennas. The most popular are the microstrip line, coaxial probe, aperture coupling, proximity coupling and

coplanar waveguide. Out of these five techniques the first two are very similar in operation and offer essentially one degree of freedom (for a fixed patch size and substrate). The proximity coupled patch has at least two degrees of freedom: the length of the feeding stub and the patch width-to-line width ratio. The aperture coupled patch antenna has at least four degrees of freedom the slot size, its position the feed substrate parameters and the feed line width.

(1) Microstrip Feed Line:

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Figure 1.3. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. The equivalent circuit that applies to this feeding technique is the parallel RLC network representing the resonant patch and the series inductor represents feed inductance of the microstrip feed line. Electromagnetic field lines are focused between the microstrip line and ground plane to excite only guided waves as opposed to radiated or surface waves [4].

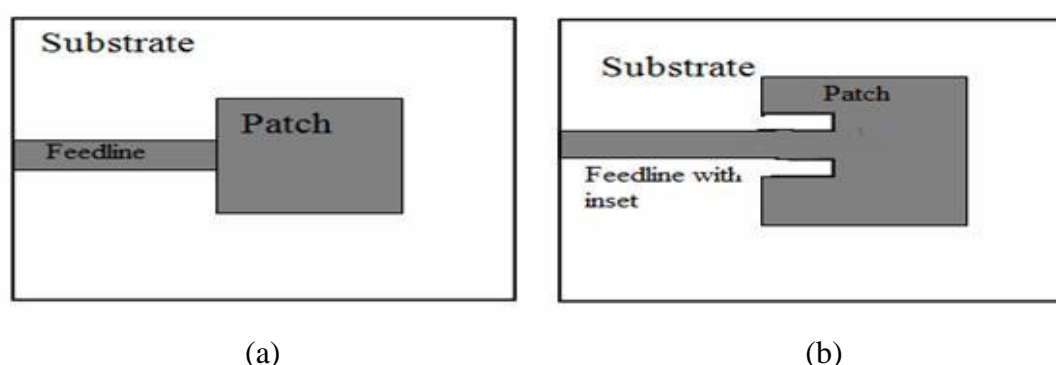


Figure 1.3: Geometry of Micro-Strip Feed line (a) Directly feed (b) Inset feed [4]

(2) Coaxial Feed:

The Coaxial feed or probe feed is a very common technique used for feeding microstrip patch antennas. As seen from Figure (1.4) the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer

conductor is connected to the ground plane. It has narrow bandwidth and more difficult to model especially for thick substrates ($h > 0.02 \lambda$). But in the array design having thousands of elements such a large number of solder joints makes fabrication difficult and lowers reliability. Its equivalent circuit is same as the microstrip feed line. Although, probe and microstrip line feeds primarily stimulate the dominant mode of the patch, the native unevenness of these feeds generates some higher-order modes which produce cross-polarized Radiation.

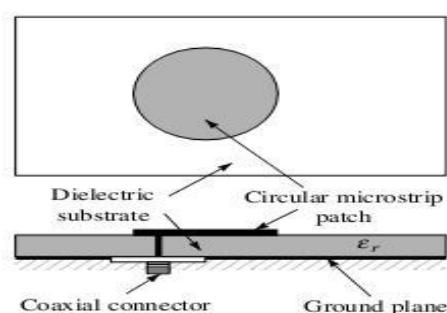


Figure 1.4: Geometry of Coaxial Probe Feed patch antenna [2]

(3) Proximity coupled feed:

The Proximity Coupled Feed technique is also called as the electromagnetic coupling scheme. As shown in Figure (1.5) two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. It is a type of non-contacting feed. Proximity coupling has the advantage of allowing the patch to exist on a relatively thick substrate for improved bandwidth on the contrary the feed line is on an effectively thin substrate which reduces spurious radiation and coupling. It provides bandwidth up to 21%. Matching can be achieved by controlling the length of the feed line and the width-to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate.

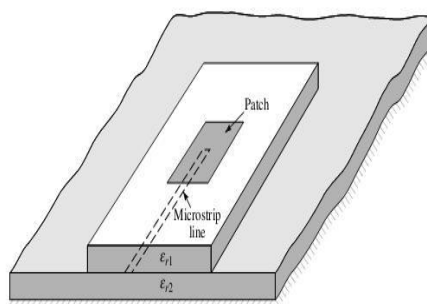


Figure 1.5: Geometry of Proximity Coupled Microstrip patch antenna [2]

(4) Aperture–Coupled Feeding Technique:

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure (1.6). Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane. The key factor of this feeding technique is that the aperture is usually smaller than resonant size, so the back lobe radiated by the slot is 15-20dB below the forward main beam. Aperture coupled antennas are advantageous in arrays because they electrically isolate the feed and phase shifting circuitry from the patch antennas. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness.

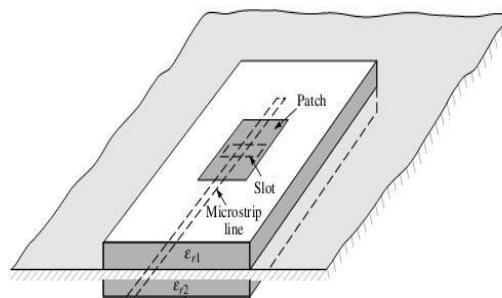


Figure 1.6: Geometry of Aperture Coupled Microstrip patch antenna [2]

(5) Coplanar waveguide feeding

The coplanar waveguide was proposed by C.P. Wen in 1969. A coplanar waveguide structure consists of a median metallic strip of deposited on the surface of a dielectric substrate slab with two narrow slits ground electrodes running adjacent and parallel to the strip on the same surface. This transmission line is uniplanar in construction, which implies that all of the conductors are on the same side of the substrate. They have many features such as low radiation loss, less dispersion, easy integrated circuits and simple configuration with single metallic layer, and no via holes required. The CPW fed antennas have recently become more and more attractive because of its some more attractive features such as wider bandwidth, better impedance matching, and easy integration with active devices or monolithic microwave integrated circuits.

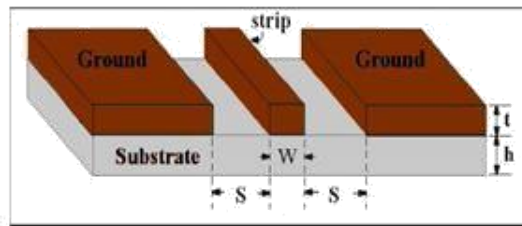


Figure 1.7: Geometry of Coplanar Waveguide Feed

Table 1.1: The comparisons between feeding method of [MPA] [4].

Characteristics	Microstrip Feed Line	Coaxial Feed	Proximity Coupled Feed	Aperture Coupled Feed	Coplanar Waveguide
Spurious Feed Radiation	More	More	Minimum	Less	More
Reliability	Better	Poor due to Soldering	Good	Good	Good
Ease of Fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	13%	2-5%	40%

1.4.3 Advantages, disadvantages and applications of MPAs:

Advantages of MPAs are given below [4]:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits (MICs).
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Their major disadvantages of MPAs are given below [4]:

- Narrow bandwidth
- Low efficiency
- Low Gain
- Poor end fire radiator except tapered slot antennas
- Low power handling capacity.
- Surface wave excitation

Applications of MPAs are given below:

- Aerospace vehicles including high-performance aircraft, spacecraft, satellites and missiles.
- Mobile radios, phones and pagers
- Base stations for personal communications
- Large ground-based phased array antennas

1.5 Antenna Parameters:

Various parameters are used to analyze the efficiency of an antenna and are discussed as following:

(A) Return Loss:

It is the difference between forward and reflected power, in dB, generally measured at the input to the coaxial cable connected to the antenna. For maximum power transfer the return loss should be as small as possible. Hence, Return loss indicates the matching between transmitter and antenna and is given by:

||

(B) Gain:

Gain of an antenna gives the measure of the efficiency of the antenna and its directional capabilities. Gain is defined as the ratio of radiation intensity in a particular direction to the radiation intensity obtained if power is radiated isotropic ally by that antenna.

(C) Voltage Wave Standing Ratio (VSWR):

The voltage standing wave ratio (VSWR) is a measure of impedance match or mismatch between the transmission line and antenna. A VSWR of 1:1 indicates a perfect match, while a VSWR of ∞ :1 indicates the worst case.

(D) Directivity:

Directivity of an antenna is defined as the ratio of radiation intensity of antenna in a given direction to the radiation intensity of that antenna averaged over all directions and it is dimensionless. It can be represented mathematically as:

$$\begin{aligned} & \frac{\text{radiation intensity in a given direction}}{\text{radiation intensity of isotropic source}} \\ &= \frac{\text{radiation intensity (W/unit solid angle)}}{\text{radiation intensity of isotropic source (W/unit solid angle)}} \\ &= \frac{\text{radiation intensity in a given direction}}{\text{total radiated power (W)}} \end{aligned}$$

1.6 Defected Ground Structure (DGS):

In recent years, there have been several new concepts applied to distributed microwave circuits. One such technique is defected ground structure. Where the ground plane metal of a micro strip (or strip line, or coplanar waveguide) circuit is intentionally modified to enhance performance. The name for this technique simply means that a “defect” has been placed in the ground plane, which is typically considered to be an approximation of an infinite, perfectly-conducting current sink. Of course, a ground plane at microwave frequencies is far removed from the idealized behavior of perfect ground. Although the additional perturbations of DGS alter the uniformity of the ground plane, they do not render it defective [5]. The defect in a ground is one of the unique techniques to reduce the antenna size. The antenna size is reduced for a particular frequency as compared to the antenna size without the defect in the ground. DGS is realized by introducing a shape defected on a ground plane thus will disturb the shielded current distribution depending on the shape of defect. The disturbance at the shielded current distribution will influence the input impedance and the current flow of the antenna. It can also control the excitation and electromagnetic waves propagating through the substrate layer. When we use microstrip patch antenna the problems which will occurs are high loss and surface waves in the substrate layer, as the losses will always occur in the radiation as the antenna is transmitting the signals. The losses that are due to the surface

waves excitation will cause decrease in the antenna efficiency, gain and the bandwidth because when surface waves occur, it can extract total available power for radiation to space wave.

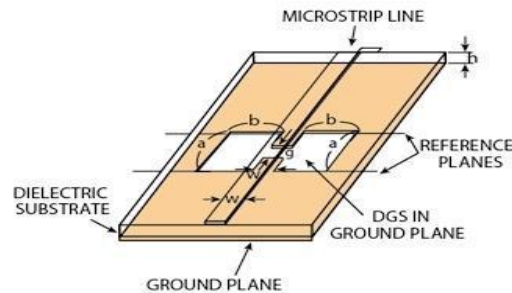


Figure 1.8: MPA with Defected Ground Structure [5].

1.6.1 DGS Element Characteristics:

The basic element of DGS is a resonant gap or slot in the ground metal, placed directly under a transmission line and aligned for efficient coupling to the line. There are several resonant structures that may be used. Each one differs in occupied area, equivalent L-C ratio, coupling coefficient, higher-order responses, and other electrical parameters. A user will select the structure that works best for the particular application [5]. Thus the microstrip antenna without DGS, the bandwidth is narrow and the return loss is high. On the other hand, microstrip antenna with DGS will provide higher operating bandwidth and less return loss. Therefore, the DGS can be integrated onto the ground plane of such antenna in order to improve its radiation, besides not requiring additional circuits are for implementation.

1.6.2 Advantages of Defected Ground Structures:

- Remove the harmonics in the ground plane.
- Reduce the antenna size.
- Improve the return loss.
- Improve the antenna gain and band width.

1.8 Objectives of Thesis:

The main objectives were designed as the following:

(A) To design and simulate a Single band for GSM frequency bands.

- Parametric studies on the proposed antenna.

(B) To design and simulate a dual band for WiMAX, IMT and Bluetooth frequency bands.

- Parametric studies on the proposed microstrip patch antenna as a foresaid.

(C) To design and simulate a multiband for WiMAX, WLAN, IMT and X frequency bands.

- Parametric studies on the proposed microstrip patch antenna as a foresaid.
- Fabrication and testing of the proposed design.

