PERFORMANCE ENHANCEMENT OF MICROSTRIP PATCH ANTENNAS FOR WLAN APPLICATIONS

Thesis submitted towards the partial fulfillment of the requirements for the award of degree of

MASTER OF ENGINEERING

IN

WIRELESS COMMUNICATION

Submitted By

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DECLARATION

I, Baljinder Singh, hereby declare that the work, which is being presented in the thesis entitled **"Performance Enhancement of Microstrip Patch Antennas for WLAN Applications"** by me in partial fulfillment of the requirements for the award of degree of Master of Engineering in Wireless Communication from Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Mrs. Amanpreet Kaur**, Assistant Professor, Electronics and Communication Engineering Department.

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

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This is to certify that the above statement made by the student is correct to the best of my knowledge and belief.

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ABSTRACT

This work covers two aspects of the microwave technology. The first is analysis and design of single band Microstrip Antenna with low back lobe level and improved FBR and second is analysis and design of Multiband Microstrip Antenna with low back lobe level and improved FBR. Effect of with and without partial ground with edge shaping on FBR is compared in the report. Another method of fractal ground plane is developed in the work to reduce back radiations. This method is most suitable for fabrication purpose and also gives miniaturized antenna. Method of corrugated dielectric reflector is also proposed in this work. Corrugations help reducing the back lobe level. Concept of metal reflector is also used to reflect back radiations in front direction and improve FBR. Work also involves back lobe reduction using two thick dielectric reflectors at the back side of the antenna of an inset feed single band and a multiband antenna. Inset feed line provides improved bandwidth and much better return loss. Maximum improvement in back lobe and FBR of is achieved by the method of partial ground plane with edge shaping. Fabrication of MSA with double back reflector is also done as well as the testing is done using VNA model no. MS46322A. Tested results along with the comparison with simulated results are also shown.

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ABBREVIATIONS

FBR	Front to Back Ratio
BLL	Back Lobe Level
SLL	Side Lobe Level
CDMA	Code Division Multiple Access
FDMA	Frequency Division Multiple Access
GSM	Global System for Mobile Communications
MSA	Microstrip Antenna
VNA	Vector Network Analyzer
WiMAX	Worldwide Interoperability Microwave Access
WLAN	Wireless Local Area Network
CST	Computer Simulation Technology
DGS	Defected Ground Structure
Wi-Fi	Wireless Fidelity
ISM	Industrial, scientific and medical radio frequency band
B.W	Bandwidth

EBG	Electromagnetic Band Gap
SRR	Split Ring Resonators

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless technology has undergone different stages of development since its emergence. It has covered many evolutionary paths and has improved performance and efficiency in mobile environment [1]. The electromagnetic spectrum is a natural resource and this resource is fully utilized by wireless communication systems. In the communication industry, wireless communication is growing very rapidly. From the last few years cellular systems have grown exponentially and there are billions of users all over the world. The cellular systems have become a major business tool in the world and an important part of our daily life in almost all the leading countries [1]. The name "Wireless" is basically used for referring a radio transmitter and receiver. An antenna forms an indispensible part of a wireless communication system & is used for transmission and reception of electromagnetic waves. It acts as a transducer to convert electrical energy to electromagnetic waves and vice versa.

1.2 Wireless Communication System and its Evolution

Presently wireless communication, by measure is the fastest growing segment of the communication field. There are many government and commercial applications such as mobile radio, satellite communication and Wireless communication where weight, size, cost, performance, ease of installation, aerodynamics profile are major constraints. The vision of the wireless communication supporting information exchange between people and devices is the communication frontier of the next few decades. This vision will allow multimedia communication from anywhere in the world. In the last few years, the development of wireless local area networks (WLAN) and WIMAX (Worldwide Interoperability for Microwave Access) represented one of the principal interests in the information and communication field. Recent developments in the wireless communication system have basically gone through four generations.

Evolution of wireless access technologies is about to reach its Fourth Generation (4G). Looking past, wireless access technologies have followed different evolutionary paths aimed at unified target: performance and efficiency in high mobile environment. The First Generation (1G) has fulfilled the basic mobile voice, while the Second Generation (2G) has introduced capacity and coverage. This is followed by the Third Generation (3G), which has quest for data at higher speeds to open the gates for truly "Mobile broadband" experience, which will be further realized by the Fourth Generation (4G) [2].

1.2.1 First Generation (1G)

It involved AMPS technology, based on the analog signals. These signals are radio signals transmitted in wave like forms. A mobile equipment transmits the signal to base station, from these signals it is got to know that where these signals are going to be send next, like next base station or mobile station or land line. Once the final destination is known, signal is once again converted back to original form by the base station. The signal received by the end user is the duplicate of the original signal and closely resembles it. The main differences between original and received signals are the quality and form. Signal destruction and interference problems are more in analog transmission than in digital communication.

1.2.2 Second Generation (2G)

In first generation narrow band analog system was used, over which voice calls and text massage could be send. The transmission speed used was 9.6 Kbps. The second generation was improved by the digital modulation. It involved converting a voice signal into digital code and then into analog signal. It overcomes the problem of privacy as in the first generation. In this form narrow band signal is used that gives more clarity to the voice calls. Second generation was first transformed into 2.5 G, then into the third generation. This in between stage involved the applications like GPRS (General Packet radio service), EDGE (Enhances Data Rates for GSM Evolution) and SMS (Short Message Service). Some of the advantages of second generation over first generation are lower power dissipation, increased sound quality**,** lesser powered radio signals and enhanced security.

1.2.3 Third Generation (3G)

Third generation of mobile system is running successfully these days. It is introduced to overcome the limitations in the second generation. Third generation network provides wide band form. Wide banding provides good clarity and real like voice. High quality is provided by the technology called packet switching, as data is sent through the packet switching. Voice calls are interpreted by circuit switching. This generation of mobile system provides data service and calling simultaneously which was not possible earlier. It supports mobile TV, video calls and mobile internet at the speed of 2 Mbps. It supports other few technologies like WCDMA, EV-DO and HSPA. This technology has a bandwidth of 15-20MHz and operates at a frequency of 2100MHz. video chatting and high speed internet are the main features of third generation. Other features are it provides global roaming, gives good voice quality, Mobile TV, 3D gaming, video conferencing, Tele-medicine and location based services

1.2.4 Fourth Generation (4G)

Fourth generation provides higher data rate than the third generation. In addition to third generation it provides Multi-Media newspaper and high definition TV programs as with more clarity as compared to simple television. Bandwidth up to 40MHz is provided. Technologies like ultra broadband internet access, HDTV streamed multimedia, gaming services and IP telephony. More over existing users can use this technology with no problem. In this generation techniques included are flash-OFDM, 802.16e mobile version of WiMAX and HC-SDMA.

In this evolution two important standards Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) technology are most rapidly growing area in the modern wireless communication. These give users the mobility to move around within a broad coverage area and still be connected to the network. This provides greatly increased freedom and flexibility in terms of wireless connectivity. For the home user, wireless has become popular due to ease of installation, and location freedom. For success of all these wireless applications we need efficient and small antenna as the size of the device is becoming smaller and smaller.

An important component of these wireless systems is the antenna. An antenna serves as the transition between the RF front-end circuitry and the radiation and propagation of electromagnetic waves in free space. An antenna is a wire or a current carrying conductor. Antenna transmits and receives electromagnetic waves by changing electromagnetic waves into electrical signals and vice versa. That current carrying signal will generate electromagnetic field around the wire, and that field will vary with the current changes. If another wire is placed near that wire, electromagnetic field will induce and that will be the copy of that but will be lesser in force. If wire is long, it will send its radiations up to a long distance. They transmit radio waves and widely used for radio, point to point, spacecraft, cellular and wireless LAN communication. Different types of antennas are used for different applications. Television antennas are used for Ultra high frequency and Very high frequency or both. Antennas are also categorized in terms of distance also like short, medium and long wave communication [3]. In today's environment, technology demands antennas which can operate on different wireless bands and should have different features like low cost, minimal weight, low profile and are capable of maintaining high performance over a large spectrum of frequencies. In this era of next generation networks we require high data rate and size of devices are getting smaller day by day. This technological trend has focused much effort into the design of Microstrip patch antennas.

Next Generation wireless communication devices have more than one application embedded in single device so antenna supporting more than one band is required and multiband operation of a microstrip antenna is another challenge, for example dual-band wireless phones have become popular recently because they allow using the one phone in two networks that have different frequencies. Tri-band phones have also gained popularity. The systems having multi-band operation require antennas that resonate at the specified frequencies. Microstrip antennas (MSA) have characteristics like low cost and low profile which proves microstrip antennas to be well suited for WLAN/Wi-MAX application systems. Microstrip antenna is discussed in detail in next section.

1.3 Microstrip Antennas

A microstrip antenna consists of a metal radiator etched on a grounded dielectric substrate. Dimensions of the radiating element like width, length and feed type describe the behavior of the antenna. Dielectric constant and height of the substrate also affect the antenna performance. Microstrip patch can be of different shapes like rectangular, square or disk shape[4]. They can provide linear, circular or dual polarization depending on the feeding technique. Microstrip patch antennas are easily fabricated, having low cost and low profile.

As shown in the given figure microstrip antenna is fed by microstrip feed line. The ground plane, feed line and patch are made up of perfect electrical conductor like copper. Microstrip patch with length L and width W sits on the substrate with height h and dielectric constant ε_r.The thickness of the ground plane is not that important.

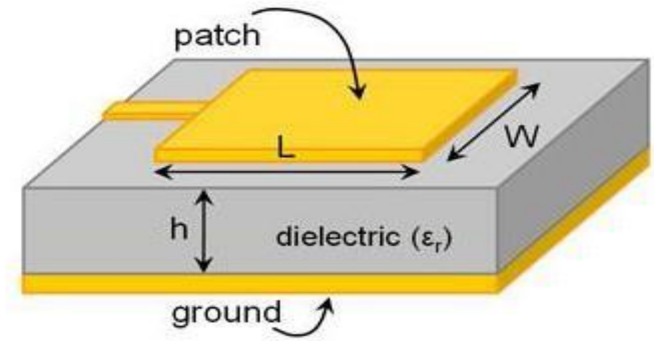


Fig.1.1 Microstrip antenna [4]

When a microstrip antenna is exited, electrical field is zero at the centre of the patch, and maximum at one end and minimum at the other end. The minimum and maximum changes side regularly, as the phase of the applied signal changes. Electric field lines do not stop at the ends suddenly, but extends up to some degree further too. Extension of these field lines is known as the phenomena of fringing [4]. To avoid fringing effect the dielectric constant of the substrate should be kept low.

1.4.1 Working of Microstrip Antenna Based on Transmission Line Model

Operation of microstrip antenna can be divided into two groups on electric and magnetic current, firstly based on the magnetic current induced around the patch and second is electrical current on the patch and the ground plane. This analysis is based on the edge voltage distribution. The two main methods based on this kind of approach are transmission lime model and cavity model. For electric current distribution method of moment is the most common one. Overall transmission line model is the simplest method of all as it gives good physical insight, but it is less accurate. Cavity model is more accurate and also gives good physical insight but it is complex in nature. The full wave models such as FTDD are very versatile, very accurate, can operate on a single element as array as well. They can also work on stacked patches. But this model gives less insight as compared to the transmission line model and cavity model [5].

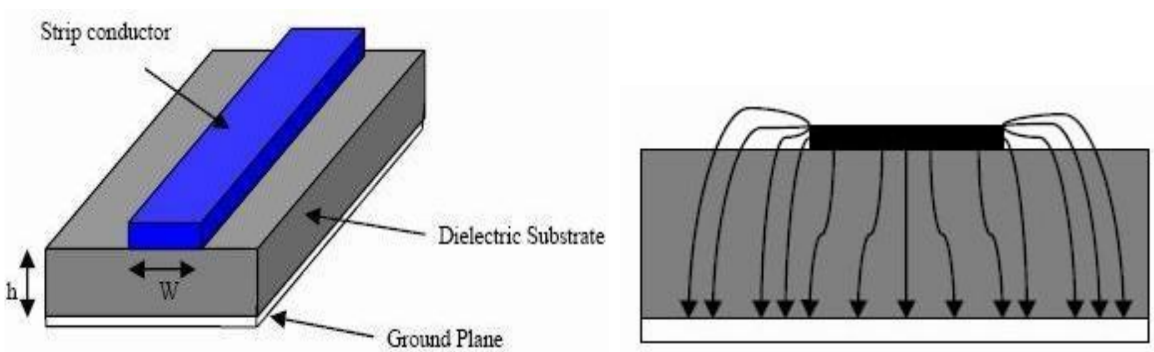
Transmission model is regarded as the best model for its simplicity and it is used in understanding the basic performance of the microstrip antenna. Basically this model was developed for rectangular patch but later on it was extended for other shapes. In this model the microstrip antenna is represented by two slots of width W and height h which is separated by transmission line of length L. In the figure given below it can be seen that whole radiations do not reside in the substrate and transmission line model can not support the clear transverse electro-magnetic (TEM) mode as phase velocities in air and substrate are different [5].

The dominant mode will be Quasi-TEM mode, it means that effective dielectric constant ε_{reff} will calculated considering fringing effect into account. The value of ε_{reff} is less than that of ε_r due to fringing effect as all the electrical field lines do not enter the substrate.

The effective dielectric constant is given by

$$\varepsilon_{reff} = (\varepsilon_r+1)/2+(\varepsilon_r-1)/2\sqrt{[1+12W/h]} \quad \ldots\ldots(1)$$

Where ε_{reff} is the effective dielectric constant and ε_r is the dielectric constant.



(a) (b)

Fig 1.2 [a] Microstrip antenna [b] Electric field line [5].

Here h is the height of the substrate and w is the width of the patch. For operating in TM10 mode, the length of the patch L must be less than half of the wavelength λ. Coordinate axis of the microtrip antenna is selected as length is along X axis, width is along Y axis and height is along Z axis. For operating in TM_{10} mode, the length of the patch must be less than half of the wave length. The length of the patch is equal to $\lambda / \varepsilon_{reff}$. The TM_{10} mode shows that there is no variation in the field along the width and half of the wavelength along the length. In the figure 1.3 [a] microstrip antenna is represented by two slots, which is open circuited at both ends and separated by a transmission line. Along the width of the patch, current is minimum due to open ends and voltage is maximum. Field is divided into normal and tangential parts according to the ground plane. In figure 1.3 (b) normal parts are out of phase because electric fields at both edges are in opposite direction. Since the patch is of length equal to half of the wavelength, they cancel each other in the broadside direction. The tangential parts are in phase and resulting field is maximum. Now the radiating element is electrically wider than it actually looks. Let the dimension of the patch on each side increased by ΔL and its mathematical expression is given by

$$\Delta L = 0.412(\varepsilon_{reff} + 0.3)[w/h + 0.264]/(\varepsilon_{reff} - 0.258)[w/h + 0.8] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The effective length of the patch L_{eff} is now becomes

$$L_{eff} = L + 2\Delta L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

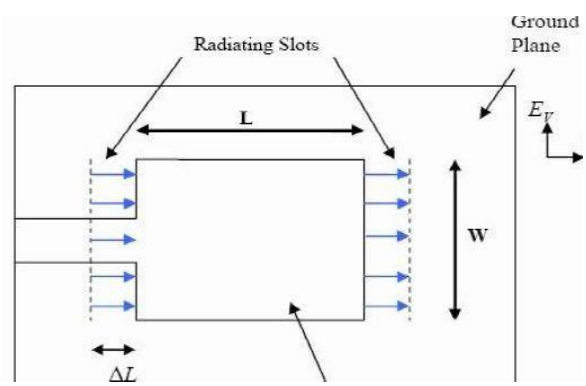
For given resonance frequency the effective length is given by

$$L_{eff} = c / 2 f_o \sqrt{\varepsilon_{reff}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

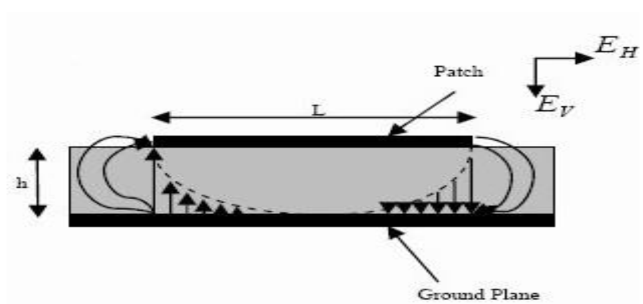
For efficient transmission the width of the patch is given by

$$W = c / 2 f_0 \sqrt{(\varepsilon_r + 1)/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Here L (length) and W (width) are the dimensions of the patch, f_0 is the resonant frequency and c is the velocity of light in air.



(a)



(b)

Figure 1.3 (a) Top view of the microstrip antenna (b) Side view of the microstrip antenna [5].

1.4.2 Advantages and disadvantages of microstrip antenna

Microstrip antenna has some advantages over conventional antenna. Many applications cover under the frequency range of 100 MHz to 100 GHz.

Advantages of microstrip antennas are –

- Lightweight
- Low profile
- Easily integrated into arrays
- Easily integrated with electronic components
- Most suitable for aerospace and mobile applications
- Both linear and circular polarizations are possible with the simple feed
- No cavity backing is required
- Feed lines and matching network can be simultaneously fabricated with the antenna structure.
- Dual frequency and dual polarization antenna can be easily made.

These antennas have some limitations but research has overcome these limitations up to a great extent. Microstrip antennas can be used in commercial areas and military services like missiles, aircrafts and rockets. Commercial antennas should be easy to use, low cost and small in size. Low cost depends upon easily available and produced components.

Disadvantages of microstrip antennas are –

- Low bandwidth
- Lower efficiency than some other antennas
- Associated tolerance problems
- Lower gain
- Large ohmic losses in the feed structure of arrays
- Complex feed structure required for high performance
- Polarization purity is difficult to achieve
- Lower power handling capacity
- Low FBR

Inspite of MSA suffering from the mentioned disadvantages it is preferred in many wireless applications as their advantages overpower the disadvantages associated with the MSA. Bandwidth of a microstrip antenna can be improved by various techniques like stacking, electromagnetic band gap (EBG) and split ring resonator (SRR) etc. Efficiency of a mcrostrip antenna can be improved by reducing the losses of the antenna. There are three types of losses – Conductor losses, Dielectric losses and Surface waves losses. Conductor and dielectric losses get worse for thinner substrates and can be removed using thicker substrates. But for thicker substrates surfaces wave losses are more. Another disadvantage is low FBR and it can be improved by using various techniques like partial ground, superstrate, aperture coupling and edge shaped ground plane etc. The MSA is exited with four major feeding techniques and these are given in next section.

1.5 Feeding Techniques

Selection of feeding techniques depends upon how much power is transferred by feed line to the radiating patch. Power transferred depends upon the impedance matching. Feeding techniques can classified in two techniques one with contacting and other with non-contacting. In contacting, radiating patch is directly given the feed as by microstrip line. In the non conducting case, power is transferred by electromagnetic coupling between radiating patch and the feed line [4]. Some of the most frequently used feeding techniques are stated as follows.

1.5.1 Microstrip Feed Line

As shown in figure 1.4 (a) in microstrip feeding, a strip line is connected to the side of the patch, in order to achieve planner structure. The touching point and width of the patch can be varied to achieve input impedance matching. Microstrip feed line is an easy technique in terms of modeling and fabrication. If thickness of the substrate is increased, surface waves and spurious feed radiation increases. Increased spurious radiations limit the bandwidth.

1.5.2 Coaxial Probe Feeding

It is the most common technique used in microstrip antenna designing. As shown in the figure 1.4 (b), the cylindrical connector is passed through the substrate and directly is in contact with the radiating patch. This technique has the advantage of locating at any desired position to get desired input impedance. Coaxial feeding is flexible and easy to fabricate. It gives low spurious radiations. If the thickness of the substrate is more, impedance matching is difficult to achieve.

1.5.3 Aperture Coupled Feeding

As shown in figure 1.4 (c), the feed line and the microstrip patch are separated by the ground plane. A cut in the ground plane provides coupling between the patch and the feed line. The aperture is generally located at the center as it provides low-cross polarization due to symmetry of the design. The amount of the coupling is determined by the size, shape and position of the slot. The spurious feed radiations are lesser in the case of aperture coupling as it separates the radiating patch from the feed line. Usually a low dielectric thick material is used as the upper substrate and a high permittivity substrate is used as the lower substrate. It is difficult to fabricate and antenna size is more as introduction of multiple layers.

1.5.4 Proximity Coupled Feeding

As shown in figure 1.4 (d), in proximity feeding there are two substrates as in case of aperture coupling, but feed line is placed in between two substrates. The radiating patch is on the top of the upper substrate. As like aperture coupling, it also prevents the antenna from spurious feed radiations. Proximity coupling provides better bandwidth due to overall increase in the antenna thickness. Impedance matching is achieved by adjusting the width-to-length ratio and length of the feed line. As in the case of, aperture coupling, proximity feed is also difficult to fabricate.

In the current research work, aperture coupled fed antennas are used. The main reason for it can be referred from table 1.1. It is very reliable, provides enhanced bandwidth and gives fewer spurious radiations. Table 1.1 shows the comparison between the basic feeding techniques and it is shown.

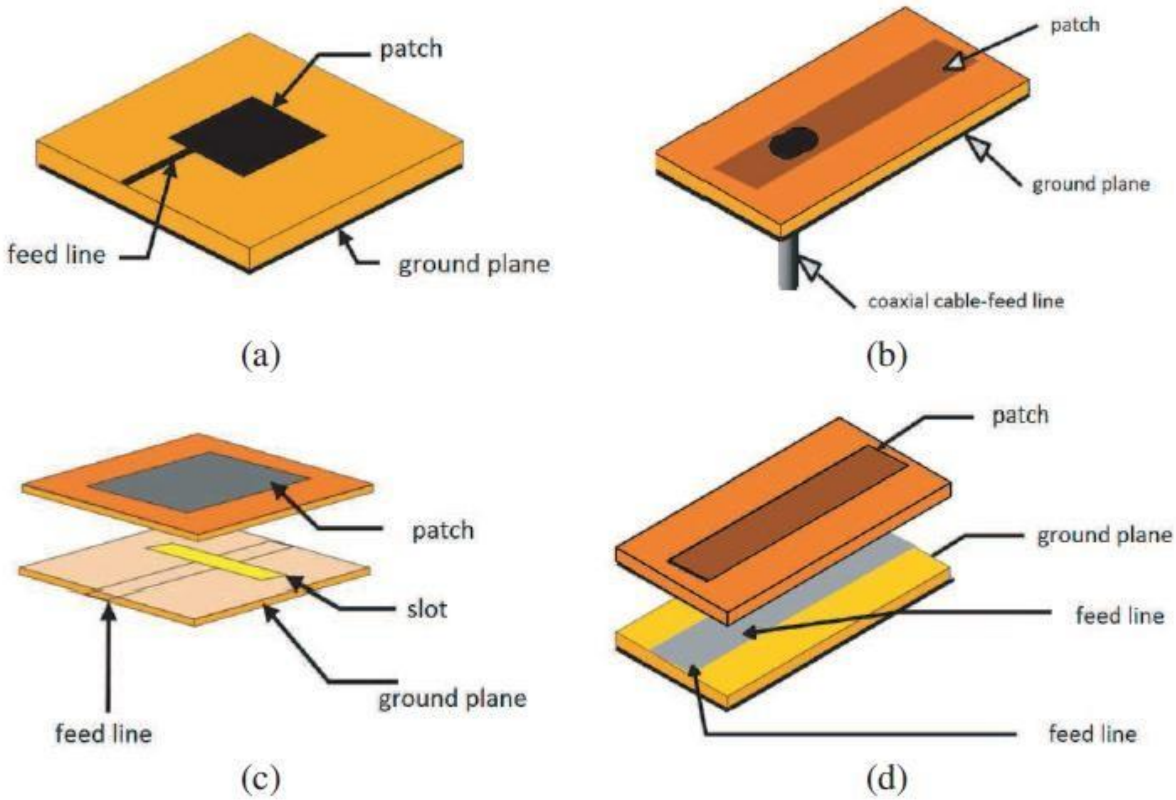


Figure 1.4 (a) Microsterip feed (b) Coaxial feed (c) Aperture coupled feed (d) Proximity feed [4].

Table 1.1 Comparison of different feeding techniques [4]

Characteristics	**Microstrip Line Feed**	**Coaxial Probe Feed**	**Aperture Coupling Feed**	**Proximity Coupled Feed**
Impedance	Easy	Easy	Easy	Easy
Reliability	Better	Poor	Good	Good
Spurious Feed Radiations	More	More	More	Less
Bandwidth	2-5%	2-5%	13%	21%

1.6 Antenna parameters

An antenna performance can be judged from its basic parameters. There are various parameters to check the performance of an antenna, some of them are stated below.

1.6.1 Return loss

Return loss (RL) is the parameter that indicates the power lost to the load and does not come back as a reflection. As it is known that standing waves are generated when transmitter is not perfectly matched to the antenna impedance. Hence the return loss is very similar to VSWR as it indicates how well the impedance matching has been done between transmission line and feed point of the antenna.

The RL is defined as

$$RL = -20\log10 |\Gamma| \quad \text{…………………………………………….. (6)}$$

In practical, VSWR of less than 2 is acceptable, that corresponds to the return loss of 9.5 dB or the power reflection of 11%.

1.6.2 Smith chart

The smith chart was discovered by Phillip H. Smith, is a graphical tool specializing in radio frequency engineering. It is helpful in solving problems of transmission lines and matching circuits. Smith chart is drawn on reflection coefficient plane in two dimensions. It is scaled in normalized impedance or normalized admittance or both. Normalization scaling used for problems having the characteristic impedance or system impedance, although most commonly used is 50 ohms.

1.6.3 Gain

The gain of the antenna is nearly related to the directivity. It shows the efficiency of the antenna as well as directional capabilities. The gain of an antenna is defined as the ratio of intensity in a given direction to the radiation intensity that is obtained if the power accepted by the antenna is radiated in an isotropic manner.

Gain = 4π radiation intensity / total input (accepted) power = $4\pi U(\theta, \phi)$ /Pin………..(7)

A high gain antenna is required to cover long range applications.

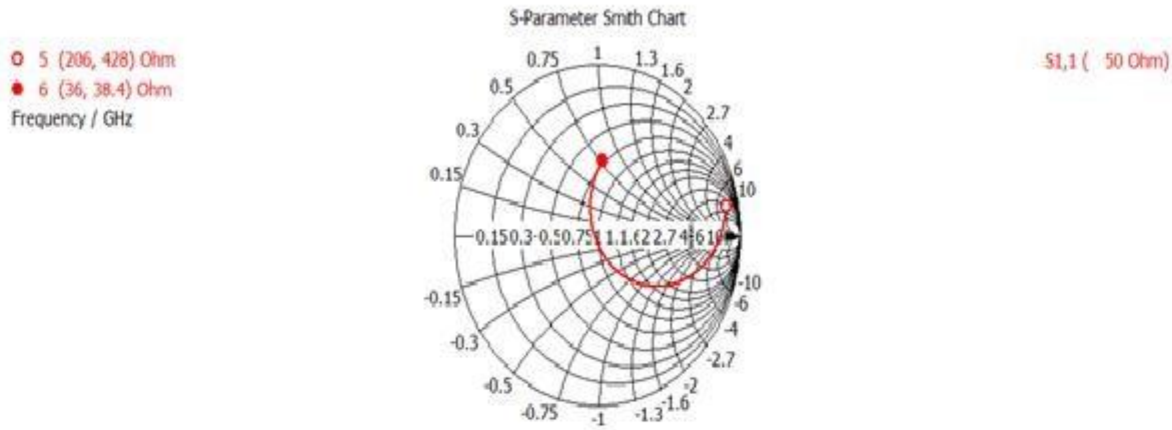


Fig. 1.5 Smith Chart [2]

1.6.4 Radiation pattern

Radiation pattern or antenna pattern is defined as the graphical representation or mathematical function of space coordinates. The radiation pattern is graphical representation of the field strength transmitted or received by the antenna. Radiation pattern of the antenna is taken over single frequency and for single polarization. The radiation patterns are generally presented as a polar form or in a rectilinear form with a dB scale. As the microstrip patch antenna radiates to its normal, patterns in ϕ=0 degree and ϕ=90 degree are much important.

1.6.5 Front to Back Ratio (FBR)

Front to back ratio (FBR) is defined as the ratio of the power gain between front and rear of a directional antenna. It is also defined as the ratio of the signal strength transmitted in forward

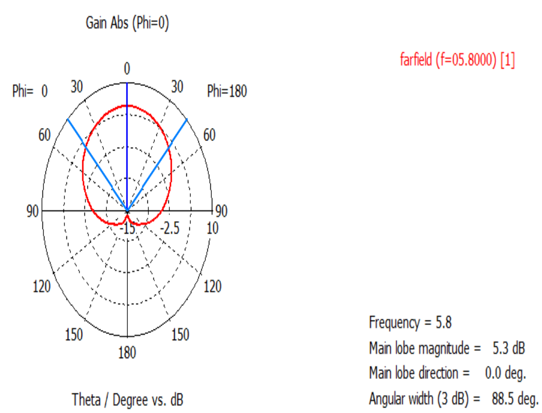


Figure 1.6 Radiation pattern at $\phi = 0$ degree and $\theta = 90$ degree [2].

direction to that transmitted in the backward direction. The ratio compares the antenna gain in a specified direction, i.e., azimuth, usually that of maximum gain, to the gain in a direction 180 degree from the specified azimuth. A front to back ratio is usually expressed in dB. FBR is highly important parameter in antenna performance. If an antenna has high FBR, that means it is radiating well in desired direction and also radiating very less in the undesired direction exactly opposite to the desired. Antenna having high FBR does not interrupt other messages in undesired direction as much as a low FBR antenna does.