1.9 Methodology:

- Extensive literature survey is conducted to study the literature available in the field of dual and multi-frequency microstrip antennas.
- Detailed study of antenna structures.
- The effects on gain, return loss and radiation pattern are analyzed For conducting simulation of proposed antenna designs, Full Wave Electromagnetic Simulation Software, Computer Simulation Technology - Microwave Studio Version 10.0 (CST MWS V10.0) has been used.
- The proposed antenna designs are projected on “Fiber-glass Reinforced epoxy” FR-4 material which is an inexpensive and readily available substrate material.
- The return loss or S_{11} parameters of the proposed antennas have been measured using Vector Network Analyzer.

1.10 Organization of Thesis:

The thesis is composed of six chapters and organized as follow:

Chapter 1:- Concentrates on the brief overview of the microstrip patch antenna and defected ground structure, advantages, disadvantages and applications antenna parameters and methods of MPAs.

Chapter 2:- History and reviews of the microstrip patch antenna and provides a literature review related to the designing of the microstrip patch antenna with defected ground structures.

Chapter 3:- Results of microstrip Patch Antenna with an H shape slot in ground plane using microstrip-line feed for single band and discussion through gain, directivity, return loss, etc.

Chapter 4:- Results of dual band microstrip patch antenna using DGS using microstrip line feed, discussion through gain, directivity, return loss, etc.

Chapter 5:- Results of multi band microstrip Patch Antenna using DGS (reduced ground) using microstrip line feed, discussion through gain, directivity, return loss, etc and fabrication of antenna is done in this chapter and comparing the simulated and fabricated results.

Chapter 6:- Conclusion and Future scope.

CHAPTER2

LITERATURE SURVEY

This chapter gives us an idea about the evolution of microstrip patch antenna using defected ground structure (DGS) with its various developments in the past.

S. Biswas *et al.* (2013) proposed the controlling higher order modes up to third harmonic of the fundamental operating frequency in a micro strip line-fed patch antenna has been successfully demonstrated. Harmonic rejection in the antenna has been achieved at its feed level using highly compact design of Defected Ground Structure(DGS). Rejection characteristics have been improved adding an open stub to the feed line. All possible higher order mode occurring in between the fundamental and the 3rd harmonic have been identified. Relative suppression of radiated fields with and without DGS-control has been quantitatively measured and effective control of harmonics has been experimentally ensured [6].

H. Malekpoor *et al.* (2013) proposed novel designs of miniaturized wideband microstrip patch antennas for ultra wideband (UWB) applications. The antennas are achieved by using folded-patch feed's techniques and shorting pins to provide the impedance bandwidths. By introducing a folded ramp-shaped feed, the impedance bandwidths of the proposed antennas are considerably enhanced. Shorting pins are utilized to miniaturize the size of the patches [7].

E. C. Beltran *et al.* (2013) proposed novel system composed of a circular aperture slot antenna and a Common-Mode (CM) noise rejection filter is presented. This antenna is differentially fed by microstrip coupled transmission lines. In order to eliminate CM noise, a notch filter based on three non-periodical defected ground structures (DGS) was implemented. The whole system achieves a fractional impedance bandwidth of about 127%. Radiation patterns in E and H planes for different frequencies were obtained for the system [8].

M. K. M. Amin *et al.* (2012) proposed a dual rectangular ring microstrip antenna with defected ground structure (DGS) for wireless application. The rectangular ring using as a patch with DGS effect has been done and improve the antenna's performance. This antenna design will be applied to 3G and 4G frequency spectrum bands and also the industrial,

scientific and medical (ISM) radio bands. The antenna small size of low gain Omni directional antenna using defected ground structure has gain improvement, it does not effects radiation pattern, bandwidth and also the beam width of antenna [9].

C. Kumar *et al.* (2012) proposed the probe-fed circular patches using Conventional and defected ground planes flashed. Some relating to cross-polarized (XP) electric fields and associated radiations. Those led to a series of understanding the nature of XP fields and to deal with them using defected ground structure (DGS) for improved XP performance. There phase of investigation limitations of dot-shaped DGS in reducing XP level. As its improved variants two new DGS geometries such as annular ring and circular arcs have been explored. The arc-DGS appears to be highly efficient in terms of suppressing XP fields [10].

M. I. Ahmed *et al.* (2012) proposed the compact dumbbell shaped defected ground structure (DGS) is applied to reduce the mutual coupling between array elements. The dumbbell DGS is inserted in the E-plane between the adjacent arrays coupled elements to suppress the pronounced surface waves. The results show that a reduction in mutual coupling of 35.6 dB is obtained between elements at the operation frequency of the array. The analysis indicates that increasing number of dumbbells reduces the mutual coupling between elements. The gain and bandwidth are reduced. The results agree with those obtained by the waveguide simulator method [11].

J. Wang *et al.* (2012) proposed compact modified dumbbell-shaped defected ground structure resonator on coplanar waveguide is proposed in this letter. By adding a smaller square resonator to the conventional modified dumbbell-shaped DGS the path difference for the electromagnetic wave propagation will be increased with a maximum M-DGS size reduction. The scheme for the reconfigurable band stop resonator is presented after considering the influence of the inserted short circuits on the resonant frequency. The resonant frequency can be reduced further by increasing the dimensions of the smaller square, and varactor diodes with higher tenability may widen the tuning rang [12].

H. Kimouche *et al.* (2012) proposed dumbbell shaped defected ground structure (DGS) is proposed to suppress higher order harmonics of an electrically small antenna. A slot loading technique is applied to a well-know low-profile antenna, the area miniaturization of a semi circular microstrip patch antenna by inserting a number of slits parallel to the radiating edges,

is investigated in relation to the quality factor. Measurement results on a prototype antenna, fully demonstrate the performance of the proposed antenna [13].

W. C. Liu *et al.* (2011) proposed and investigated a novel triple-frequency micro strip-fed planar monopole antenna. Defected ground structure (DGS) is used in this antenna, which has a rectangular patch with dual inverted L-shaped strips and is fed by a cross-shaped strip line, for achieving additional resonances and bandwidth enhancements. The designed antenna has a small size. There is a good agreement between the measured and simulated results. Experimental results show that the antenna gives monopole-like radiation patterns and good antenna gains over the operating bands [14].

B. R. Guan *et al.* (2011) proposed in this letter, an ultra broadband antenna (UWB) loaded with defected ground structure (DGS) is presented. The UWB antenna with circle radiation patch is fed with 50 Ohm microstrip line. The DGS structure is introduced to the ground under the feed line and hence the frequency selectivity is also introduced to this UWB antenna. The DGS structure the stop band of the antenna can be adjusted in a range [15].

V. S. Kushwah *et al.* (2011) proposed it includes size reduction of amplifiers; enhancement of filter characteristics and applications to suppress harmonics in patch antennas. This paper presents an improved method of size reduction of a microstrip antenna using defected microstrip structure. It does so by introducing imperfections in the microstrip antenna on the conducting layer using a DMS designed defect. The results are very encouraging as it increases the number of components in a given constant area. A new proposal, called defected microstrip structure (DMS), has been successfully used in reducing the size of, and can be further used as tuning technique for, rectangular patch antennas [16].

A. Kumar *et al.* (2010) proposed the electromagnetic band gap (EBG) structures have been used to improve the performance of the antennas. In this work, an extensive design study of some specific antennas will be presented. The design of antennas with one-dimensional EBG, so called defected ground structure (DGS) has been carried out for various parameters improvement. The present study includes dumbbell shaped slots in the ground plane of the antennas. The initial results are indicating that using a DGS in the ground plane of the planar structures increases their electrical length and prevent the propagation in a particular band [17].

D. Guha *et al.* (2009) proposed defected ground structure (DGS) to suppress cross-polarized (XP) radiation from a microstrip patch antenna has been reinvestigated using a new DGS geometry for much improved characteristics. The presence of the DGS shows as much as 30dB isolation of the XP level from its peak radiation and that compared to an identical patch without DGS indicates an improvement by as much as 12 dB. The relative suppression in XP values are found to be around 7–12 dB over elevation around the bore sight of the patch [18].

D. Nashaat *et al.* (2009) proposed we describe a novel approach to reduce the antenna size and provide multiband operation. Electromagnetic band gap (EBG) structure is used as defect ground plane structure to reduce size and achieve multiband resonant frequencies. Two cells of spiral-shaped defected ground structure (DGS) with each cell composed of spiral with four arms are used in the design. Simulation results show that more than 50% reduction in size was achieved as well as five resonant frequencies resulted from the new design. One resonance resulted from the fundamental patch antenna while the other four resulted from spiral arms [19].

A. Kumar *et al.* (2008) proposed defected ground structures (DGS) have been developed to improve characteristics of many microwave devices. It can also be used for the antenna size reduction. The DGS is easy to be an equivalent LC resonator circuit. The value of the inductance and capacitance depends on the area and size of defect. In this paper the effect of dumbbell shaped DGS, to the size reduction of a microstrip patch antenna and used to increase the efficiency of the microstrip patch antenna, in which the electric walls are placed surrounding the patch [20].

D. J. Woo *et al.* (2008) proposed new techniques to suppress multiple frequency bands with a single defected ground structure (DGS) unit are developed. The stacked spiral DGS, in which the spiral-shaped defects with different size are aligned in the transverse direction to the guiding direction of the coplanar waveguide (CPW), provides multiple resonance frequencies. The composite spiral rectangular DGS is proposed to provide two resonance frequencies with the same characteristic of the cascaded spiral and dumbbell-shaped DGS units. The slow-wave effects for the proposed DGSs are greater than that of conventional spiral- or dumbbell-shaped DGS [21].

H. Liu *et al.* (2005) proposed that a micro strip patch antenna integrated two-dimensional photonic band gap (PBG) and one dimensional defected ground structure (DGS) jointly in

ground plane. It is demonstrated that application of both PBG and DGS eliminates the second and third harmonics and improves the return loss level. Moreover, the combination use of PBG and DG decreases the occupied area by 70% compared to the conventional PBG patch antenna [22].

D. J. Woo *et al.* (2005) proposed we present an effective technique of second and third harmonic suppression for a Wilkinson power divider by using an asymmetric spiral defected ground structure (DGS). The transfer function of the asymmetric DGS shows signal rejection characteristics at two different resonance frequencies and the characteristics of asymmetric. DGS is modeled by two parallel *RLC* resonance circuits in cascade. Using asymmetric DGS the size of a quarter-wave line is reduced by 9.1% compared to that of conventional divider without a DGS [23].

M. S. Joung *et al.* (2005) proposed demonstrates new systematic approaches to equivalent circuit model extraction for defected ground structure (DGS) directly from full-wave frequency domain simulation. A simple circuit model for lossy DGS circuits without any optimization of lumped element component and lossless circuit model relative complex along with a determined starting point of optimization of lumped element. The efficient and accurate means to produce the complete equivalent models of DGS circuit for the design of various RF and microwave circuits such as oscillators that may require the high accurate nonlinear design procedures [24].

P. R. Prajapati *et al.* (2005) proposed compact proximity fed stacked circular disc microstrip antenna (SCDMA) with dumbbell shaped circular head DGS has been proposed in this work. Proposed DGS structure enhances bandwidth, reduced average area of both circular patches, increases radiation efficiency by and also improves VSWR. These bands are suitable for WLAN and WiMax applications respectively [25].

Y. Chung *et al.* (2004) proposed presents a high isolation dual-frequency orthogonally polarized rectangular patch antenna utilizing micro strip feed line integrated with a defected ground structure (DGS). The demonstrated approach results in a significant improvement in port isolation in comparison to a conventional dual-polarized antenna fed by simple micro strip lines, Image impedance of a micro strip line with DGS is controlled by the DGS geometry without modifying the dimension of the line. The high impedance line is

effectively implemented using a micro strip line with 75 line width by incorporating the DGS [26].

Y. Chung *et al.* (2004) proposed the present's multifunctional microstrip transmission lines for designing a high port-isolation dual-frequency orthogonally polarized rectangular patch antenna and the antenna-integrated power amplifier. The proposed lines were realized through the integration of defected ground structures (DGSs) with conventional micro strip lines. . High-order harmonic signal suppression of the power amplifier at the 2.5-GHz port was accomplished by the dumbbell-shaped DGS, thereby improving the efficiency of the amplifier [27].