1.7 Back Radiations in Antennas

Back radiations are the radiations in 180 degree opposite to that of direction of maximum gain. In a directional antenna, direction of maximum radiations is the main lobe. The other lobes are the side lobes. The lobe at the 180 degree opposite to the main lobe is called back lobe as shown in the figure. Power in the back lobe is always much less than that of in major lobe[5]. At millimeter and microwave frequency, the size of the antenna becomes very small. Despite this advantage it has the disadvantage of back radiations.

Back radiations limit the use of antenna market because back radiations are undesirable as these radiations cause power loss. In transmission, lots of energy is wasted due to back radiations. Any other equipment can be interfered by the back radiations. In receiving antennas, by mistake wrong signals can be picked due to the interference caused by the back radiations.

1.7.1 Importance of Increasing FBR

For good performance of antenna, high FBR is required. As the radiations in the front increase, an improved signal strength is received at the front side of the antenna. Due to improved signal strength, the gain of the antenna increases. A high gain antenna is required for long range applications. Increment in FBR also shows the decrease in level of the back lobe, which is undesired. An antenna with increased back lobe can interfere many other signals or can lead to reception of undesired signal. Due to increase in FBR, there is not much power loss in sending and receiving the signal.

1.7.2 Techniques to Increase FBR

There are various technique to improve front to back ratio of a Microstrip Antenna. Some of them are mentioned as follows :-

1.7.2.a. Partial Ground Plane

It is the most common and easy technique to increase FBR. By reducing the ground plane, ground plane edge diffraction can be minimized and it leads to less spurious radiations. So, back lobe level is reduced by using the partial ground plane. Reduction in back lobe level provides high front to back ratio.

1.7.2.b. Electromagnetic Band Gap (EBG)

This is the technique of improving antenna performance by providing band gap structures in the antenna. Small cylindrical structures are inserted in the substrate of antenna and these structures touch the ground plane on the lower side and microstrip patch on the upper side. These band gap structures provide good impedance matching and very few losses, which leads to high gain and improved front to back ratio.

1.7.2.c. Metal Reflector

This technique uses a metal reflector at the back side of the antenna. The spurious radiations which go to the back side of the antenna, strike on that metal reflector. After striking, these radiations reflect back and can be turned into desired radiation by adjusting the direction of the metal reflector according to the maximum gain.

1.7.2.d. Split Ring Resonators (SRR)

There are two types of split ring resonators to improve the antenna performance. First type of resonator is just like EBG and inserted inside the substrate and provides proper connection between ground and microstrip patch. In this technique antenna performance enhances due to proper impedance matching. Second type of resonator is cutting rings in the ground plane, which provides impedance matching and also minimize the ground plane edge diffraction, which leads to improved FBR. First type of SRR can only be placed in co-axial probe feeding.

There are various other techniques like leaky wave antenna (LWA), Fabry-Perot cavity, back substrate reflector and ground plane edge shaping etc., which are proved to be very useful in improving the FBR of the Microstrip Antenna. As most of the long distance applications require high FBR, current research work concentrates on design, simulation and analysis of these techniques to improve FBR.

1.8 Organization of the Thesis

Chapter 1 includes the introduction of wireless communication system, evolution of wireless communication system, antenna as a vital part of wireless communication systems, Microstrip Antennas, basic feeding techniques, various antenna parameters, back radiations, importance of FBR and techniques to increase FBR.

Chapter 2 includes the literature survey of the techniques used for back lobe suppression in single band Microstrip Antenna. Then the survey followed by the designs of the multiband antenna. Then research gaps in study and the objectives of thesis are defined.

Chapter 3 includes the 1st objective of the research and the design and simulation of Microstrip Antenna for WLAN with high front to back ratio using partial ground plane with edge shaping. Comparison of radiation properties of simple and proposed antenna is done. Antenna works at IEEE 802.11a band for WLAN application.

Chapter 4 includes the 2nd objective of the research and the design and simulation of Microstrip Antenna for WLAN with reduced back lobe level using fractal shaped ground plane. Comparison of radiation properties of both simple and proposed antenna is done. Antenna works at IEEE 802.11a band for WLAN application.

Chapter 5 includes the 3rd objective of the research and the design and simulation of Microstrip Antenna for WLAN with low back lobe level using partial ground plane with edge shaping and grooves in the dielectric reflector in the back side of the antenna. Antenna works at IEEE 802.11a band for WLAN application.

Chapter 6 includes the 4th objective of the research and the design and simulation of single band Microstrip Antenna for WLAN with reduced back radiations using metal reflector at the back side of the antenna. Comparison of radiation pattern of the ordinary Microstrip Antenna and the proposed antenna is done. Antenna works at IEEE 802.11a band for WLAN application.

Chapter 7 includes the 5th objective of the research and the design and simulation of Microstrip Antenna for WLAN with low back radiations using two dielectric substrates as reflector. Comparison of radiation properties of both simple and proposed antenna is done. Antenna works at IEEE 802.11a band for WLAN application.

Chapter 8 includes the 6th objective of the research and design and simulation of Multiband Microstrip Antenna with low back radiations using two dielectric substrates as reflector. Comparison of radiation properties of both simple and proposed antenna is done. Antenna works at IEEE 802.11a band for WLAN application.

Chapter 9 Discussion of Fabrication and testing of the antenna for validation of the results discussed in chapter 7,

Chapter 10 Covers the conclusion of the research work done and future scope of the current research in practical scenarios.

CHAPTER 2

LITERATURE SURVEY

2.l Introduction

As high FBR is required for long range communication, current chapter describes the evolution of techniques used to suppress back radiation and increase FBR of the Microstrip Antenna.

2.2 Literature Survey on Various Techniques used for Suppression of Back Lobe

In 1981, James W. Mink and Keith R. Carve [6] proposed that material played a vital role in antenna design. PTFE was electrically and mechanically robust and it was easily available in variable thickness. By right choice of material temperature effected on antenna can be reduced.

In 1986, Daniel H. Schaubert and peter L. Sullivan [7] proposed the design that antenna can have specific input impedance. In aperture coupled antenna increasing the aperture length improved coupling between feed line and microstrip patch and length of the stub could be adjusted to get desired reactance. Position of the patch played vital role, it was found that maximum coupling was obtained when patch was centered over the aperture.

In 1989, Daniel H. Schaubert et al. [8] proposed antennas with different dimensions and different feeding methods. They proposed three feeding techniques, first one was microstrip feed along the radiating edge and second along non radiating edge and third one was co-axial probe feed. Feeding technique with radiating edge showed more radiation resistance.

In 1989, Hugo F. Pues and Antoine R. Van De Capelle [9] proposed the method for bandwidth improvement. Fluctuations in the frequency could be stabilized by reactive input impedence matching network. There was low mismatch when compared to the reference antenna.

In 1992, Clarke and M. Cuha [10] proposed a design with aperture fed stacked patch antenna. Two patches and two foam substrates were used. It was found that best results came when size of the lower patch is same as the upper one. Proposed antenna provided the bandwidth of 18%.

In 1992, David M. Pozar [11], proposed the solutions for good electrically and mechanically improvements; he provided good features like low cost, easy to fabricate and lightweight. He proposed thick and low permittivity substrate for bandwidth improvement. But that led to spurious feed radiations. He proposed antennas with stacking to improve bandwidth.

In 2004, Ronald H. Johnston et al. [12], proposed a design with feed line and patch etched on the top of the substrate and a slot was on the back side of it to provide coupling, and a cavity on the back side to block back radiations. Proposed antenna was low profile and small in size, so antenna provided good front to back ratio of 21 dB.

In 2006, Qinjiang Rao et al. [13], proposed an slot coupled antenna with dielectric reflector to prevent spurious back radiations. Compared to existing techniques to reduce back radiations like cavity and metal reflector, proposed antenna provided good front to back ratio of 23 dB and high cross polarization.

In 2007, O. Losito [14], proposed a broadband and broadbeam leaky wave tapered antenna. A new leaky wave antenna (LWA) was designed with connecting the metal strip with the ground plane and ran on a simple procedure FDTD. The use of physical ground gave side lobes reduction and allowed using the simple feeding network. New antenna gave higher gain and better efficiency. Two advantages of this antenna were its wider beam and 9 dB of reduction in back lobe level.

In 2008, Yi-Chie Lee et al. [15], proposed printed antenna using the high impedance ground plane (HIGP) to improve the radiation pattern. HIGP was just like electromagnetic band gap structures used for reduction of surface wave loss and improved the side and back lobe level. As compared to the reference antenna the proposed antenna showed the improvement of 5 to 10dB. There was also reduction in mutual coupling and gain is increased by 2dBi.

In 2008, Jia-Hui-Fu et al. [16], proposed a broadband antenna with low back lobe. Microstrip antenna was working for millimeter-wave band. Antenna was having H-shaped coupling slot feeding and includes parasitic patch methods. Then the same antenna was designed for two elements array. This H-shaped slot antenna had much better radiation performance than the reference antenna. Antenna showed 19% bandwidth and low side lobe and back lobe.

In 2011, Nan-Chang and Jyun-Ming Lin [17], proposed antenna with long feed line that efficiently coupled the energy from the feed to patch via slot in the ground plane. Antenna with larger ground plane showed lesser back radiations. Larger back radiations were there at the low frequency band.

In 2011, M.J. Al-Hasan et al. [18], proposed uniplanar-compact electromagnetic band gap aperture coupled millimeter-wave dielectric resonator antenna. Antenna was designed of low temperature co-fired ceramic (LTCC) substrate. Simulation results showed the advantage of using UC-EBG. This resonator antenna showed good results in terms of back radiations and improvement of 9.4 dB over conventional antenna.

In 2012, P.N. Bhagat and V.B. Bharu [19], proposed an antenna with electromagnetic band gap structures placed in the patch and antenna worked for ISM band. Results of the slotted antenna and slotted antenna with electromagnetic band gaps in the patch were compared. It was shown that bandwidth requirement was fulfilled and the back lobes were reduced. The return loss of the proposed antenna reached up to -39dB and it showed improvement of 7 dB in back radiations.

In 2012 M.T. Ali and at el. [20], proposed a reconfigurable planar antenna array (RPAA) and the antenna is added with microwave absorber. The antenna consisted of 16 elements. The radiating elements were different from the feeding network by an air gap. Separating the feed line from the patch elements prevented the spurious radiations. Antenna had RF switches that allowed the beam pattern in the desired direction. Additional material was incorporated at the back of the top substrate. Antenna was efficient enough to reduce the back lobe by 10dB as compared to simple MSA.

In 2012, B. Bhuvaneswari and K. Malathi [21], proposed a design with mushroom electromagnetic band gap placed at the inset feed line of microstrip patch. The design was proposed for single patch and two element array of patches as well. The optimal position of EBG was at 1.5mm away from both sides of the feed line. In array of elements case there was a significant improvement of 5 dB in the back lobe and side lobes as well. Directivity of the antenna increased due to optimal radiation patterns.

In 2012, Tan, M.N.M. and S. Rahman [22], proposed an antenna array incorporated with electromagnetic band gap (EBG) to reduce the level of back lobe of microstrip antenna array. Simulation of four different types of EBGs had been done and radiation pattern is shown. It gave the best result when only one slot of antenna is inserted. Maximum improvement of 7dB was achieved. If the slots were in 9 columns, then only there was an improvement, otherwise back lobe level was seen to be increased.

In 2013, Alias H. and Sulaiman M.A. [23], proposed an aperture coupled antenna with back lobe reduction. The antenna was based on the 2 by 2 planar array antenna. Two patches were placed with different feeding. Four dumbbell shaped slots were there to suppress the back lobes. Antenna was designed for WLAN and back lobe was reduced from 4 to .4887 dB. There was also an improvement of 4.3 dB in return loss.

In 2013, Jie Wie and Zhi Ning Chen [24], proposed a small substrate integrated waveguide (SIW) choke antenna array with comb shaped choke to reduce the back lobe level. The comb-shaped choke was consisted of array of quarter wavelength microstrip lines with short-end on the lower part of the array. The choke was used to reduce the edge diffraction and thus to reduce the back radiations. The antenna with choke showed an improvement of 10dB over the antenna without choke.

2.3 Literature Survey on Methods to Design a Multiband Antenna

In 1998, A.Serrano et al. [25] reported a dual band GSM/DCS 1800 printed antenna made with bow-tie radiating element. The antenna was excited by a vertical SMA connector with the outer conductor connected to the ground plane of the antenna. The radiation characteristics of the antenna were similar to those of conventional microstrip patches.

In 1999, Guo et al. [26] proposed a U-slot circular patch antenna with L-probe feeding. The authors had described the combination of the L-probe and U-slot broad banding techniques, in the design of a broadband single-layer circular patch antenna. For a foam substrate of thickness, the bandwidth of the resulting antenna was 15% wider than that using the U-slot alone and 14% wider than that using the L-probe alone.

In 2000, Rowe et al. [27] proposed a broadband microstrip patch antennas for MMICs. The stacked antenna consisted of a 50Ω microstrip feed line and a patch element fabricated on alumina substrate which emulated the high dielectric constant materials used in MMICs. The parasitic patch elements were etched in Rogers RT/duroid 58880 laminates and were separated by form dielectrics. Good efficiency, a broad impedance bandwidth and large front to back ratio eliminated the need for cavities or other structures to reduce back radiation. The proposed antenna structure exhibited an improvement over the stacked patch antenna.

In 2000, Borja et al. [28] proposed a high directivity fractal boundary microstrip patch antenna showed that a patch antenna with a fractal boundary exhibits localized modes. The localization effect produced an electric current density that was mainly concentrated in certain regions at the boundary. The result was that the microstrip fractal boundary antenna behaved as an array of antennas. When the localized modes were properly in phase, a broadside pattern was obtained and the directivity increased in comparison with the directivity of the antenna at the fundamental mode frequency.

In 2000, R.Lelaratne and R.J. Langley [29] proposed a dual-band patch antenna for mobile satellite systems. The antenna excited two separate modes which resulted dual linear polarization on each bands. The dual frequency band design, based on a rectangular patch, had a single feed point, suppresses unwanted mode interference and produced acceptable radiation patterns.

In 2000, D.Viratelle and R.J. Langley [30] proposed a dual band printed antenna for mobile telephone applications. The compact, lightweight, low-cost and dual-band antenna was printed on a flexible printed circuit material and conductor area. The basic Inverted F antenna was simply modified by separating part of the upper plate to create a second resonance. A single coaxial feed connected to the inner patch excited both frequency bands. Shorting pins were replaced by strip conductors.