Y. J. Sung *et al.* (2003) proposed a microstrip patch antenna using the defected ground structure (DGS) to suppress higher order harmonic presented. An H-shaped defect one ground plane with only one or more unit lattices has been utilized and yielded band stop characteristics. Comparing with a conventional microstrip patch antenna without the DGS unit cell, the radiated power of the DGS patch antenna at harmonic frequencies has been drastically decreased [28].

CHAPTER 3

SINGLE BAND MICROSTRIP PATCH ANTENNA USING DEFECTED GROUND STRUTURE

In this chapter design single band microstrip patch antenna using (DGS) the H- shape defect in the ground plane. Now using this type of defect reduce the harmonic radiation and increasing the conversion efficiency. This Design has been simulated using CST (Computer simulation Technology) Microwave studio 2010.

3.1 Design and simulation of single band microstrip patch antenna with a H- shape slot in ground plane.

In this design etched the H- shape defect in the ground plane and the proposed antenna fed by microstrip in side feeding. The resonate frequency 1.8 GHz with band width 193 MHz. The return loss of proposed antenna is -20 dB and covering the GSM band.

Table 3.1: Design specifications of substrate:

Thickness of Substrate	1.59 mm
Dielectric constant (ϵ_r)	4.4
Tangent loss	0.0009

Table 3.2: Optimized parameters:

W_s	52 mm
W_p	26 mm
L_s	52 mm
L_p	26 mm
W_1	1.8 mm
W_d	1.8 mm
L_d	20 mm
G	0.2 mm

3.1.2 Antenna Design:

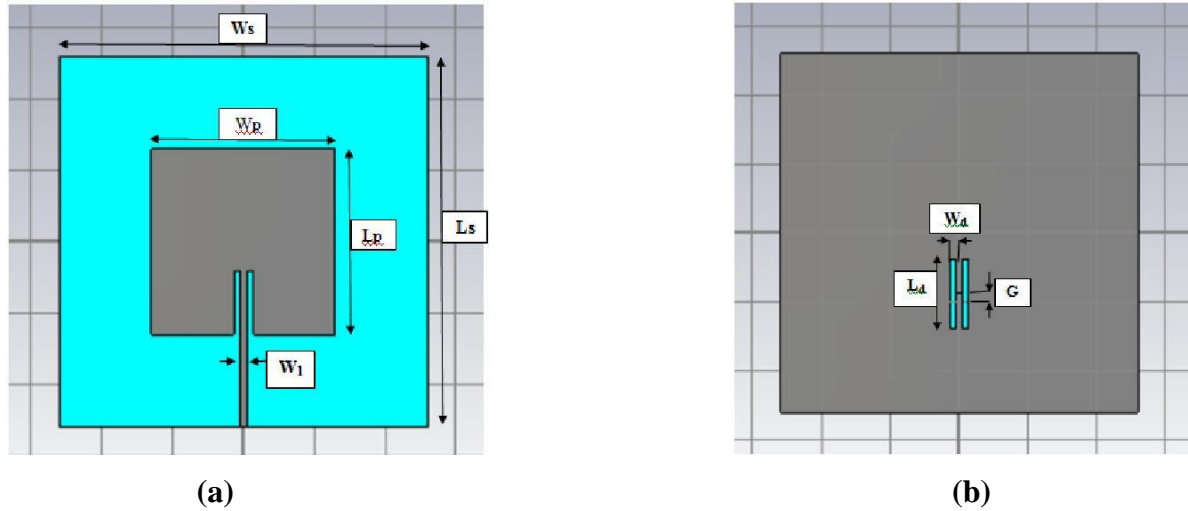


Figure 3.1: Simulated Design (a) Front view (b) Back view

3.2 Simulated Results:

3.2.1 Return Loss and Antenna Bandwidth:

It is the difference between forward and reflected power, in dB, generally measured at the input to the coaxial cable connected to the antenna. For maximum power transfer the return loss should be as small as possible. Figure (3.2) shows the S_{11} parameters (return loss) for the proposed antenna resonates at 1.8 GHz having value of -20dB. The bandwidth of the antenna can be said to be those range of frequencies over which the return loss is greater than -10 dB (corresponds to a VSWR of 2). The bandwidth of the proposed patch antenna is 193 MHz.

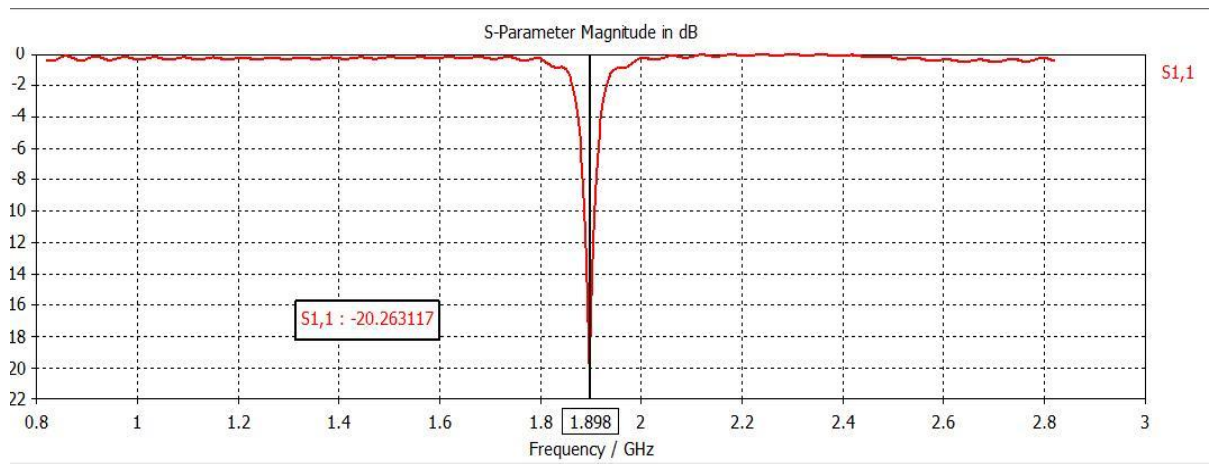


Figure 3.2: Return Loss at 1.8 GHz

3.2.2 Directivity:

Figure 3.3 plot of directivity of the proposed antenna represents the amount of radiation intensity i.e. is equal to 2.42 dBi. The simulated antenna radiates power more in the direction of main lobe maximum which is about 100 times as much as radiated by a non directional isotropic antenna for same power input.

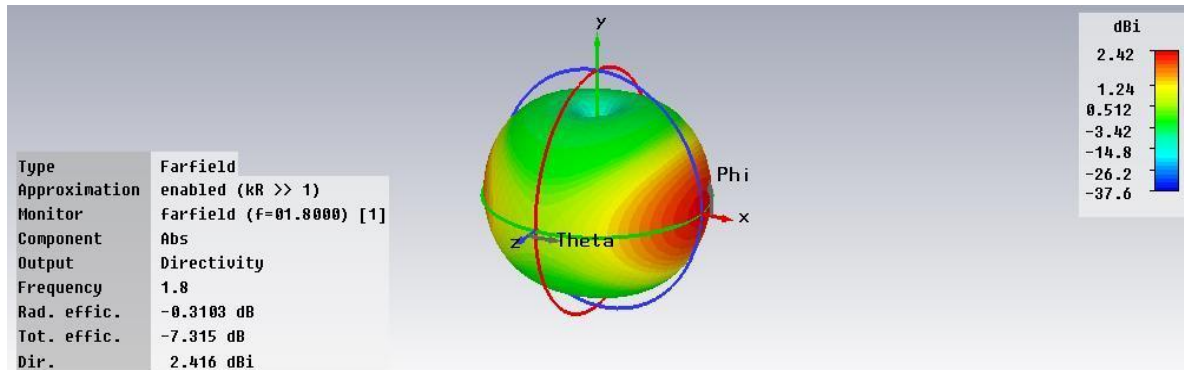


Figure 3.3: Directivity at 1.8 GHz

3.2.3 Gain:

The gain of the antenna in a particular direction is more as compared to isotropic antenna radiating in all directions. The Gain plot Figure 3.4 gives the gain = 12.6 dB. The gain of the proposed antenna is more as compared to isotropic antenna which means that more the gain, more directional is the antenna. Also, the bandwidth of the antenna proposed is good, so the proposed antenna is useful for the GSM band (1.88 GHz to 1.90 GHz).

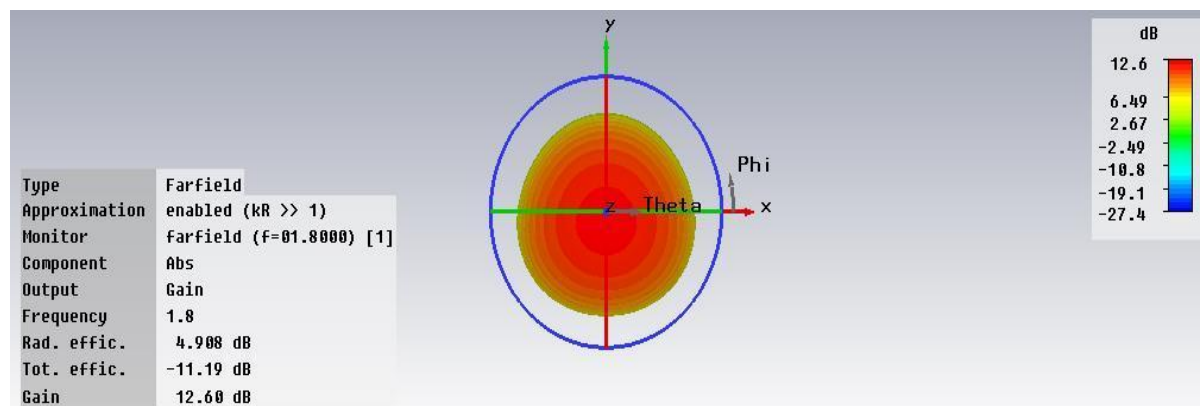


Figure 3.4: Gain at 1.8 GHz

3.2.4 Voltage Standing Wave Ratio (VSWR):

VSWR is a measure of how much power is delivered to an antenna. This does not mean that the antenna radiates all the power it receives. Hence, VSWR measures the potential to

radiate. A low VSWR means the antenna is well-matched, but does not necessarily mean the power delivered is also radiated. The VSWR plot for the design antenna is shown in Figure 3.5. The value of VSWR is 1.91 at resonating frequency. At a VSWR of 2.0, approximately 10% of the power is reflected back to the source.

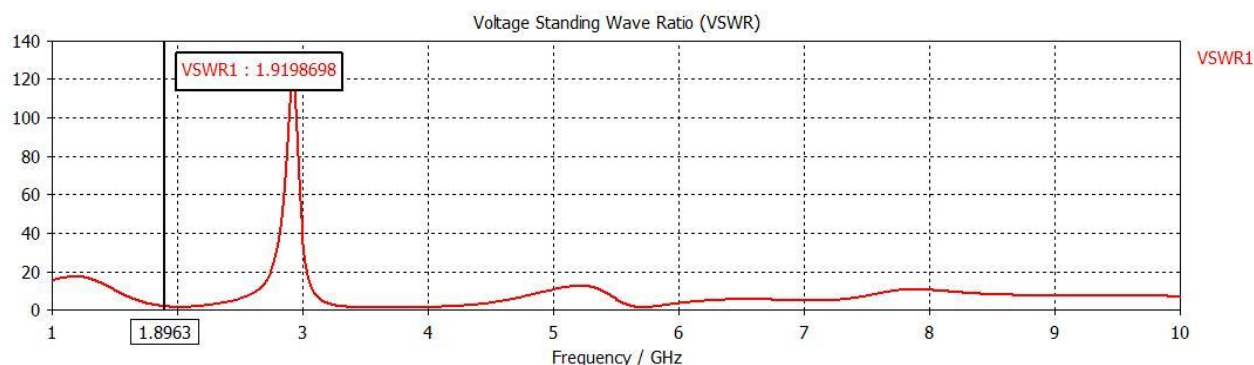


Figure 3.5: Simulated VSWR at 1.8 GHz

3.2.5 Current Distribution:

The current distribution graph shows the direction of the current flow and the intensity of the current. In this antenna is shown in Figure 3.6 the surface current graph below shows that the current is distributed along the whole patch area but it is maximum at the center along the feed line. From back view current density as maximum which is responsible for the resonate frequency.

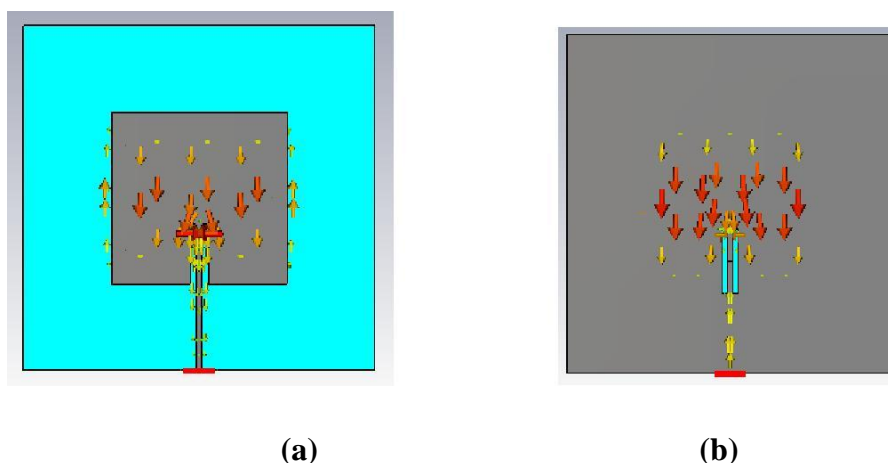


Figure 3.6: The current distribution of proposed antenna (a) Front view (b) Back view at resonate 1.8 GHz.

3.3 Conclusion:

In this chapter using (DGS) in microstrip patch antenna which is composed of a one square patch on the upper plane and etched the H-shape defect in ground plane and we achieved the GSM band which resonates at 1.8 GHz and having bandwidth approximately 193 MHz. The designed antenna gave good return loss -20 dB, gain of this antenna 12.6 dB and directivity of this antenna is 2.42 dBi. This type of antenna gives properly 50 ohm impedance matching and useful for wireless application.

CHAPTER 4

DUAL BAND MICROSTRIP PATCH ANTENNA USING DEFECTED GROUND STRUTURE

The continuous growth of wireless communication systems has led to an unstoppable demand to integrate several frequencies in a single wireless platform which uses single antenna to cover various frequency bands. This phenomenon is also occurs in medical equipment applications and the emergence of variety telemedicine equipments. Therefore, a suitable antenna design is required to operate in ISM band and also can be adapted in latest wireless frequency spectrum. Thus, it is become a challenge to develop an antenna that has a bandwidth which is can cover at various frequency bands applications.

4.1 Design and simulation of a Dual band microstrip patch antenna with a slot in ground Plane.

In this design here using two rectangular rings using as a patch and connected in the single bridge .This proposed antenna cut the slot in ground plane then improve the bandwidth and reduce the size of antenna. In this dual-frequency design give a wide band at resonate frequency 2.7 GHz and second band resonate 4.6 GHz and they cover the WiMax, Bluetooth and IMT band. The band width of proposed antenna is 59 MHz and 241 MHz. The value of S_{11} at 2.7GHz is around -28.83 dB and 4.6 GHz is around at -16.97 dB.

Table 4.1: Design specifications of substrate:

Thickness of Substrate	0.82 mm
Dielectric constant ϵ_r)	4.7
Tangent loss	0.019
Material	FR4

Table 4.2: Optimized parameters:

Specification	Dimensions (mm)
Substrate ($W_s \times L_s$)	55×44×0.8
Line feed ($L_f \times W_f$)	20×2.07
Ground ($L_g \times W_g$)	20×20
DGS ($L_g \times W_d$)	20×1.48
L_1	22.6
L_2	15.6
W_1	30.0
W_2	17.4
L_b	5.3
W_b	8.0
D_1	2.6
D_2	1.3

4.1.1 Antenna design:

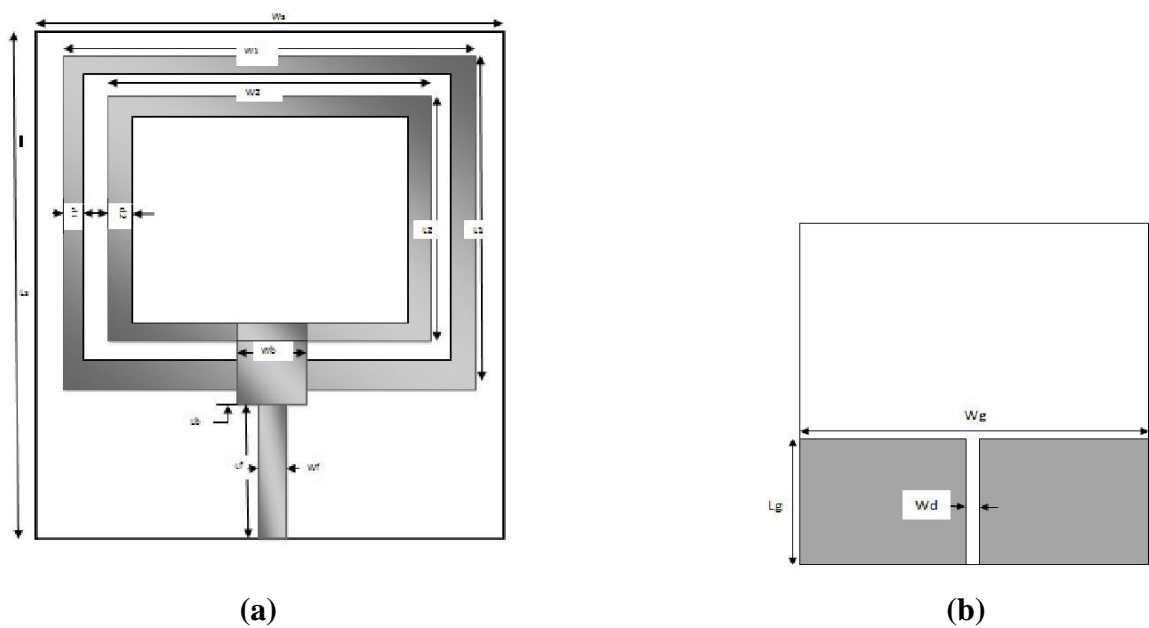


Figure 4.1: Simulated Design (a) Front view (b) Back view

4.2 Simulated Results:

4.2.1 Return Loss and Antenna Bandwidth:

Shows Figure (4.2) Dual band antenna first give a wide band and covering the WiMAX, Bluetooth and IMT band at first resonate frequency (2.7 GHz) having a bandwidth of 59 MHz (1.91-3.51 GHz) and second resonate frequency (4.6 GHz) having a bandwidth 241 MHz (4.35-4.96 GHz). The bandwidth is measured below 10 dB, as visible that two dips are formed, so the proposed antenna is called dual band antenna but also the center point of both the dips is below 10 dB so it is called dual band antenna, covering a large range of frequencies. The value of S_{11} at 2.7 GHz is around -28.83 dB and 4.6 GHz is around at -16.97 dB.

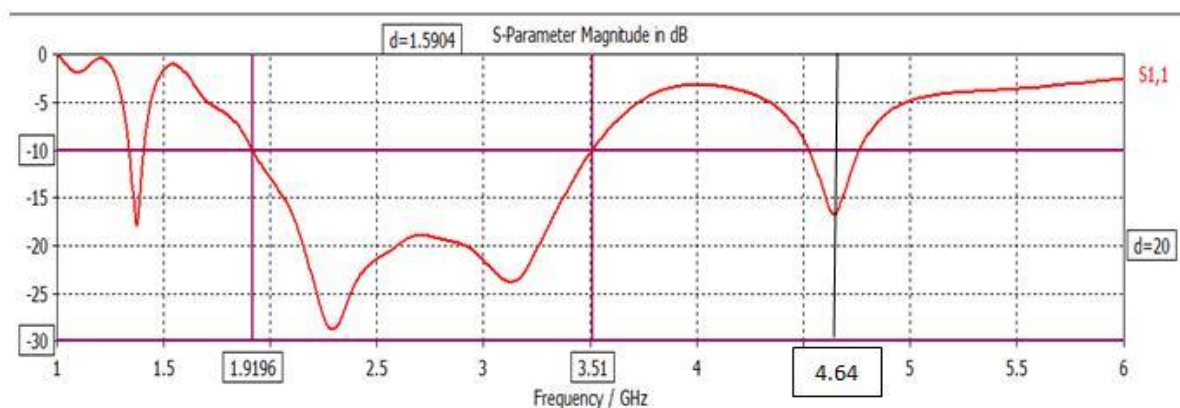


Figure 4.2: Return Loss of Simulated Antenna

4.2.2 Directivity:

Figure 4.3 plot of directivity of proposed antenna represents the amount of radiation intensity i.e. is equal to 3.48 dBi at 2.7 GHz and 3.522 dBi at a 4.6 GHz. The red portion in the figure defines the maximum radiation.

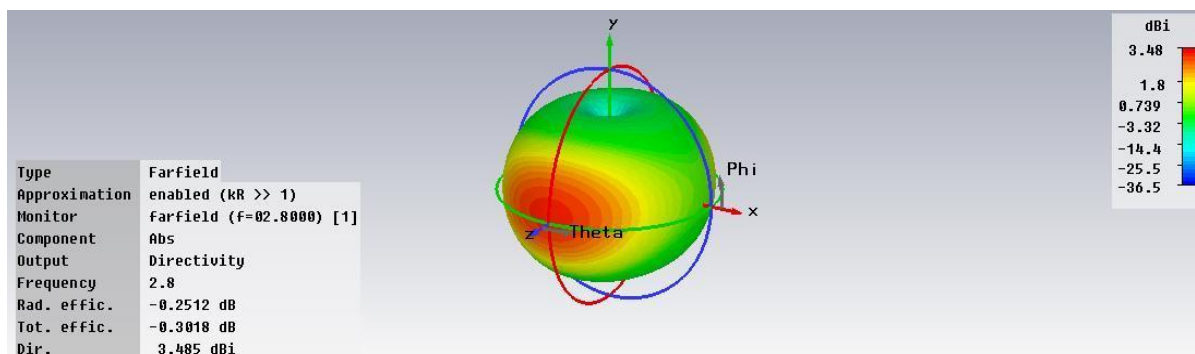


Figure 4.3: Directivity at 2.7 GHz

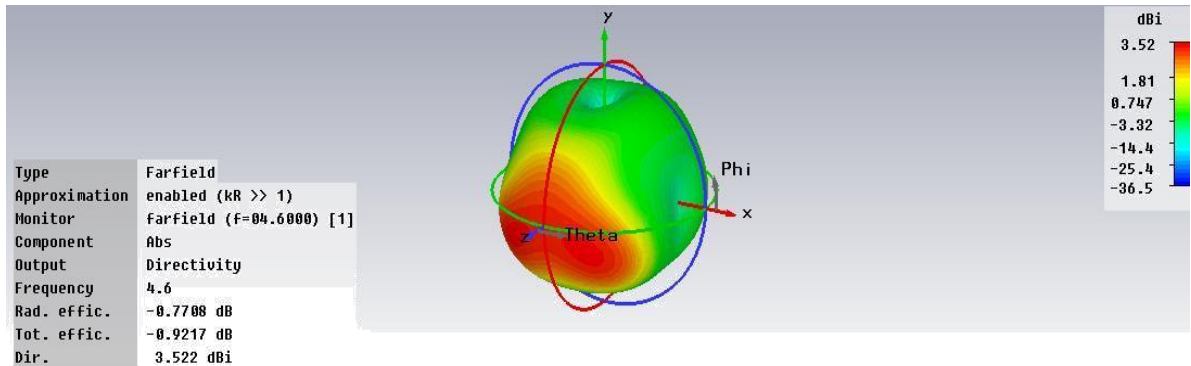


Figure 4.4: Directivity at 4.6 GHz

4.2.4 Gain:

In this design a reduced ground structure is used which decreases the gain of the antenna but the overall antenna parameters are efficient. The gain of proposed antenna is 3.233dB at 2.7 GHz and 2.75 dB at 4.6 GHz.