In 2001, Baligar et al. [31] proposed a broadband two-layer shorted patch antenna with low cross-polarization. The antenna had a bandwidth of 11% centered around 1.975GHz with a gain of 8.6dB, and exhibited better than -13dB cross-polarization levels in the H-plane. The computed and measured results of the co-planar configuration of the structure were compared with antenna's new two-layer stacked configuration. The stacked geometry was found to reduce radiated cross-polarization levels significantly and offered a larger impedance bandwidth, a higher gain and radiation efficiency compared to the co-planar structure as well as the patch antenna structure.

In 2001, F.Yang et al. [32] presented a switchable dual band circularly polarized patch antenna with single feeding. The antenna utilized two diode controlled slots in the patch for dual band operation and a pair of tuning stubs was used to tune the CP performance. The structure had the advantage of low profile, small and is suitable for GPS, satellite links and other wireless communication applications.

In 2003, K.L. Wong et al. [33] proposed a Low-Profile Planar Monopole Antenna for Multiband Operation of Mobile Handsets. The proposed antenna had a planar rectangular radiating patch in which a folded slit is inserted at the patch's bottom edge. The folded slit separated the rectangular patch into two sub patches, one smaller inner sub patch encircled by the larger outer one. The proposed antenna was then operated with the inner sub patch resonating as a quarter-wavelength structure and the outer one resonating as both a quarter-wavelength and a half wavelength structure.

In 2005, Robert Borowiec et al. [34] proposed a substantial reduction in antenna size was achieved due to the use of the inverted-F antenna concept combined with a capacitive feeding system. A miniaturized printed monopole antenna suitable for cellular handset terminals was presented which operates in three frequency bands, that is, GSM 1800, PCS 1900, and UMTS.

In 2006, Zhengwei et al. [35] proposed a novel Compact Wide-Band Planar Antenna for Mobile Handsets. It was capable of covering the major wireless communication and navigation systems bands like GSM, GPS, DCS, PCS, UMTS, and WLAN. The radiating patch was jointly designed with the shape of the ground plane to optimize its performance.

In 2006, P. Ciais et al. [36] presented a planar inverted-F antenna (PIFA) operated in penta-band suitable for handheld terminals. This antenna consisted of capacitively loaded shorted patches, a slot, and an efficient antenna-chassis combination to achieve multiband and wideband performances to operate in the 850 MHz, 900 MHz, 1800 MHz, 1900 MHz, and UMTS bands.

In 2006, K.L. Wong et al. [37] developed an internal GSM/DCS Antenna Backed by a Step-Shaped Ground Plane for a PDA Phone. The antenna consisted of two radiating strips to operate at about 900 and 1800 MHz for GSM/DCS operation, and was backed by a short circuited to a step shaped ground plane. With the use of the step-shaped ground plane, which was to be placed at the top edge of the system ground plane of a PDA phone, the antenna could be employed in very close proximity to the possible RF shielding metal cases for battery and associated RF module/circuitry, with almost no degradation in the antenna performances.

In 2008, RongLin et al. [38] proposed a Novel Low-Profile Broadband Dual-Frequency Planar Antenna for Wireless Handsets. The antenna featured low profile due to the introduction of an S-strip and a T-strip which were separately printed on the two sides of a thin substrate (no via process is involved in the fabrication), forming the two-strip monopole. The bandwidth of the dual frequency planar antenna was enhanced by taking advantage of the two-strip configuration and the mutual coupling between the planar monopole and the two strip monopole.

In 2010, Jyoti R. Panda and Rakhesh S. Kshetrimayum [39] proposed a design of a simple Microstrip fed monopole patch antenna for the radio frequency identification (RFID) and wireless local area network (WLAN). The antenna had two different resonant paths (forming an F–shaped structure), supported two resonances at around 2.44 GHz and 5.18 GHz, which were reserved for RFID and WLAN applications. Effectively consistent radiation pattern and large impedance bandwidth had been observed. Impedance bandwidth for -10 dB return loss in the 2.44 GHz and 5.18 GHz center frequency reached 0.65 GHz (2.12 GHz to 2.77 GHz) and 0.59 GHz (4.91 GHz to 5.50 GHz) respectively. The proposed antenna was simple and compact in size providing broadband impedance matching, consistent radiation pattern and appropriate gain characteristics in the RFID and WLAN frequency range.

In 2010, Xiaoang Li and Chao Li [40] Proposed a novel multi-slotted Microstrip patch antenna with high gain. The design adopted contemporary techniques such as probe feeding and multislotted patch. These techniques could contribute to the enhanced performance of the antenna. The design also employed a novel shape patch. By integrating these techniques the proposed design offered low profile, high gain and compact antenna element. The maximum gain at the resonant frequency of 2.45GHz was 11.35dBi. The lowest return loss could be -34.49 dB at 2.45GHz. The proposed design had a simple structure and a compact dimension of 87mm*51mm. The proposed design was suitable for particular wireless communication application such as Wi-Fi and WLAN.

In 2011, Kapil Parmar et al. [41] proposed a new dielectric resonator antenna (DRA) designed for WLAN applications, where a simple M-shaped dielectric resonator (DR) was excited by a conformal patch connected to a microstrip line. The simulation process was done by using computer simulation Technology (CST) Microwave studio suite 2010.The simulated results showed that the proposed DRA achieved an impedance bandwidth of about 31.32% for VSWR $\leq$

2, covering a frequency range from 4.63 GHz to 6.35 GHz. The antenna also provided a gain range of 5.64-7.34 dB across the operating bandwidth. The proposed antenna was suitable for wireless local area networks (WLAN 5.15-5.30GHz) (IEEE 802.11a). It had also application in high performance radio LAN (HIPERLAN) which operated across 5.15 to 5.30 GHz.

In 2011, S. Natarajamani et al. [42] proposed a design and analysis of compact probe fed slot antenna. The proposed antenna had simple structure consisting Ω-shape on a rectangular patch, the overall dimension of the antenna came around 36mm*26mm*5.127mm and fed by 50Ω probe feed. The impedance matching and radiation characteristics of the designed structure were investigated by using MOM based IE3D. The simulation results showed that the antenna impedance bandwidth of the antenna reaches about 31 %(4.25GHz-5.8GHz) with return loss better than -10 dB over the chosen frequency spectrum. The proposed antenna gain of 9dBi and 7dBi were achieved. Its radiation patterns were also studied.

In 2012, Jerzy Guterman et al. [43] proposed an omnidirectional low profile microstrip antenna for WLAN applications in laptop computers. By wrapping the patch antenna around the screen edge, very good omnidirectionality was achieved. The designed structure, fed by a microstrip inverted line, could be easily integrated inside the display plastic cover. An antenna prototype had been fabricated and tested. Good agreement had been obtained between simulations and experimental results. An adequate coverage of the whole 2.4 GHz ISM band had been achieved.

2.4 Research Gaps

- Use of Fabry-Parot cavity, back cavity and superstrate etc. are proved to bew efficient techniques to improve the gain of Microstrip Antenna. These techniques can be employed as well while reducing the back lobe level.
- Modified aperture coupled techniques can be used to reduce back lobe level and attaining good percentage of bandwidth.
- The use of parasitic elements, stacked patches, using thick substrate of low permittivity etc. have proved to improve the bandwidth of the antenna. However, the broad banding design in MSA results in high volume inspite of its efficient results. The work regarding the reduction of profile can be done.

- Defected Ground Structure (DGS) has been proved to be very efficient tool in improving the antenna performance. DGS can be employed to improve bandwidth and gain of the antenna as well.

2.5 Objective of the Thesis

- Design and simulation of Microstrip Antenna with low back lobe using partial ground plane with edge shaping with an improvement of 16.6 dB and FBR of 35.4 dB.
- Design and simulation of Microstrip Antenna with low back lobe level using fractal shaped ground plane with an improvement of 9.2 dB in back lobe and FBR of 28.3 dB.
- Design and simulation of Microstrip Antenna with low back lobe level using partial ground, edge shaping and grooves in lower substrate used as a reflector with an improvement of 10.3 dB in back lobe and FBR of 30.9 dB.
- Design and simulation of Microstrip Antenna with low back lobes and high FBR using metal reflector at the back side of the antenna with an improvement of 13.5 dB in back lobe and FBR of 33.2 dB.
- Design and simulation of Microstrip Antenna with low back lobe level using two thick dielectric reflectors at the back end of the antenna with an improvement of 11.6 dB in back lobe and FBR of 23.1 dB.
- Design and simulation of Multiband Microstrip Antenna with low back lobe level using two thick dielectric reflectors with an improvement of 3.8 dB in back lobe and FBR of 13.6 dB at 4 GHz and improvement of 9 dB in back lobe and FBR of 28 dB at 5.2 GHz.
- Fabrication and testing of the antenna to validate the results.
- Analysis of the results for the applications in the current technology in wireless communication.

CHAPTER 3

Back Lobe Suppression of a Single Band Microstrip Antenna Using Partial Ground Plane with Edge Shaping and Dielectric Substrate as a Reflector

3.1 Introduction

In this chapter, the first objective of research work is achieved using the technique of partial ground plane with edge shaping. In the first part of this chapter the working of the proposed technique is introduced and its effects on radiation properties are analyzed. In second part, the design of the antenna and its dimensions are discussed in detail, result of the proposed antenna and its comparison with the conventional antenna is discussed in detail.

3.2 Antenna Design and Simulation Results

3.2.1 Antenna Design

Microstrip patch antenna (conventional) is designed on Rogers RT5880 material of ε_r=2.2 at 5.2 GHz frequency band using the equations (1) to (5) of transmission line model discussed in the introductive part. Length and width of the patch are optimized using these equations.

$$L_s = 6h + L \quad \text{……(9)}$$

$$W_s = 6h + W \quad \text{……(10)}$$

Where h is the height of the substrate,

L is the length of the patch,

W is the width of the patch,

W_s is the width of the substrate and

L_s is the length of the substrate.

The dimensions of the patch, ground plane and substrate are mentioned in Table 3.1. The length and width of the feed line are 4.9 mm and 1 mm respectively. Figure 3.1 shows the designed antenna.

Table 3.1 – Design Specification of Conventional Antenna

Dimensions	Value (mm)
Length of the patch	18.1
Width of the patch	22
Length of the substrate	28.08
Width of the substrate	32.28
Height of the substrate	1.58
Width of the feed line	1

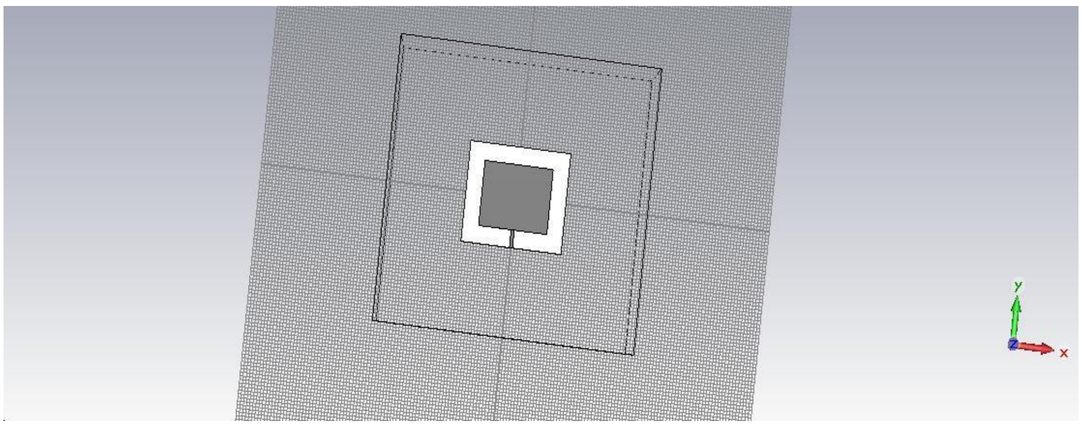


Figure 3.1 Snap shot of the top view of the conventional Microstrip Antenna.

3.2.2 Simulation Results

Figure 3.2 shows Return Loss plot and it can be seen in this figure that conventional antenna exhibit bandwidth of 132.9 MHz and return loss of -35.4 dB.

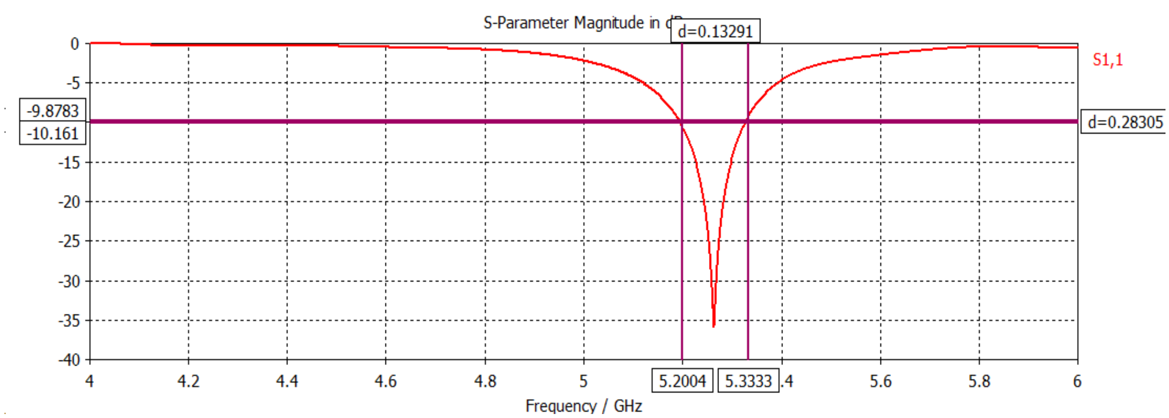


Figure 3.2 Return loss plot of the conventional antenna

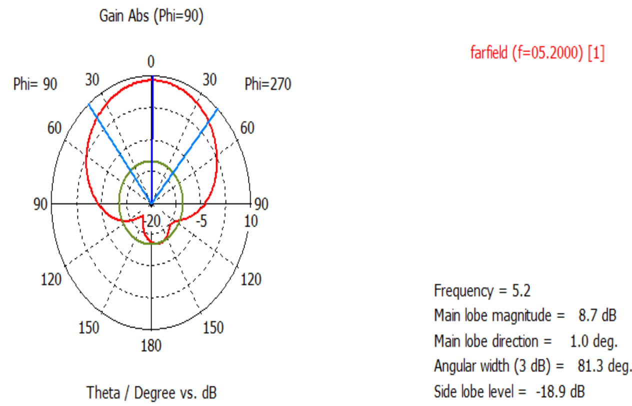


Figure 3.3 Radiation pattern of conventional at 5.2 GHz

As seen from the figure 3.3 Conventional antenna exhibit SLL of -18.9 dB. To improve FBR of the conventional antenna, technique of partial ground with edge shaping and back dielectric reflector is proposed and the proposed design is given in the following section.

3.3 Improvement in FBR using partial ground with edge shaping and dielectric reflector

3.3.1 Design of Proposed antenna

In order to improve FBR the proposed antenna is designed using the conventional antenna. Partial ground plane is used firstly in the proposed design to overcome the problem of large back lobe. Cause of back radiation is ground plane edge diffraction. Using partial ground plane problem of back radiations is minimized and FBR is increased by 3.5 dB and SLL is reduced by 3.9 dB and that can be seen in the Figure 3.6 Further edge shaping is used which involves etching slots in the ground plane along the length of the ground plane and can be seen in the Figure 3.4. Edge shaping also decreases the level of back lobe[18]. Further to avoid back radiations a back reflector of same dimension as of the partial ground plane is used at the back side of the antenna[43]. Back reflector is of same material and of same height as that of the patch substrate Partial ground used is made by etching the ground plane of 4.14mm from both sides along the

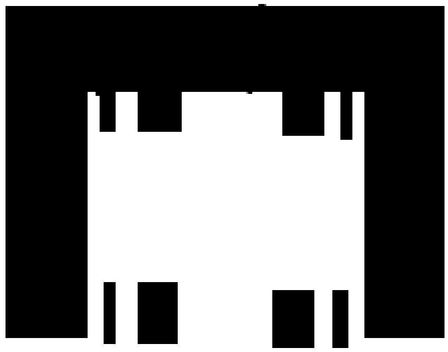


Figure 3.4 Ground plane used in proposed antenna after edge shaping.

length and 2.04mm from the upper side along the width. Partial ground plane with edge shaping used in the proposed design to reduce the back lobe level is shown in the figure 3.4. Here black potion shows the etched part and white portion shows the remaining ground. The four slots used near the centre of the ground plane are of 3*5 mm of size and other four are of 2*5mm of size.

3.3.2 Simulation Results of Proposed Antenna

After edge shaping antenna exhibits a Bandwidth of 115.67 MHz and Return Loss of -16.7 dB and that can be seen in Return loss plot after edge shaping in Figure 3.5.

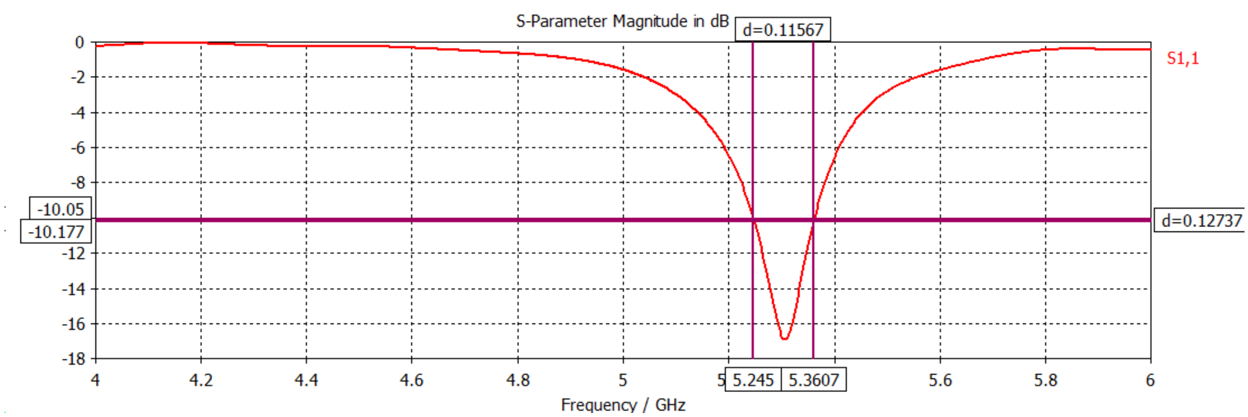


Figure 3.5 Return loss plot after partial ground and edge shaping

After edge shaping antenna exhibits very low back lobe as compared to conventional antenna and that can be seen in Radiation pattern of designed antenna shown in Figure 3.6. after edge shaping it exhibits back lobe of -27.4 dB.

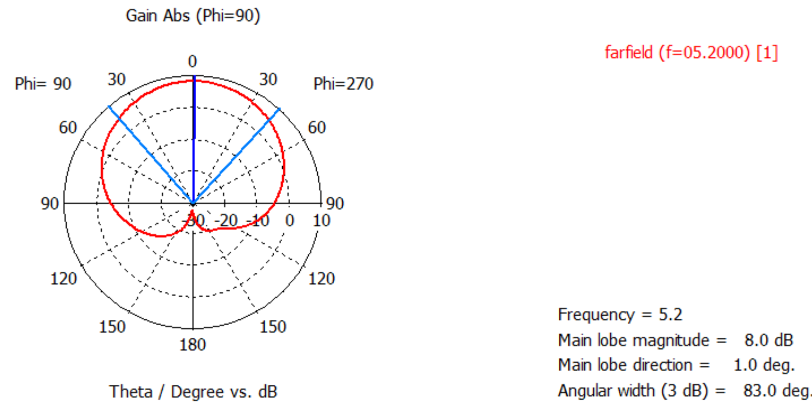


Figure 3.6 Radiation Pattern after partial ground edge shaping at 5.2 GHz

Comparison of radiation properties of both the antennas is shown in table 3.2.

Table 3.2 - Comparison of conventional and proposed antenna

Property	Conventional antenna	Proposed antenna
Gain (dB)	8.74	8.01
Bandwidth (MHz)	132.9	115.67
Back lobe level (dB)	-10.8	-27.4
Front to back ratio (dB)	19.5	35.4

Conventional antenna exhibit back lobe level of -10.8 dB and FBR of 19.5 dB, where proposed design shows BLL of -19.5 dB and FBR of 35.4 dB. Proposed design exhibits gain of 8.01 dB and bandwidth of 115.67 MHz, where conventional antenna exhibits gain of 8.74dB and bandwidth of 132.9 dB. There is a decrease in both the parameters after applying the proposed technique.

3.4 Conclusion

Partial ground plane prevents the ground plane edge diffraction and reduces back radiations and that leads to improvement of 3.5 dB in FBR over conventional antenna and ground plane edge shaping further reduces the back lobe radiations and shows 15.9 dB improvement in FBR over conventional antenna. This antenna works at IEEE 802.11a WLAN band.

CHAPTER 4

Back Lobe Suppression of a Single Band Antenna using Fractal Shaped Ground Plane

4.1 Introduction

This chapter covers the second objective of the thesis work. A single band Microstrip antenna designed in chapter 3 is now used with a fractal shaped ground to reduce the back lobe level in radiation pattern of the antenna. The results are analyzed to see the practical implementations of the antenna.

4.2 Antenna Design and Simulation Results

4.2.1 Design of Conventional Antenna

In this section a MSA is designed and simulated at 5.2 GHz on a Rogers RT substrate with ε_r =2.2. The antenna design is mentioned in chapter 3, section 3.2.

4.2.2 Simulation Results of Conventional Antenna

Return Loss plot of the antenna is shown in Figure 4.1 and it has a resonant frequency of 5.5 GHz, bandwidth of 132.9 MHz from 5.178 to 5.317 GHz and Return Loss of -35.4 dB. Figure 4.2 shows its radiation pattern with a SLL of -18.9 dB.

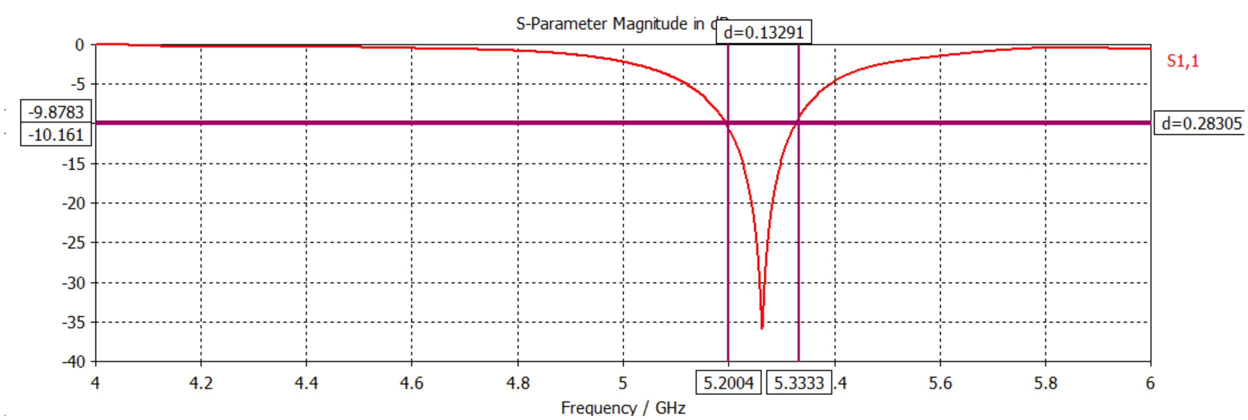


Figure 4.1 Return Loss Plot of Conventional MSA

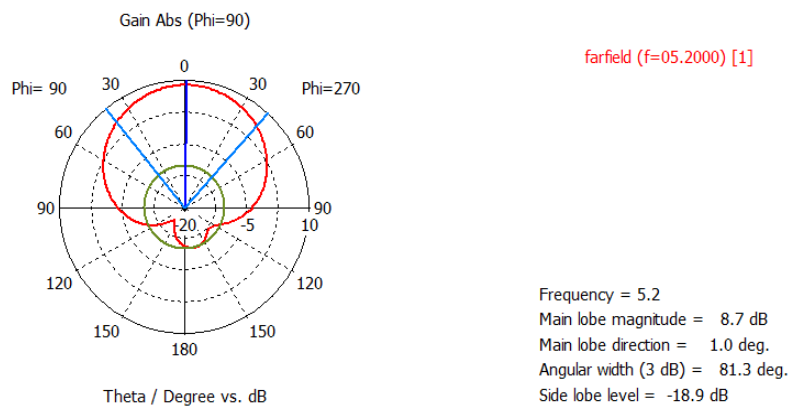


Figure 4.2 Radiation pattern of conventional MSA at 5.2 GHz

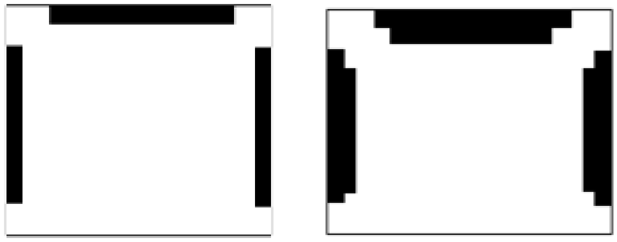
4.3 Improvement in FBR using Fractal Shaped Ground Plane

4.3.1 Proposed Design

In order to reduce back lobe level for increasing the directivity in the desired direction, the ground plane is modified into a fractal shape. Etching of the ground plane symmetrically leads to the reduction of edge diffraction[22]. Reduction in edge plane diffraction causes low spurious back radiations. Proposed antenna shows good performance in terms of back radiations. First iteration is done to reduce the back lobe level and then second iteration is done to further reduce the back lobe level. In first iteration ground plane is removed 1.14 mm form both sides along the length and 1.04 mm on the upper side only along the width. In second iteration (proposed design), 1 mm metal is removed from both sides along length and 3 mm is etched along the width. Following figure shows the ground plane after second iteration. Ground plane after 1st and 2nd iteration is shown in figure 4.3 (a) and (b) respectively. Here black portion shows the etched .

4.3.2 Simulation Results of Proposed Antenna

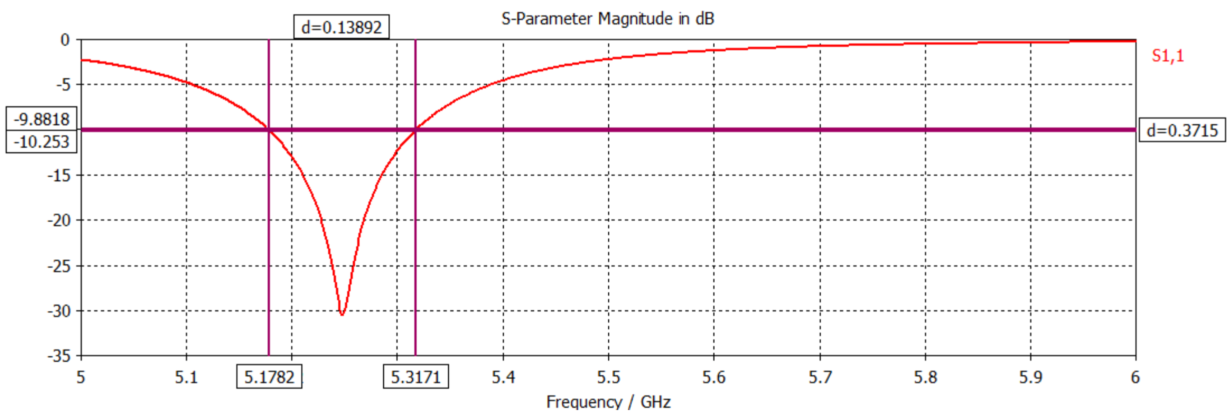
Figure 4.4 shows the comparison of Return loss of MSA after 1st and 2nd iterations. After 1st iteration antenna exhibits return loss of -30 dB and bandwidth of 138.9 MHz. After 2nd iteration ground plane portion and white part shows the remaining ground plane that is used in the design



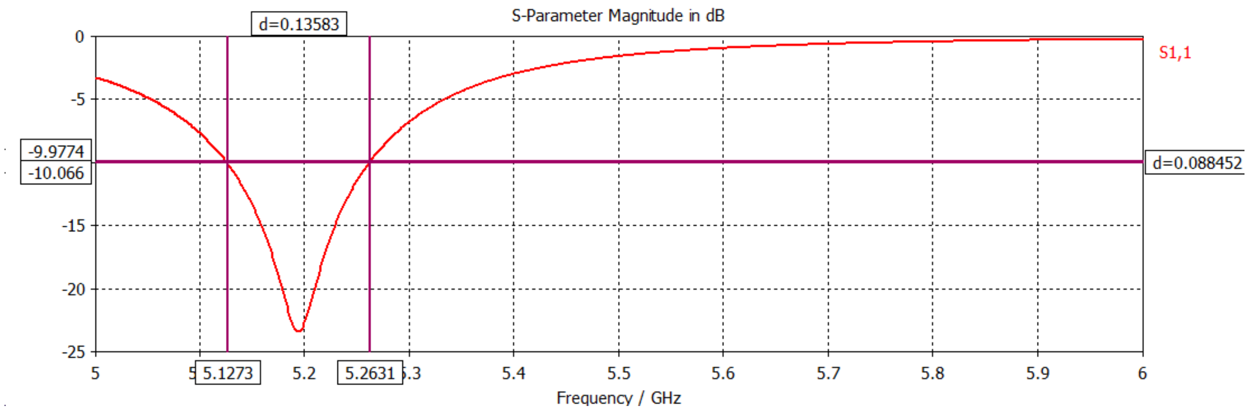
(a) (b)

Figure 4.3 Ground plane (a) After the first iteration (b) After 2nd iteration

antenna exhibits return loss of –22.5 dB and bandwidth of 135.8 MHz. The polar plots of the three antennas are shown in the figure 4.5 and it can be easily seen that back lobe level is lesser in antenna after first iteration as compared to the conventional one and, in second iteration level of the back lobe is further reduced.