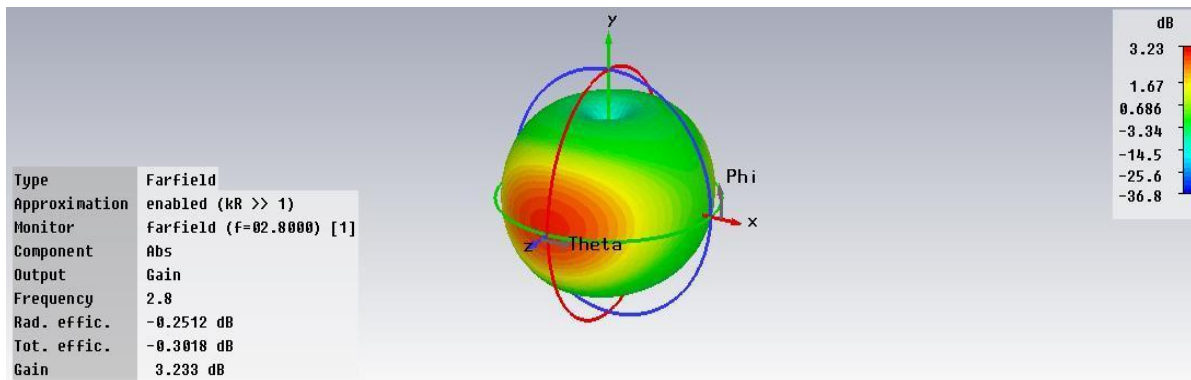


Figure 4.5: Gain of Designed Antenna at 2.7 GHz

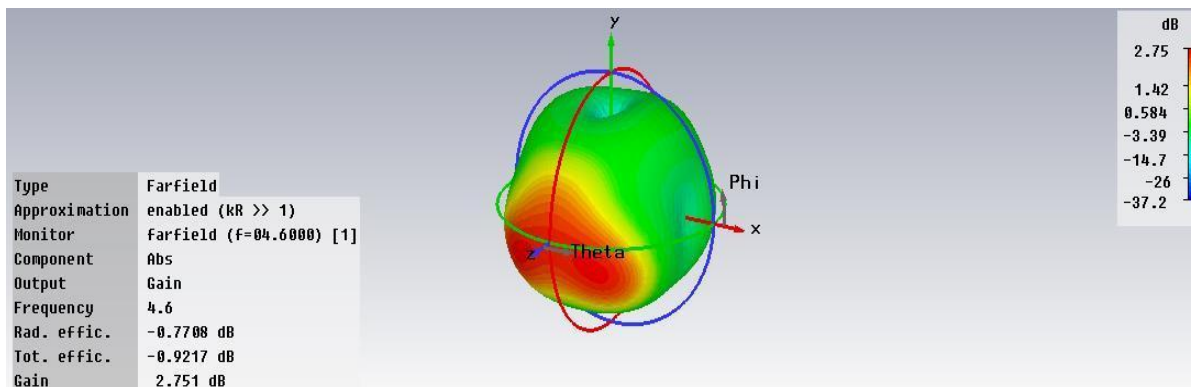


Figure 4.6: Gain of the Designed Antenna at 4.6 GHz

4.2.5 VSWR:

VSWR is another parameter defined for antenna which shows that how well the antenna is matched. The value of VSWR for a good antenna is less than or equal to 2 for practical antennas, The designed antenna gives a VSWR of 1.2 at 2.7 GHz and 1.3 at 4.6 GHz, which is below 2 so That value defines that the antenna is perfectly matched.

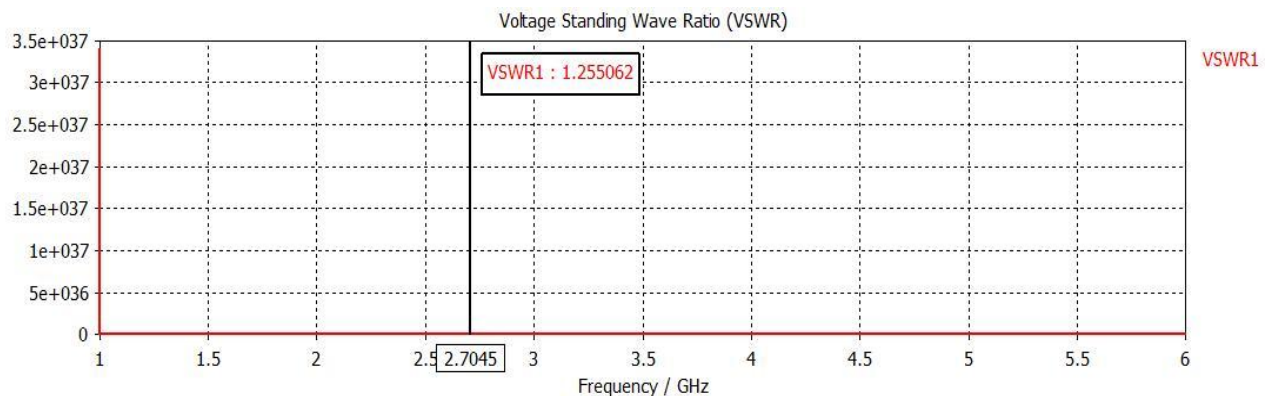


Figure 4.7: Simulated VSWR at 2.7 GHz Frequency

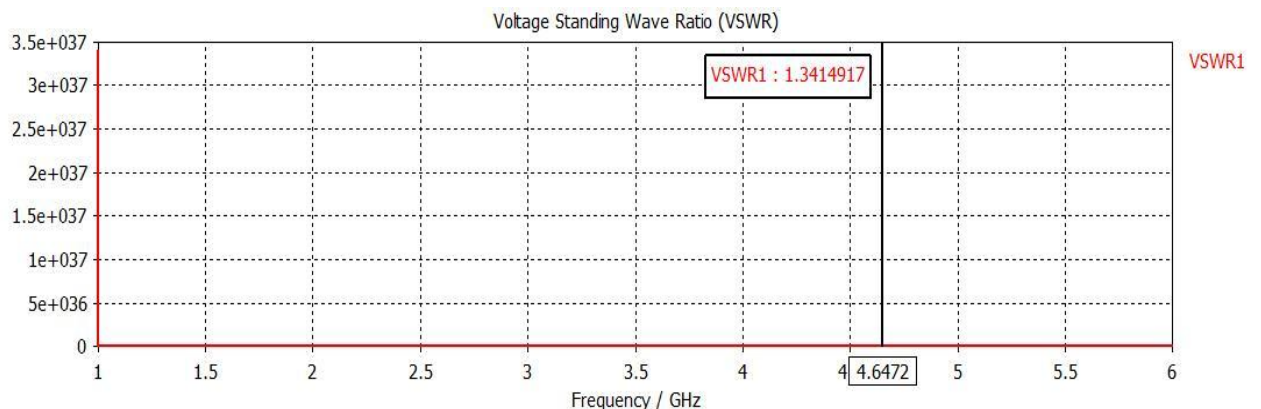


Figure 4.8: Simulated VSWR at 4.6 GHz Frequency

4.2.6 CURRENT DISTRIBUTION

The current distribution graph shows the direction of the current flow and the intensity of the Current. First resonate frequency 2.7 GHz which is lower frequency band that occur due to the bridge patch and outer ring of rectangular patch which effect the lower frequency band in which show the current distribution at resonate frequency 4.6 GHz which show the bridge patch and inner most rings are responsible for the middle frequency band.

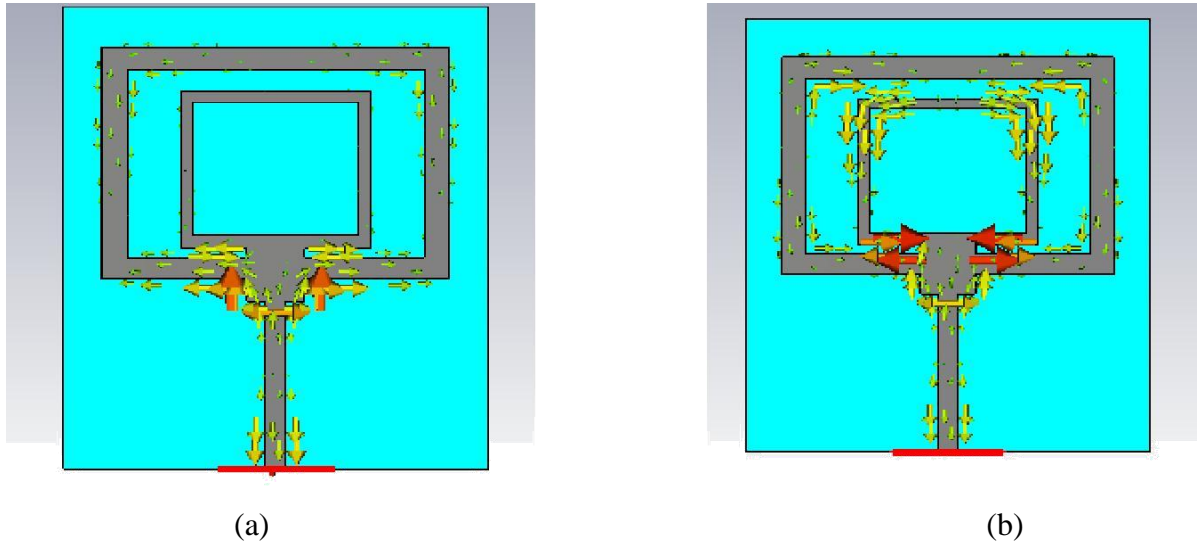


Figure 4.9: The current distribution at resonate frequency (a) 2.7 GHz and (b) 4.6 GHz

4.3 CONCLUSION

The results of the dual band antenna operating at 2.4 GHz and 4.6 GHz are summarized in the Following:

Table 4.3: Comparison of the antenna parameters values of Dual band Antenna resonating at 2.7 GHz and 4.6 GHz

Resonating frequency (GHz)	Return loss (dB)	Bandwidth (MHz)	VSWR	Directivity (dBi)	Gain (dB)
2.7	-28	590	1.2	3.48	3.2
4.6	-17	241	1.3	3.52	2.7

In this design here using a two ring work as a patch and defect in ground plane, both rings are connected to a single bridge show in Figure 4.1. The defect in ground plane and give a wide band at resonate in 2.7 GHz the most effect. The above designed antenna gives excellent results in two resonating frequencies 2.7 GHz and 4.6 GHz and bandwidth 590 MHz, 291 MHz and return loss -28 dB and -17dB and cover the WiMax and IMT and Bluetooth band. These parameter values and can be used for various applications in military, Rader and various wireless applications and give the 50 ohm impedance matching.

**MULTI BAND RECTANGULAR MICROSTRIP PATCH ANTENNA
USING DEFECTED GROUNG STRUCTURE (DGS)**

In this chapter design multiband microstrip patch antennas using defected ground structure and cover the various band which useful in wireless communication. In this design using a three ring they are connected with single bridge work as a patch and defect in reduced ground plane. The slot in ground plane improves the performance of antenna and reduces the size of antenna. This designed antenna fulfills the requirement of areas like industrial, scientific and medical [ISM].

5.1 Design and simulation of multiband microstrip patch antenna with a defect in reduced ground plane.

The proposed antenna using the microstrip feed line and covering the multiband frequency first resonate frequency (3.5 GHz) with band width 1267 MHz second resonate frequency at (5.4 GHz) with band width at 1150 MHz . The value of S_{11} at 3.5 GHz is around -34.24 dB and 5.4 GHz is around at -35.81dB and they cover up the WLAN, WIMAX and IMT band. The third Resonate frequency (7.1 GHz) with band width 290 MHz and the S_{11} is -31.24 dB. This band covers the X band and which are used in satellite and give the good return loss and batter bandwidth.