(a)



(b)

Figure 4.4 Return loss plot of designed antenna (a) after 1st iteration (b) after 2nd iteration

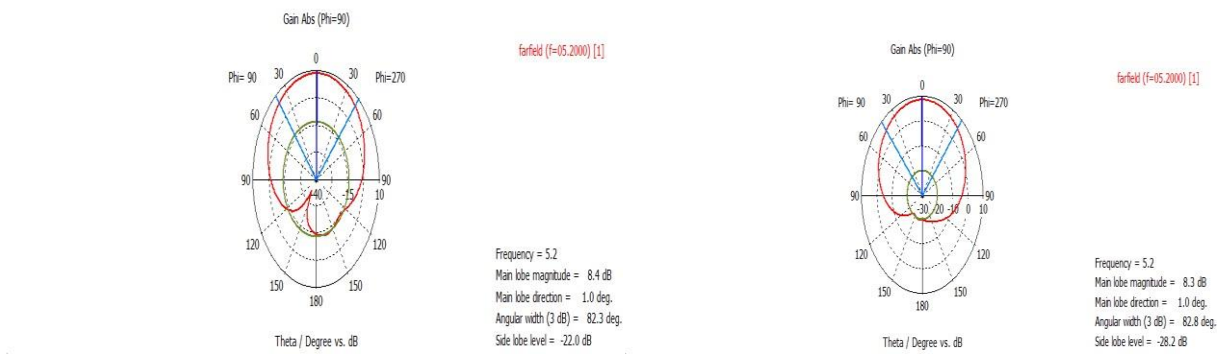


Figure 4.5 Radiation pattern after (a)1st iteration (b) 2nd iteration at 5.2 GHz

Comparison of conventional antenna , after first iteration and 2nd iteration is given in table 4.1.

Table 4.1 - Comparison of all the three antennas

Antenna type	Conventional	First iterated	Proposed
Gain (dB)	8.74	8.44	8.32
Bandwidth (MHz)	132	138.9	135.8
Back lobe level (dB)	-10.8	-14.8	-20
Front to back ratio (dB)	19.5	23.2	28.3

Table 4.1 shows the comparison of conventional antenna with the designed antenna after 1^{st} and 2^{nd} iterations. Gain of conventional antenna, after first iteration and after second iteration is 8.74 dB, 8.44 dB and 8.32 dB respectively. Bandwidth of conventional antenna, after 1^{st} iteration and after 2^{nd} iteration is 132, 138.9, 135.8 MHz respectively. BLL of conventional antenna, after 1^{st} iteration and after 2^{nd} iteration is -10.8, -14.8, -20 dB respectively. FBR of conventional, after 1^{st} and 2^{nd} iteration is 19.5, 23.2 and 28.3 dB respectively.

4.4 Conclusion

To improve the FBR of the conventional antenna ground plane is cut in fractal shape. After first iteration there is an improvement of 4 dB in back lobe level and 3.7 dB in FBR. After 2^{nd} iteration there is further improvement of -5.2 dB in back lobe level and 5.1 dB in FBR. Antenna resonates at 5.2 GHz frequency and it is suitable for WLAN applications.

CHAPTER 5

Back Lobe Suppression of a Single Band Antenna using Corrugated Back Reflector

5.1 Introduction

In this chapter, the third objective of the research work is covered as back lobe of proposed Microstrip antenna is reduced using the technique of partial ground plane with edge shaping and corrugated back reflector. In the first part of this chapter working of the technique is introduced and its effects on radiation properties are analyzed. In the latter part of the chapter the design technique is compared to the existing one and feasibility of the structure is analyzed.

5.2 Design and Simulation Results of Conventional Antenna

5.2.1 Design of Conventional Antenna

Microstrip patch antenna (conventional) is designed on Rogers Ultralam2000 with $\varepsilon_r = 2.5$ at 5.8 GHz frequency band using the equations (1) to (5) of transmission line model discussed in the chapter 1. Equations (9) and (10) are used for the dimensions of the substrate. Figure 5.1 shows top view of conventional antenna and its design parameters are given in table 5.1

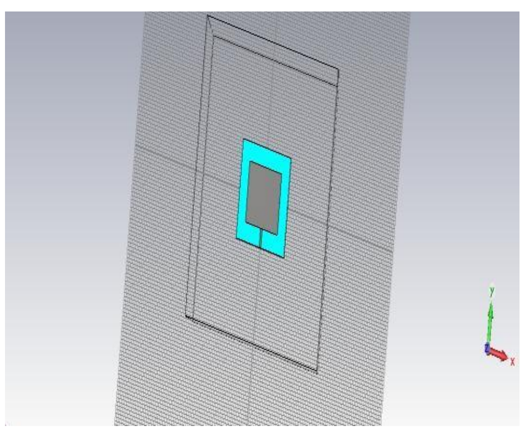


Figure 5.1 Top view of the conventional antenna

Table 5.1 - Design specifications of conventional antenna

Dimensions	Value (mm)
Length of the patch	15.7
Width of the patch	19.7
Length of the substrate	25.54
Width of the substrate	29.54
Height of the substrate	1.58
Width of the feed line	1

5.2.2 Simulation Results of Conventional Antenna

Figure 5.2 shows the return loss plot of conventional antenna. It can be seen from the figure that conventional antenna exhibits bandwidth of 147.4 MHz and Return Loss of -23 dB. Figure 5.3 shows radiation pattern of conventional antenna at 5.8 GHz.

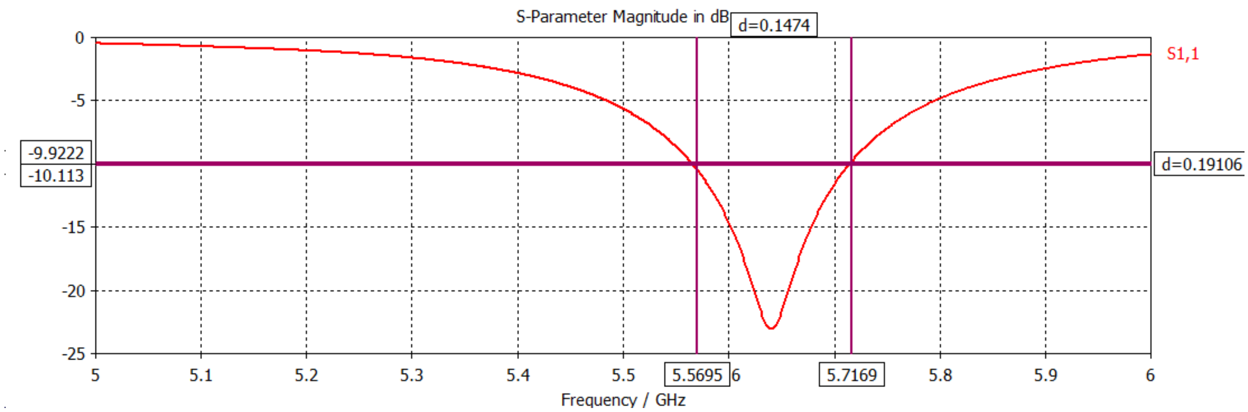
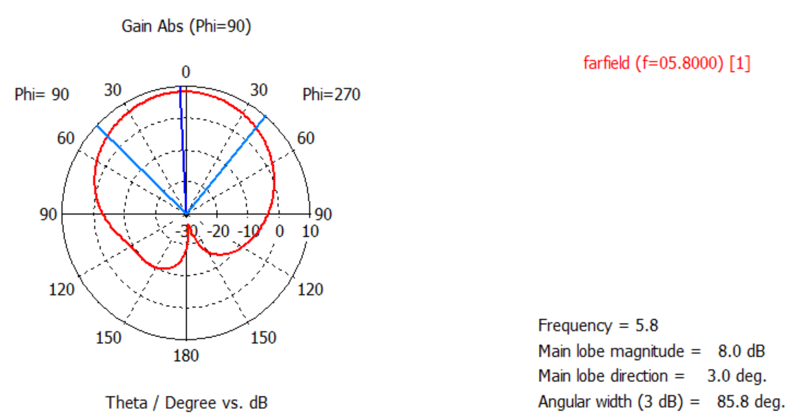


Figure 5.2 Return loss plot of conventional antenna



5.3 Radiation pattern of conventional antenna

5.3 Improvement in FBR using Corrugated Dielectric Substrate

5.3.1 Design of Proposed Antenna

Front view of the proposed antenna is given in figure 5.4. In order to increase FBR of the antenna, firstly partial ground plane with edge shaping is used to reduce the ground plane edge diffraction and it is shown in figure 5.5 (a). In the ground plane of proposed design, the black part is the etched part and white one is the remaining part. Ground plane is removed 4 mm from both sides along the length and 4 mm from the upper side along the width. There are four 4*2 mm symmetric slots which start from 3 mm distance away from the centre. There is a back reflector used to further reduce the back lobe level. Back reflector is of 3 mm height and same width as the upper substrate and its length is equal to the partial ground plane to prevent ground plane edge diffraction. There are two 4 mm wide grooves in the reflector. Grooves are 1.5 mm in height and are rightly placed below the area of four slots i.e. 3 mm away from the centre. Back dielectric reflector of same width as of the upper substrate and length is equal to the partial ground plane. The dielectric reflector used is of same material as that of the upper substrate. To further reduce the back lobe level two grooves in the dielectric reflector are cut and it can be seen in figure 5.5 (b), it helps reducing the ground plane edge diffraction[16].

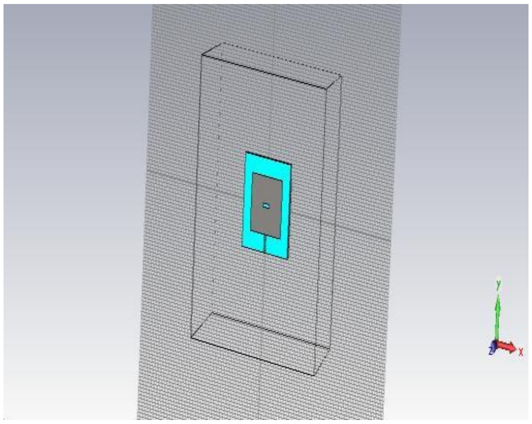


Figure 5.4 Top view of proposed antenna

Partial ground plane with edge shaping used in the proposed design is shown in the figure 5.5.

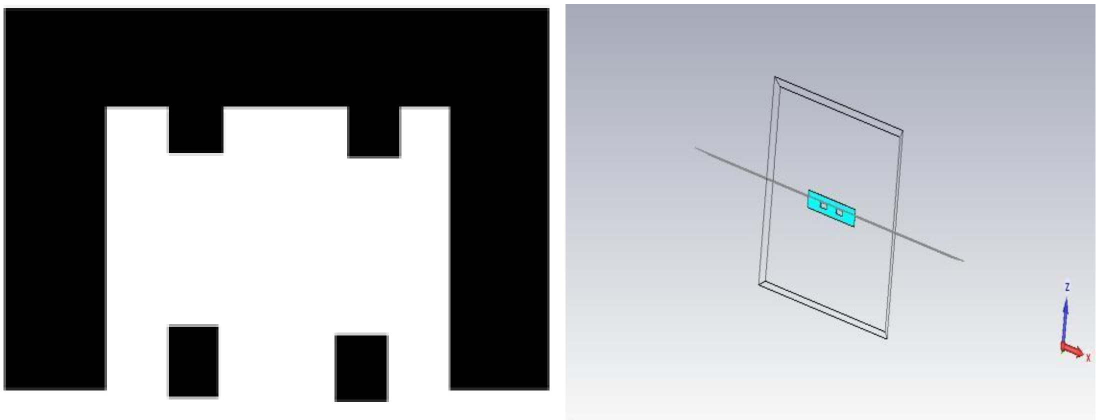


Figure 5.5 (a) Partial ground plane used (b) 3D view of the proposed design.

5.3.2 Simulation Results of Proposed Antenna

Figure 5.3 compares the return loss plots of both the antennas and it is shown that proposed antenna exhibits bandwidth of 123 MHz and Return Loss of -17 dB. Figure 5.7 shows the radiation pattern of the proposed antenna at 5.8 GHz. After using corrugated back dielectric reflector there is an improvement of -10.3 dB in back lobe and 9.8 dB in FBR over conventional antenna.

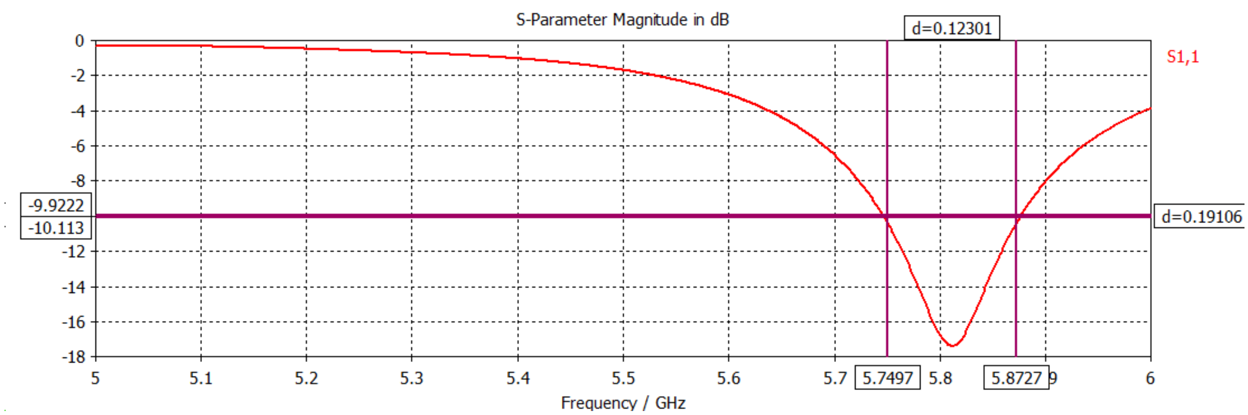


Figure 5.6 Return Loss Plot of Proposed antenna with partial ground and corrugated back reflector

Table 5.2 compares the radiation performance of both conventional and proposed antenna with edge shaped partial ground and corrugated back dielectric reflector.

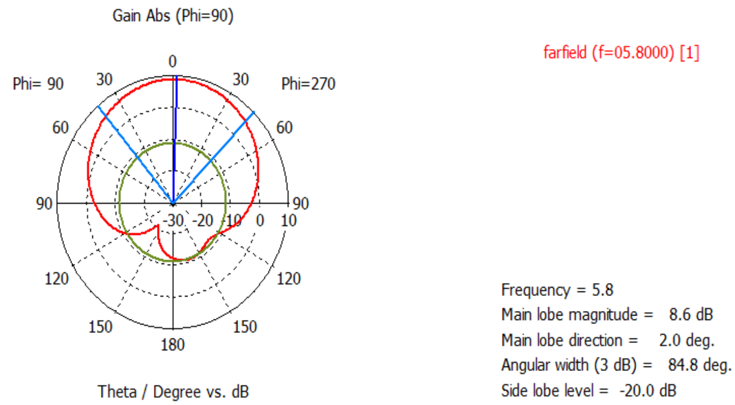


Figure 5.7 Radiation pattern of the proposed antenna at 5.8 GHz

Table 5.2 - Comparison of conventional and proposed antenna

Property	Conventional antenna	Proposed antenna
Gain (dB)	8.59	8.037
Bandwidth (MHz)	147.4	130
Back lobe level (dB)	-12.5	-22.8
Front to back ratio (dB)	21.1	30.9

Gain and bandwidth of conventional and proposed antenna are 8.59, 8.037 dB and 147.4, 130 MHz respectively. BLL and FBR of conventional and proposed antenna are -12.5, -22.8 dB and 21.1 and 30.9 dB respectively.

5.4 Conclusion

Reduced ground with edge shaping minimizes the back radiations and these are further minimized by using corrugated reflector at the back end of the antenna. Proposed antenna after using above said techniques shows an improvement of -10.3 dB in the back lobe and 9.8 dB in FBR over conventional antenna. Antenna resonates at 5.8 GHz frequency which is suitable for WLAN applications.

CHAPTER 6

Back Lobe Suppression of a Single Band MSA using Metal Reflector

6.1 Introduction

In this chapter, the fourth objective of the thesis is covered as back lobe of a Microstrip Antenna is reduced using the technique of metal reflector. In the first part of this chapter working of the technique is introduced and its effects on radiation properties are discussed. In second part, the design of the antenna and its dimensions are discussed in detail and result of the proposed antenna and its comparison with the conventional antenna is discussed in detail.

6.2 Design and Simulation Results of Conventional Antenna

6.2.1 Design of Conventional Antenna

In this section a MSA is designed and simulated at 5.2 GHz on a Rogers RT substrate with ε_r =2.2. The antenna design is mentioned in chapter 3, section 3.2. figure 6.1 shows the front view of the conventional antenna.

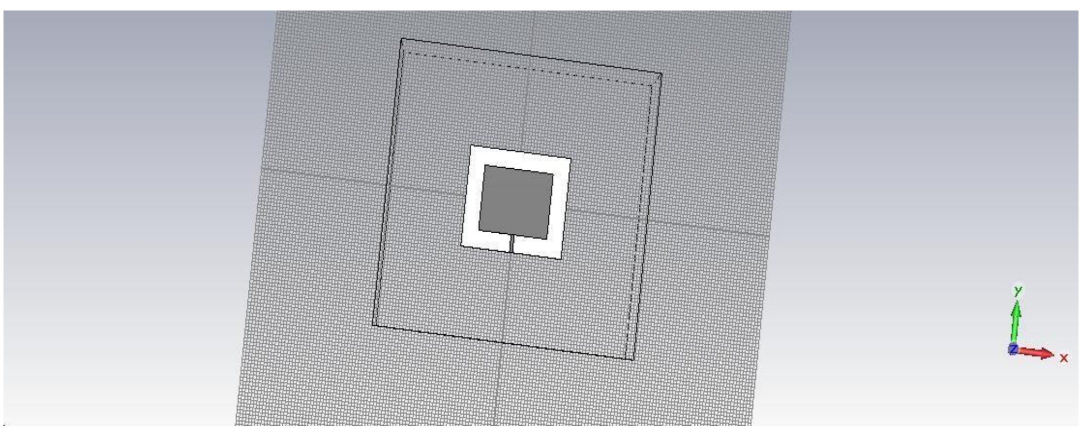


Figure 6.1 front view of the conventional antenna

6.2.2 Simulation Results of Conventional Antenna

Figure 6.2 shows the return loss of the conventional antenna. Antenna exhibits bandwidth of 132.9 MHz and return loss of –36 dB. Figure 6.3 shows the radiation pattern of conventional antenna. Conventional antenna has SLL of -18.9 dB.

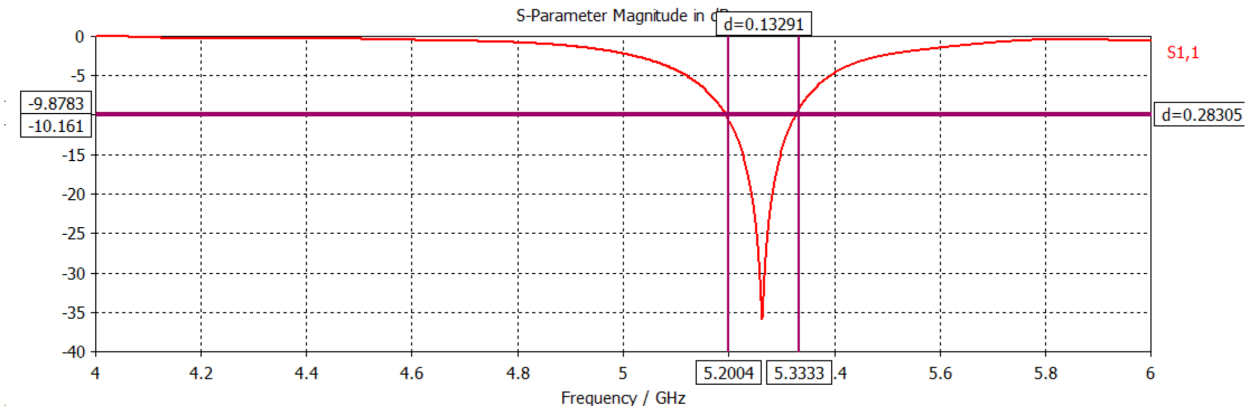


Figure 6.2 Return loss plot of conventional antenna

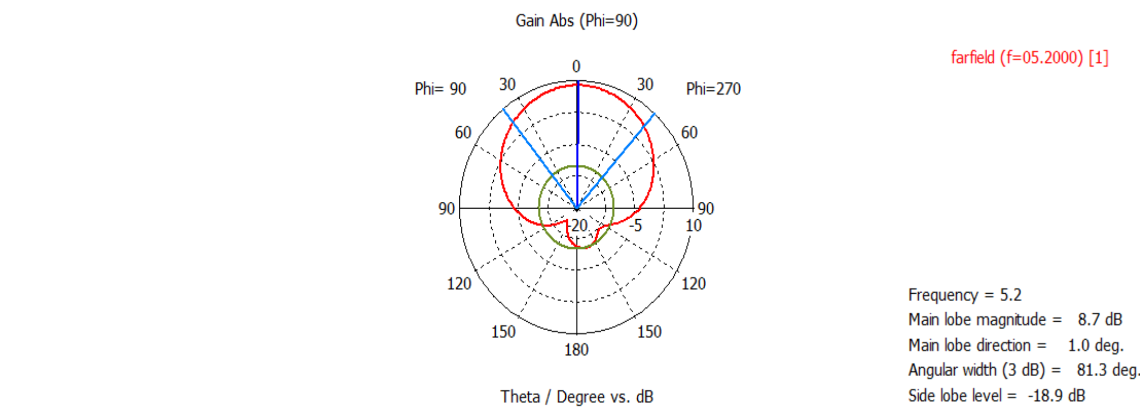


Figure 6.3 Radiation pattern of conventional antenna at 5.2 GHz

6.3 Improvement in FBR using Metal Reflector

6.3.1 Design of Proposed Antenna

Proposed antenna is designed by just adding a metal reflector at the back side of the antenna. Metal reflector reflects the back radiations and provides good front to back ratio[19]. The optimum size of the reflector is exactly equal to the ground plane to prevent ground plane edge diffraction and reduce the back lobe level.

6.3.2 Simulation Results of Proposed Antenna

Figure 6.4 shows the return loss plot of proposed antenna. Proposed antenna i.e. with metal reflector exhibits bandwidth of 137.8 dB and return loss of -29 dB. Figure 6.5 shows the radiation pattern of the antenna with metal reflector. Conventional antenna has a SLL of -18.9 dB and with reflector has a SLL of -30.9 dB.

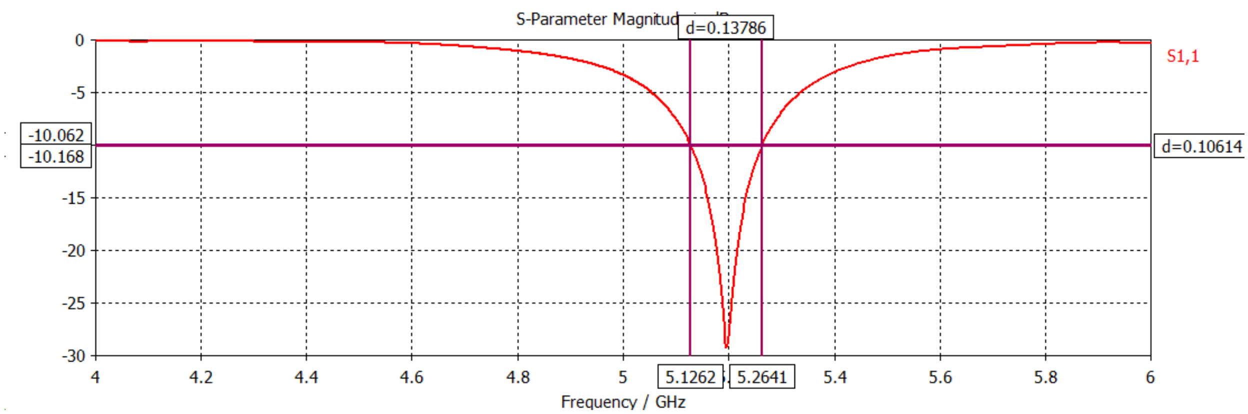


Figure 6.4 Return loss of proposed antenna.

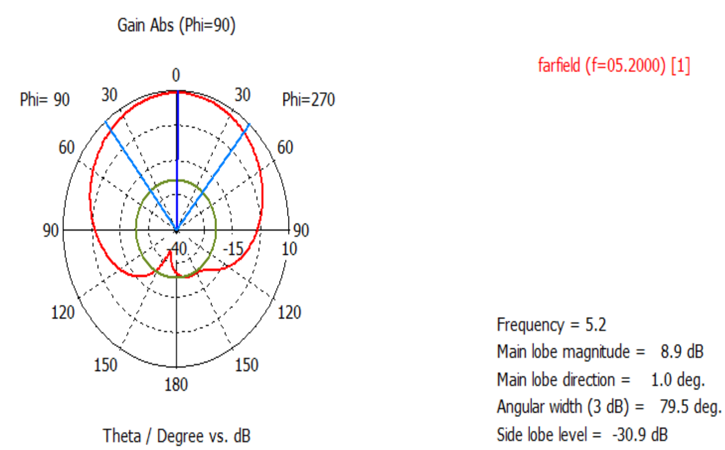


Figure 6.5 Radiation plot of the proposed antenna.

Radiation performances of both the antennas can be compared in the Table 6.1. There is an increment of 0.165 dB in gain and around 5 MHz in bandwidth in proposed antenna with reflector as compared to the conventional antenna without reflector.

Table 6.1 - Comparison of both the antennas

Property	Conventional antenna	Proposed antenna
Gain (dB)	8.74	8.905
Bandwidth (MHz)	132.9	138

Back lobe level (dB)	-10.8	-24.3
Front to back ratio (dB)	19.5	33.2

Gain and bandwidth of conventional and proposed antenna are 8.74, 8.905 dB and 132.9, 138 MHz respectively. BLL and FBR of conventional and proposed antenna are -10.8, -24.3 dB and 19.5 and 33.2 dB.

6.4 Conclusion

Due to reduction in ground plane edge diffraction provided by metal reflector there is an improvement of -13.5 dB in back lobe level and 13.7 dB in FBR in the proposed antenna with metal reflector over the conventional antenna. Antenna resonates at 5.2 GHz which is suitable for WLAN applications.

CHPATER 7

Back Lobe Suppression of a Single Band and a Multiband Antenna using Two Dielectric Reflectors

7.1 Introduction

In this chapter a new technique for suppression of back lobe and improvement in FBR is introduced. Here a double dielectric reflector is used at the back side of the MSA designed at 5.8 GHz and the radiation properties of the proposed antenna are compared with antenna without back reflectors.

7.2 Design and Simulation Results of Conventional Antenna

7.2.1 Design of Conventional Antenna

A Microstrip patch antenna (conventional) is designed on FR4 with ε_r=4.4 at 5.8 GHz frequency band using the equations (1) to (5) of transmission line model discussed in the chapter 1. Length and width of the patch are optimized using equations (9) and (10). Conventional antenna uses inset feed, which provides better return loss and enhances bandwidth. Improved return loss is good for fabrication purposes also, because when antenna is fabricated, return loss generally goes up due practical and fabrication losses. So this antenna is good for real world scenario. Top view of the conventional antenna is given in figure 7.1. Table 7.1 shows the dimensions of the MSA designed at 5.8 GHZ.

Table 7.1 Design specification of Conventional Antenna

Dimensions	Value (mm)
Length of the patch	10.74
Width of the patch	15.4
Length of the substrate	20.5
Width of the substrate	24.4
Height of the substrate	1.5
Width of the feed line	1

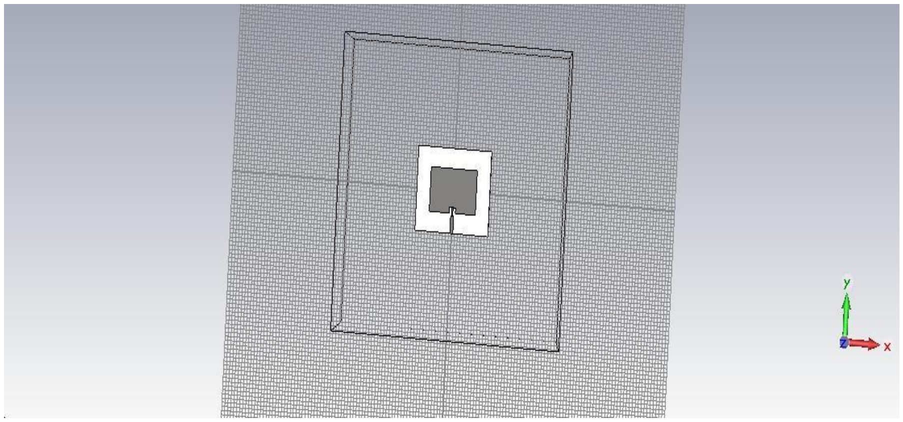


Figure 7.1 Top view of the designed antenna.