Table 5.1: Design specifications of substrate:

Thickness of Substrate	0.82 mm
Dielectric constant (ϵ_r)	4.4
Tangent loss	0.0009
Material	FR4

Table 5.2: Optimized parameters:

Specification	Dimensions (mm)
Substrate ($W_s \times L_s$)	55×44×0.8
Line feed ($L_f \times W_f$)	20× 2.07
Ground ($L_g \times W_g$)	10×10
DGS ($L_g \times W_d$)	20×1.48
L_1	27.6
L_2	15.6
L_3	9.0
W_1	36.0
W_2	19.7
W_3	12.2
D_1	2.6
D_2	1.3
D_3	0.65
L_b	7.8
W_b	6.0

5.1.1 Antenna Design:

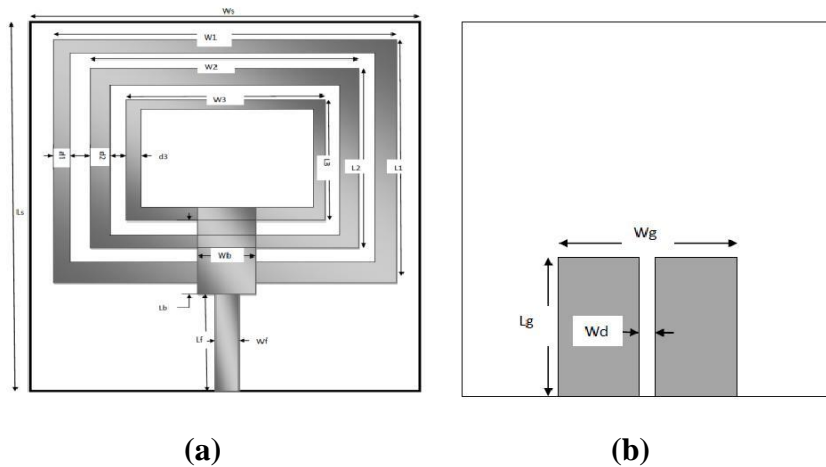


Figure 5.1: Simulated Design (a) Front view (b) Back view

5.2 Simulated Results:

5.2.1 Return Loss and Antenna Bandwidth:

The return loss should be more negative for best power coupling, as per discussed antenna parameters for better performance and wideband requirement. That is, return loss is the negative of the reflection coefficient expressed in decibels. Thus we measure return loss at 10dB. The proposed antenna obtain multiband frequency first resonate frequency (3.5 GHz) with band width 1267 MHz (2.55-3.85 GHz) and second resonate frequency at (5.4 GHz) with band width at 1150 MHz (4.84-6.00 GHz). The value of S_{11} at 3.51 GHz is around -34.24 dB and 5.48 GHz is around at -35.81dB and they cover up the WLAN, WIMAX and IMT band. The third resonate frequency (7.1 GHz) with band width 290 MHz (7.01-7.30 GHz) and the S_{11} is -31.24 dB. This band covers the X band and which are used in satellite and radar.

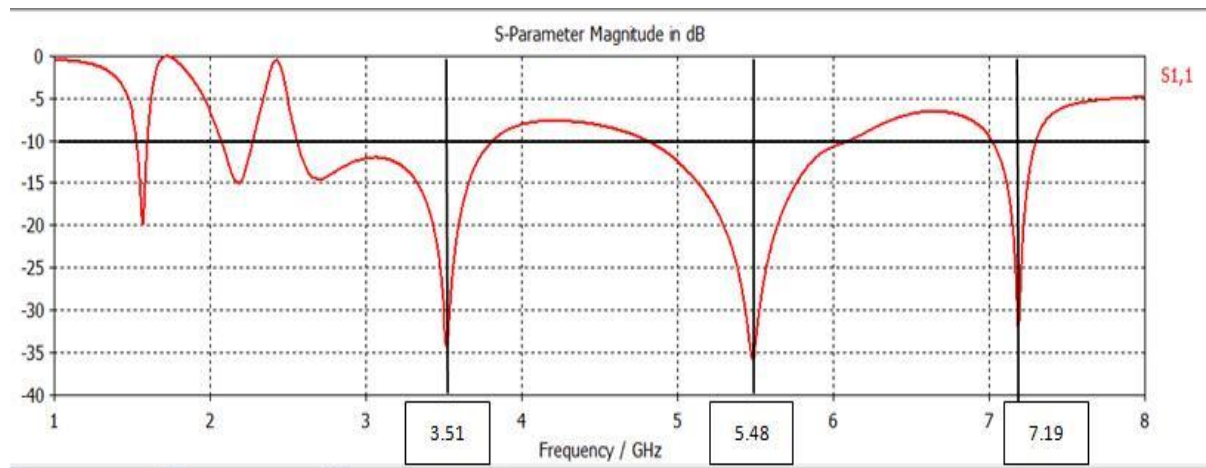


Figure 5.2: Return Loss of Multiband Antenna

5.2.2 Directivity:

Figure 5.3 the plot of directivity of proposed antenna represents amount of radiation intensity i.e. is equal to 3.77 dBi at 3.5 GHz, 3.68 dBi at 5.4 GHz and 5.67 dBi at 7.1 GHz. The red portion in the figure defines the maximum radiation.

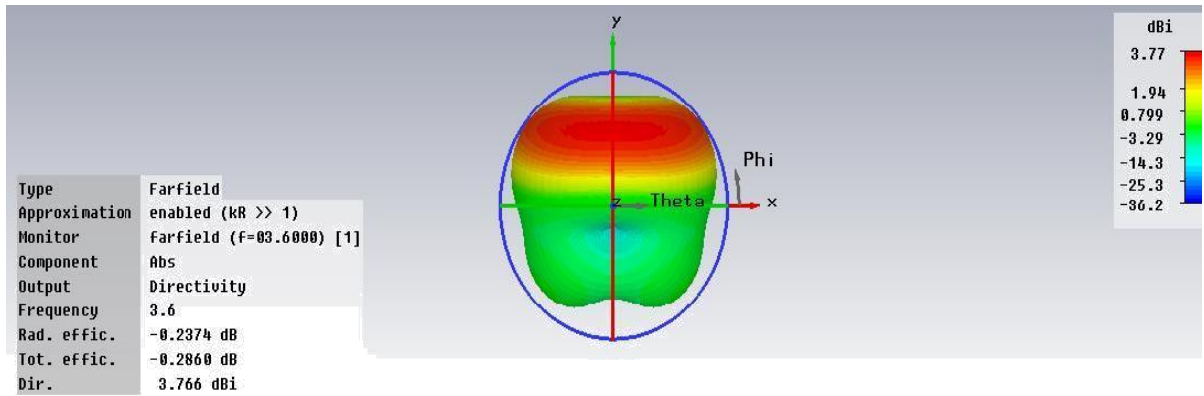


Figure 5.3: Directivity at 3.5 GHz

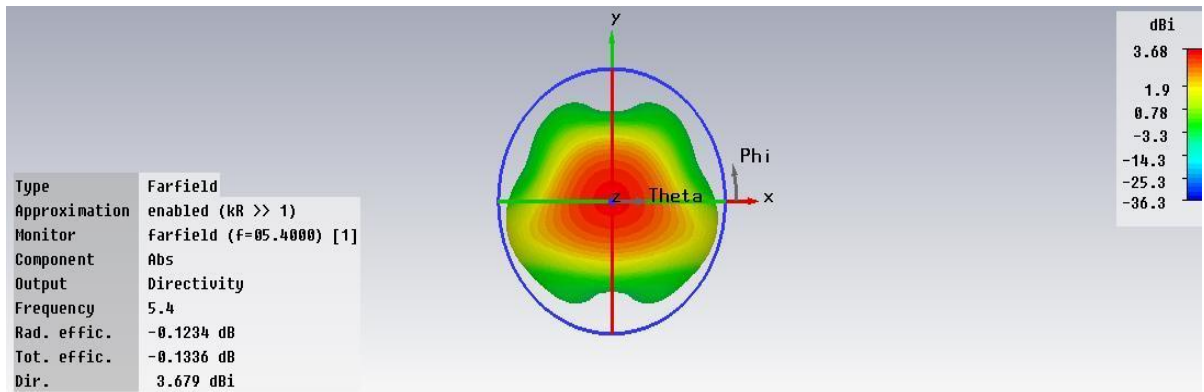


Figure 5.4: Directivity at 5.4 GHz

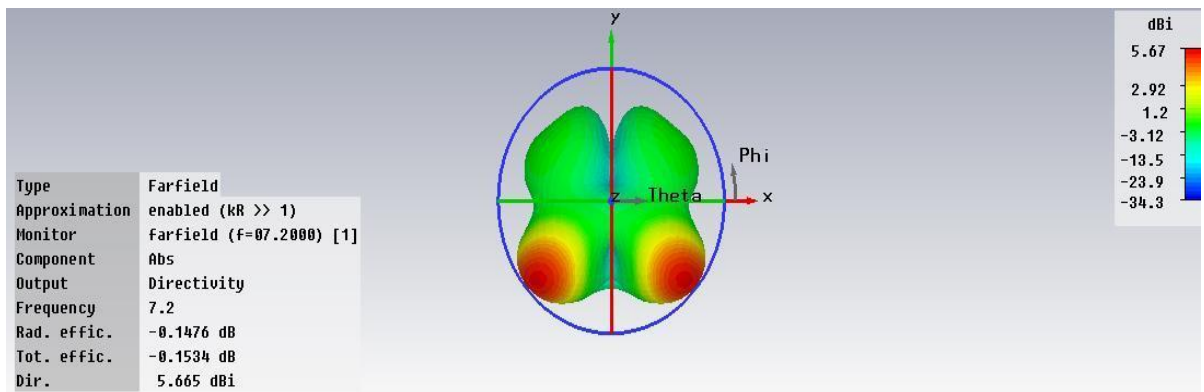


Figure 5.5: Directivity at 7.1 GHz

Gain:

In this design a reduced ground structure is used which decreases the gain of the antenna but the overall antenna parameters are efficient. The designed antenna gives a gain of 3.53 dB at 3.5 GHz, 3.56 dB at 5.4 GHz and 5.52 dB at 7.1 GHz. The simulated results of gain at three different frequencies are given below:

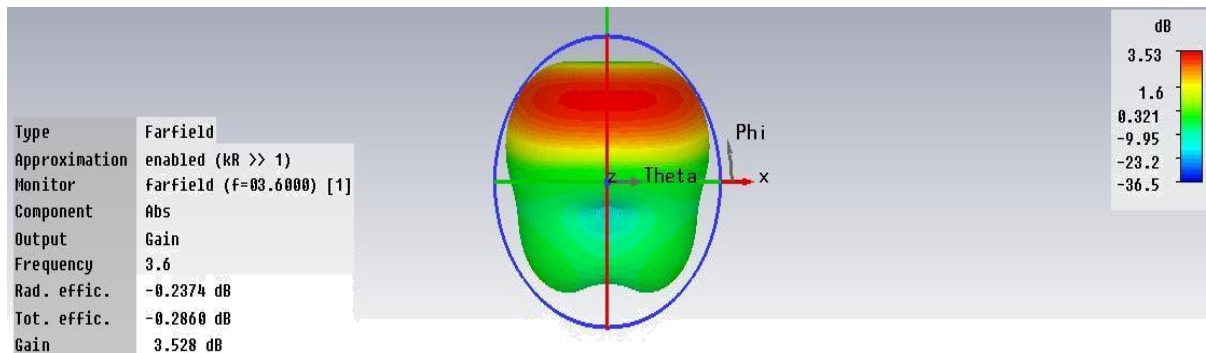


Figure 5.6: Gain of the designed Antenna at 3.5 GHz

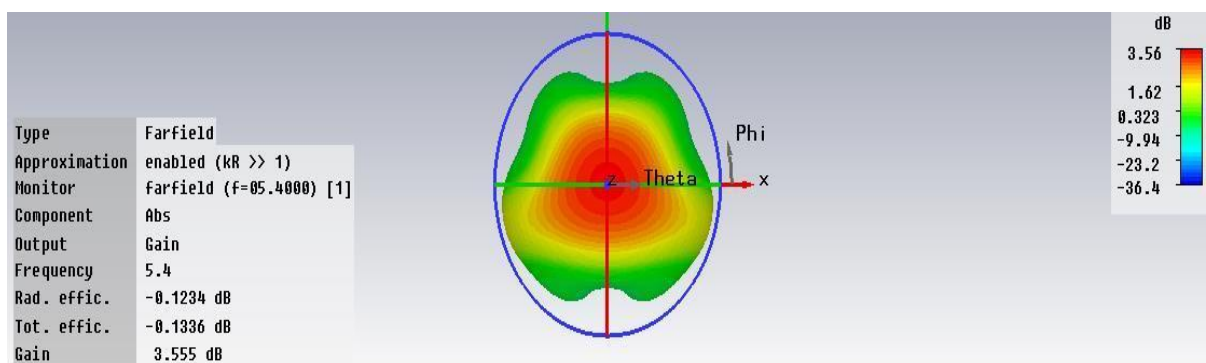


Figure 5.7: Gain of the designed Antenna at 5.4 GHz

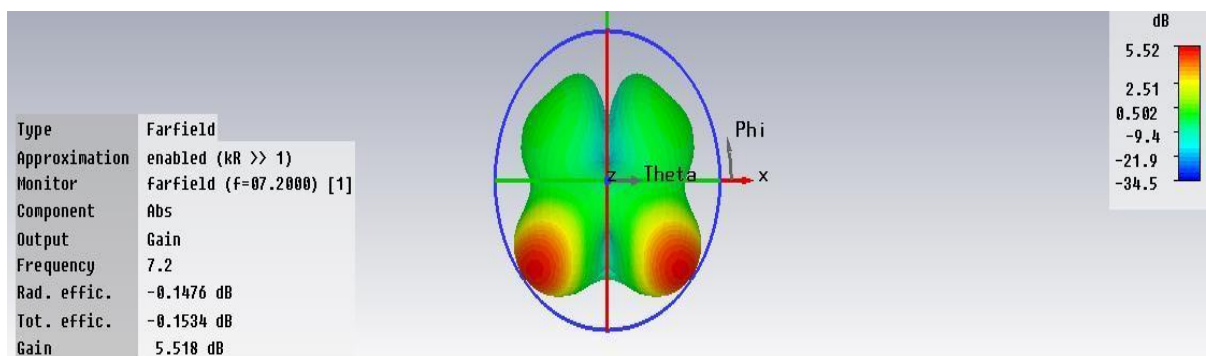


Figure 5.8: Gain of the designed Antenna at 7.1 GHz

5.2.3 VSWR:

The proposed antenna VSWR is less than 2 this reason is acceptable value and there is less power reflected back to source. The simulated antenna gives VSWR of 1.04 at 3.5 GHz, 1.03 at 5.4 GHz and 1.05 at 7.1 GHz. The simulation results of VSWR at three different resonating frequencies are given as follows:

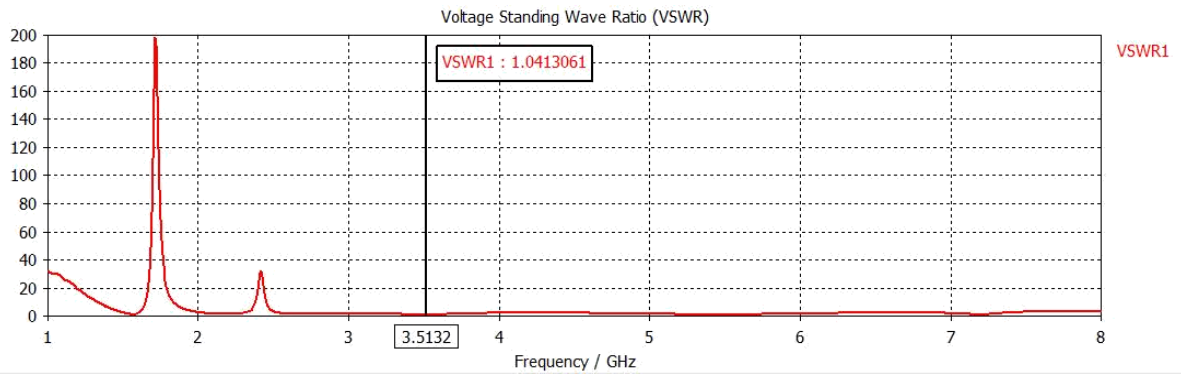


Figure 5.9: Simulated VSWR at 3.5 GHz Frequency

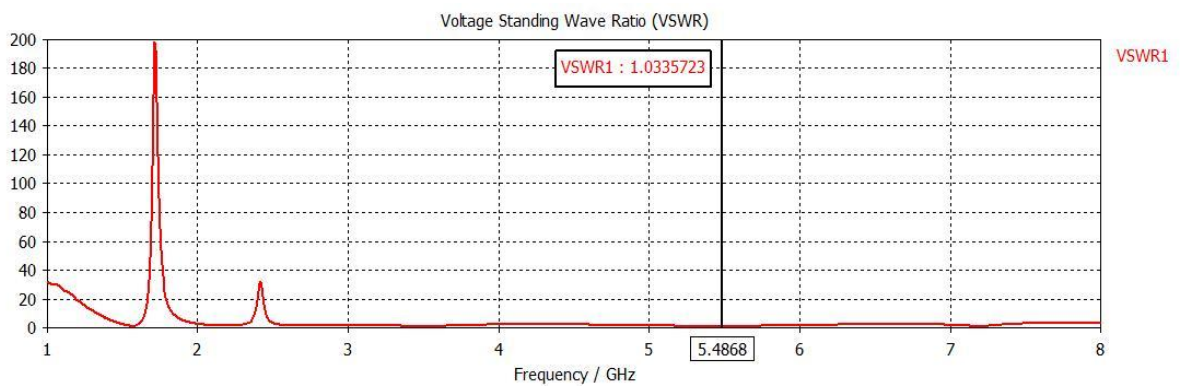


Figure 5.10: Simulated VSWR at 5.4 GHz

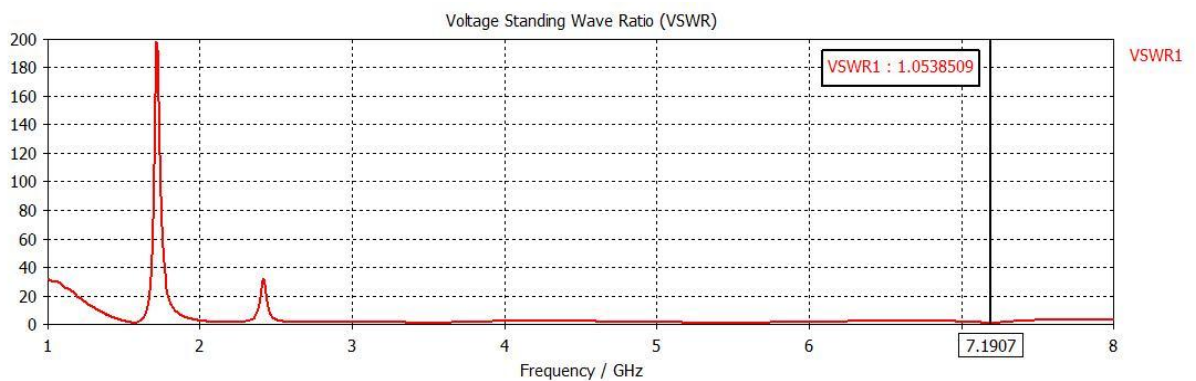


Figure 5.11: Simulated VSWR at 7.1 GHz

5.2.4 Current Distribution:

The current distribution graph shows the direction of the current flow and the intensity of the current. In this antenna is shown in figure (a) show current distribution at resonate frequency 3.5 GHz which is lower frequency band that occur due to the bridge patch and outer ring of rectangular patch which effect the lower frequency band .The current distribution at resonate frequency 5.4 GHz which show in figure (b) the bridge patch and inner most rings are responsible for the middle band frequency in Figure (c) current distribution at 7.1 GHz the inner most rings are responsible for upper band.

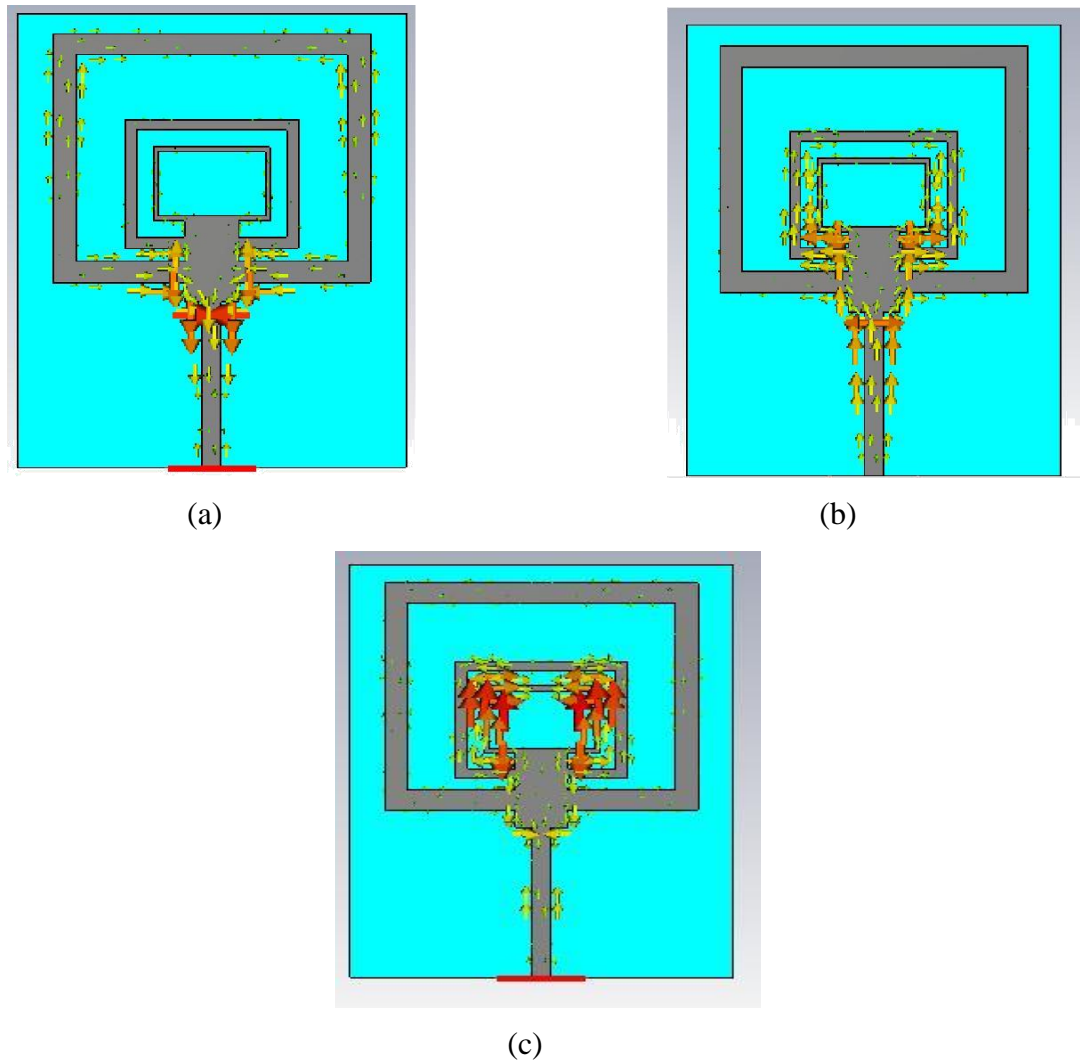


Figure 5.12: The current distribution at (a) 3.5 GHz (b) 5.4 GHz and (c) 7.1 GHz

The results of the above designed antenna are summarized in the following table.

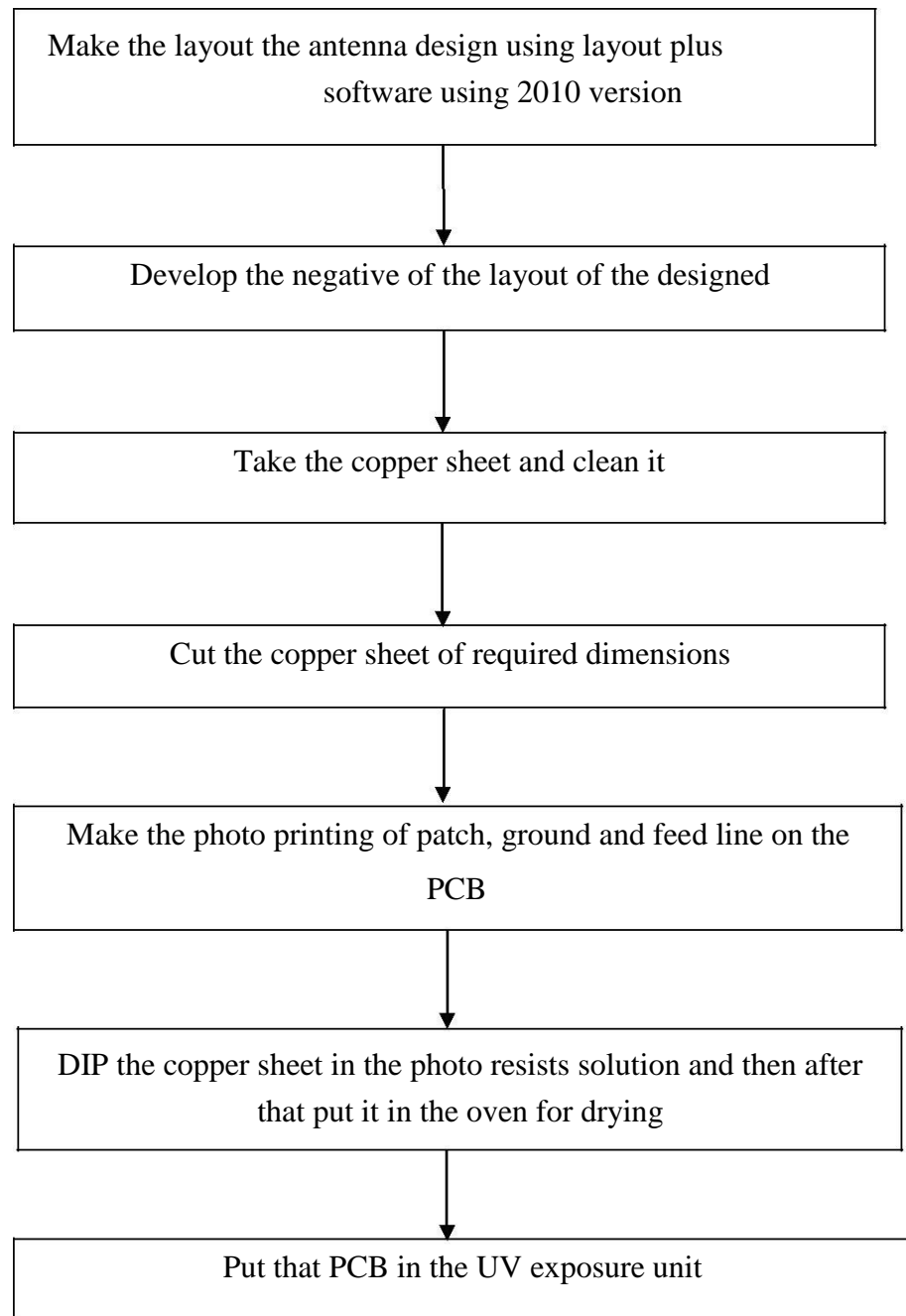
Table 5.3: Comparison of the antenna parameters values of multiband antenna resonating at 3.5 GHz, 5.4 GHz and 7.1 GHz

Resonating frequency (GHz)	Bandwidth (MHz)	VSWR	Directivity (dBi)	Return loss (dB)
3.5	1267	1.04	3.77	-34
5.4	1150	1.03	3.68	-35
7.1	290	1.05	5.67	-31

5.3 Fabrication and Testing of Multiband Microstrip Patch Antenna.

5.3.1 Flow Chart of Antenna Fabrication Process:

There are various steps followed when we fabricate an antenna. This can be shown via a flow chart:



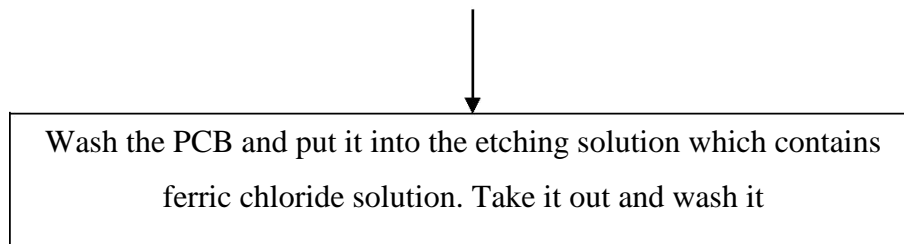


Figure 5.13: Flow Chart of Antenna Fabrication Process

5.3.2 Instruments used while fabricating proposed MPA:

The hardware used to design of the antenna includes two processes namely PCB (Printed circuit board) design and testing of the antenna. The various steps for the PCB design are explained as:

Negative developing: The negative development is done by software. The whole design is designed in this software and then print out of that design is taken.

The PCB cutter is used to PCB's as per desired size. The actual size of antenna i.e. Substrate size of material, like FR4 ($\epsilon_r = 4.4$) is used here. Figure 5.14 shows the PCB cutter.



Figure 5.14: PCB cutter

Operations on PCB: - Now the PCB is dipped once in the photo resist developer placed in Yellow light. It dried in an oven for 3-5 minutes.



Figure 5.15: PCB Coating Unit

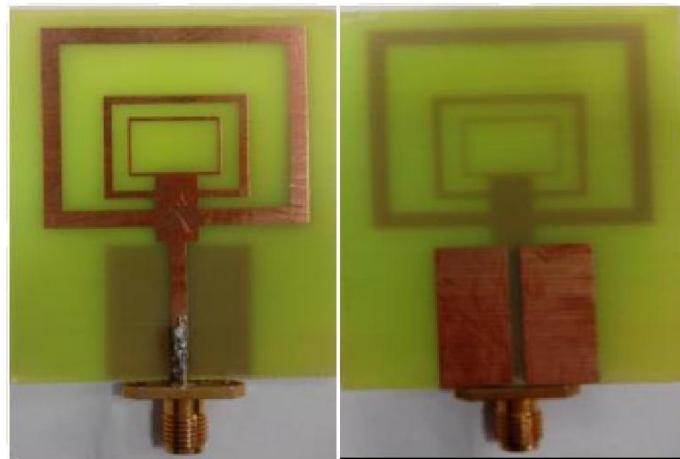
The oven unit is used to dry the final design on antenna, which contain the paint on the layer that protects the copper to clean up. Thus, the oven dries the PCB at 140-150 degree temperature properly. Figure (5.16) shows the picture of the Oven Unit.



Figure 5.16: Oven Unit

5.3.3 Fabricated Antenna:

Below are the some fabricated antennas. Figure 5.17 shows the multiband antenna with defected ground structure covering the WiMAX, WLAN, IMT and X bands The fabricated MPA with microstrip feed line. The simulated results of antennas are discussed in above:



(a) Front view

(b) Back view

Figure 5.17: Fabricated antenna connected with SMA connector

5.3.4 Testing of proposed MPA:

The multiband microstrip patch antenna using for wireless application was designed in (CST MWS V10.0). But practically, antenna has been tested using VNA Model No: E5071C, frequency range is 9 KHz-8.5 GHz and is shown below:



Figure 5.18: Instrument used for Testing



Figure 5.19: Measured Result of proposed MPA

The proposed antenna first resonates at 3.51 GHz covering the range from (3.5- 3.9 GHz) with a bandwidth of 430 MHz and second resonance at 5.48 GHz covering the range from (5.1- 5.8 GHz) with a bandwidth of 700 MHz. The proposed antenna covers the WiMAX, IMT and WLAN bands.

It was found that the results have some variations given below:

- In the multiband, the first simulated result covers the frequency band (2.5- 3.5) GHz and in the fabricated results, the antenna shifts to the right and covers the frequency bands 3.5 GHz to 3.9 GHz and the antenna's response in terms of return loss is more but the bandwidth is less and the second simulated result covers the frequency band (4.8- 6.00 GHz) in the fabricated results, the antenna shifts to the right and covers the frequency band (5.1-5.8 GHz).
- The return loss graphs show that the resonant frequencies have shifted in the magnitude from the designed frequency for all the designs. The root cause of the shift could be due to the FR-4 board, which has that varies the thickness of the substrate from 0.82 to 0.87. In the practical world, a material which has varying length, width, and height, will affect the resonant frequency to shift, during simulation it is assumed a constant. Other factors affecting etching accuracy such as chemical used, surface finish and metallization thickness also could be the reason for shifting the resonant frequency.

Table 5.4: Comparison between simulated results and fabricated results

Parameters	Simulated Results	Fabricated Results
Frequency Covered	(2.5-3.8 GHz), (4.8-6.0 GHz)	(3.5-3.9 GHz), (5.1-5.8 GHz)
Return Loss	-34 dB, -35dB	-40 dB, -35dB
Bandwidth	1267 MHz, 1150 MHz	430 MHz, 700 MHz
Applications	WLAN, WiMAX and IMT	WLAN, WiMAX and IMT

5.3 Conclusion:

In this chapter triple rectangular ring work as a patch and defect in reduced ground plane. The proposed antenna gives a better return loss of -34 dB, -31 dB and -31 dB respectively. The gain of antenna is 3.53 dB, 3.56 dB and 5.52 dB and directivity of antenna is 3.77 dB, 3.68 dB and 5.67 dB which is good and suitable for WLAN, WiMAX and IMT applications. The fabricated results gives the dual band but there is shift in frequency due to the FR-4 board, which has that varies the thickness of substrate from 0.82 to 0.87. In practical world, a material which has varying along a length, width, and height, will affect resonant frequency to shift, during simulation it is assume a constant. The other factors affecting etching accuracy such as chemical used, surface finish and metallization thickness also could be the reason for shifting the resonant frequency. The antenna gives a wide bandwidth, better return loss adding defect in ground and optimizing the width of ground we get a good impedance matching and also reduction in harmonics that occur during optimization.

6.1 Conclusion

In this thesis report three configurations of microstrip patch antenna using microstrip inset feeding techniques. The first design of single band microstrip patch antenna with a H- shape defect in ground plane, second is the dual band rectangular microstrip patch antenna with a slot in ground plane and third is the multiband rectangular Microstrip patch antenna with a reduced ground and defect in ground plane. The various antenna parameters like return loss, VSWR, directivity, gain, and current distribution are studied for antenna designing. The effect of physical parameters on the antenna parameters are also studied in this thesis report.

Initially, the work starts with the designing of the single band rectangular microstrip patch antenna using DGS. In this design using a H-shape defect in ground plane and reduce the higher order harmonics in microstrip patch antenna. The resonate frequency of proposed antenna 1.8 GHz and cover the GSM band. This designed single band antennas give efficient results. The results give return loss of -20 dB bandwidth of 193 MHz respectively. The antenna has various applications in mobile phones, electronic devices like microwave ovens and satellite communication etc.

Second, design a dual band rectangular patch in which we using a patch as dual rectangular ring and the size of ground and substrate are same and DSG effect has been done as shown in Figure 4.1. Both rings are connected to a single bridge and the length of inner ring and bridge patches have been optimized to control the bandwidth of antenna. The resonate frequency 2.7 GHz and 4.6 GHz .The results give a return loss -28dB and-17 dB with bandwidth 590 MHz and 241 MHz and cover the WiMAX, IMT and Bluetooth applications.

Finally, the multiband antenna using [DGS] gap in the reduced ground plane helps in improving the results and bandwidth and gives the multiple bands. Here using a patch as triple rectangular ring and with a slot in reduced ground plane by viewing the current distribution graph, the varying the length in ground to obtain the desired results of the antenna. The designed antenna efficiently resonates at 3.5 GHz, 5.4 GHz and 7.1 GHz. The

results gives a return loss -34 dB, -31 dB and -31 dB with bandwidth 1267 MHz, 1150 MHz and 290 MHz and covers the WiMAX, WLAN, IMT and X band.

6.2 Future Scope

The designed antennas in this thesis report are used in various applications like WLAN, IMT, WiMAX, GSM and X band etc.

6.2.1 Various techniques can also be used in future to design antenna which are as follows:

The future development this work another type of slot in the ground plane like a T-shape, U-shape and E shape improve the return loss, gain and bandwidth of antenna then covering the band using the varies application. Now this work focusing on enhance the gain by implement the array patch technique and also implement the different patch shape to configure the optimal performance. The other feeding techniques of microstrip patch antenna like coaxial feeding, aperture coupling and CPW can also be used in future to design microstrip patch antenna. A metamaterials is a metallic or semiconductor substance whose properties depend on its inter-atomic structure rather than on the composition of the atoms themselves. Certain metamaterials bend visible light rays in the opposite sense from traditional refractive media. Some metamaterials also exhibit such behavior at infrared (IR) wavelengths. Possible applications of transparent metamaterials with negative indices of refraction include red and IR lasers, optical communications systems, spectrometry, monitoring systems to detect trace gases in the atmosphere, medical diagnostic equipment and optical cloaking devices. In metamaterials both ϵ_r and μ_r are negative.

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