7.2.2 Simulation Results of Conventional Antenna

Figure 7.2 shows the return loss of the conventional antenna. It can be seen from the figure 7.2 that conventional antenna exhibits bandwidth of 258.8 MHz and return loss of -45 dB. Figure 7.3 shows the radiation pattern of conventional antenna and it is shown in the figure that conventional antenna exhibits a SLL of -12.1 dB.

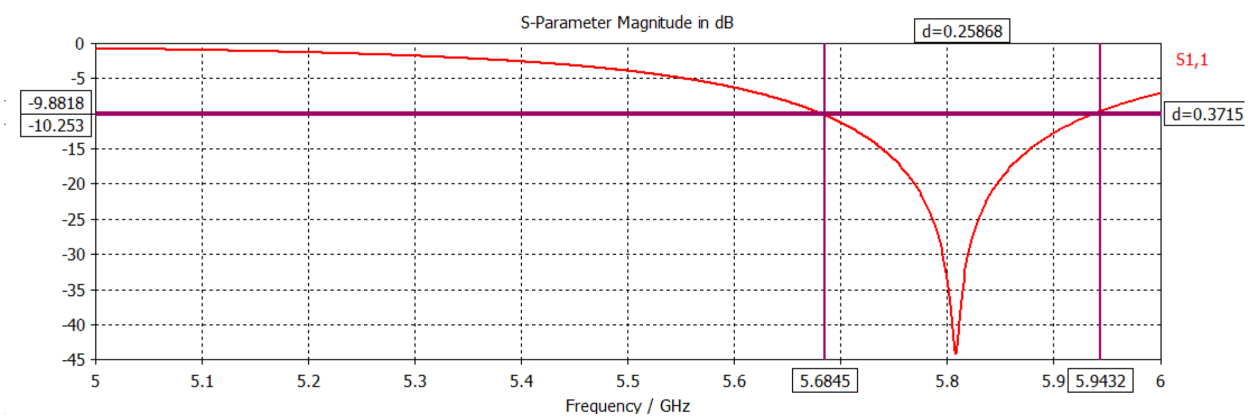


Figure 7.2 Return loss plot of the conventional antenna

7.3 Improvement in FBR of Conventional Antenna using Double Back Dielectric Reflector

7.3.1. Design of Proposed Antenna

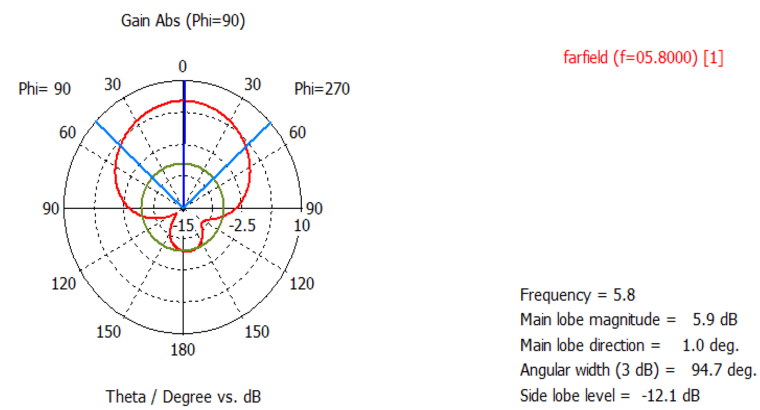


Figure 7.3 Radiation pattern of conventional antenna at 5.8 GHz

There are two 3.2 mm thick dielectric substrates at the back side of the designed MSA are used to prevent ground plane edge diffraction. Both these reflectors have same dimensions as that of the upper substrate so that they can cover the full ground plane and can give better results in terms of back radiations[14]. A tiny slot of 1.35×2 mm is there at the lower side of the patch to make it an inset feed. The width of the feed line that goes inside the slot is 0.4 mm. Figure 7.4 shows the side view of designed antenna.

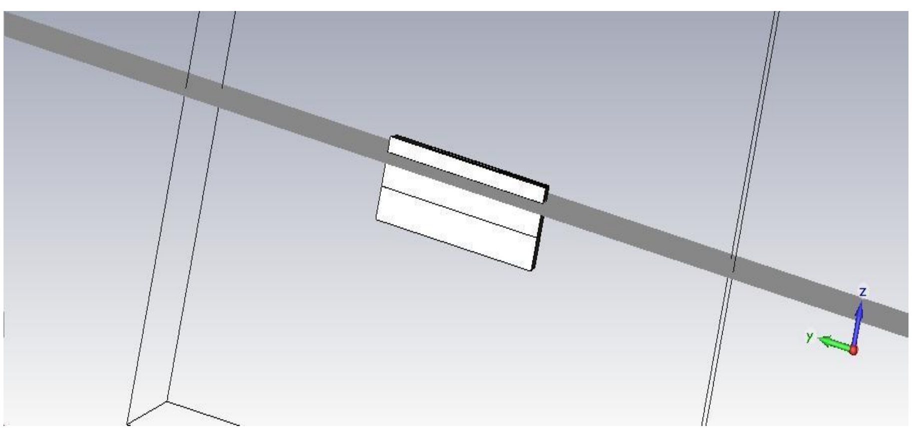
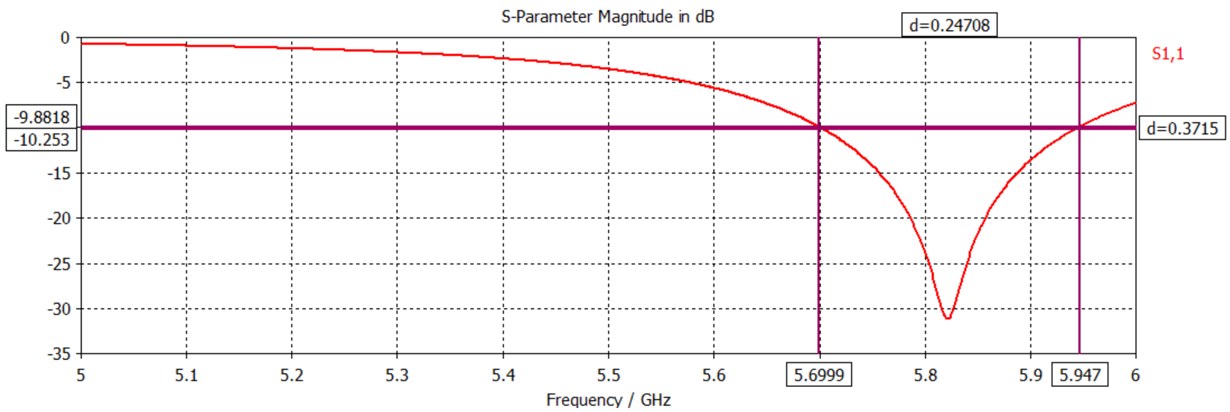


Figure 7.4 Side view of the proposed antenna.

To improve FBR Two substrate layers acting as a reflector are pasted below the ground layer of the antenna and it can be easily seen from the figure 7.4

7.3.2 Simulation Results of Proposed Antenna

Figure 7.5 shows the return loss plot of the proposed antenna. Proposed antenna with double reflector at back side exhibits bandwidth of 247 MHz and return loss of -31 dB. Figure 7.6 shows radiation pattern plot of proposed antenna and it can be seen from the figure that proposed antenna exhibits a SLL of -23 dB and there is an improvement of around 11 dB over conventional antenna.



(b)

Figure 7.5 Return loss plot of proposed antenna.

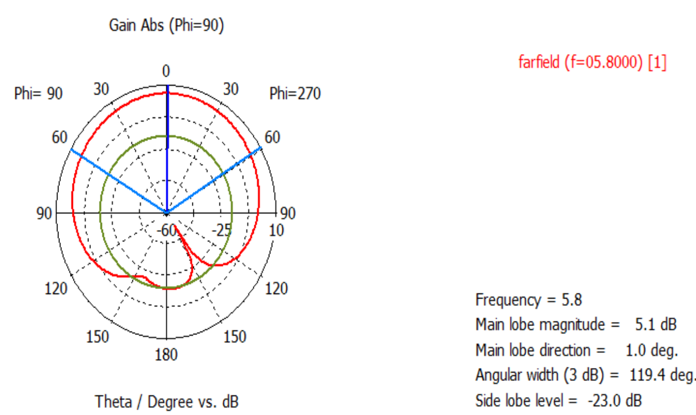


Figure 7.6 Radiation pattern of proposed antenna at 5.8 GHz

Radiation properties of the designed antenna with and without reflectors are compared in Table 7.2. Conventional antenna exhibits bandwidth of 258 MHz and gain of 5.863 dB. The proposed antenna exhibits bandwidth of 247 MHz and gain of 5.148 dB.

Table 7.2 Comparison of conventional and proposed antenna

Property	Conventional antenna	Proposed antenna
Gain (dB)	5.863	5.148
Bandwidth (MHz)	258	247
Back lobe level (dB)	-6.4	-18
Front to back ratio (dB)	12.3	23.1

BLL and FBR of conventional antenna is -6.4 dB and 12.3 dB respectively and of proposed antenna is -18 dB and 23.1 dB respectively.

7.4 Back Lobe Suppression of Multiband MSA using Double Reflector

In this section, last objective of the thesis is covered. Here a multiband antenna is designed using edge feeding technique and then FBR of the designed antenna is improved by two thick dielectric reflectors below the ground plane of the antenna then results of the proposed antenna and its comparison with the conventional antenna is discussed in detail.

7.4.1 Design of Conventional Antenna

Microstrip patch antenna (conventional) is designed on FR4 with ε_r=4.4 at 5.2 GHz frequency band using the equations (1) to (5) of transmission line model discussed in chapter 1. Length and width of the patch are optimized using equations (9) and (10). Then another 4 GHz frequency band is obtained by cutting slots along the width of the patch surrounding the feed line and making it an inset feed line[35].. Length and width of the patch are 15 and 21 mm respectively. Length and width of the substrate are 36.75 and 28.65 mm respectively and height of the substrate is 1.6 mm. dimensions of the ground plane are same as the substrate. There is a slot 4.15×5 mm in which 2.35 mm wide feed line is there and surrounding gap is 0.9 mm. Top view of the conventional antenna is given in figure 7.7 and he dimensions of conventional antenna are given in Table 7.3.

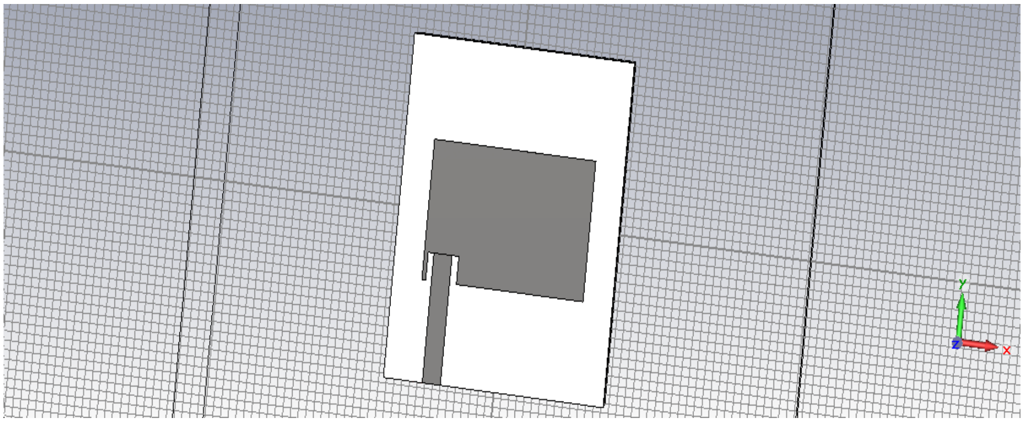


Figure 7.7 Top view of the conventional Microstrip antenna.

Table 7.3 – Design specification of Conventional Antenna

Dimensions	Value (mm)
Length of the patch	15
Width of the patch	21
Length of the substrate	36.75
Width of the substrate	28.65
Height of the substrate	1.6
Width of the feed line	2.35
Gap from feed line	0.9
W× L of the slot in patch	4.15×5

7.4.2 Simulation Results of Conventional Antenna

Figure 7.8 shows the return loss plot of conventional antenna. As it can be seen from the figure 7.8 conventional antenna exhibits bandwidth of 157 MHz and return loss of -20.5 dB at 4 GHz frequency band and bandwidth of 166 MHz and return loss of -49.6 dB at 5.2 GHz frequency band. Radiation pattern of conventional antenna at 4 GHz and 5.2 GHz is given in figure 7.9 (a) and (b) respectively.

7.5 Improvement in FBR of Multiband MSA using Double Back Dielectric Reflector

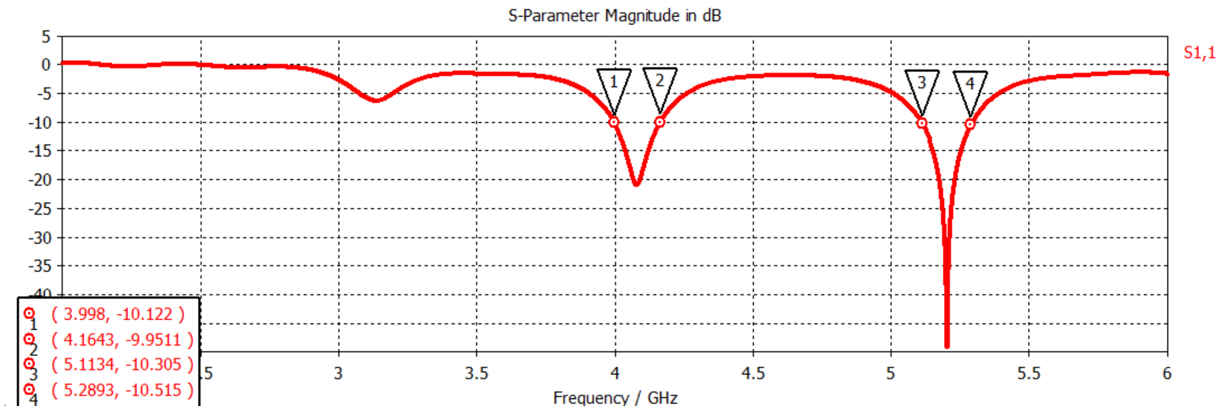


Figure 7.8 Return loss plot of conventional antenna

Figure 7.9 Radiation pattern of conventional antenna at (a) 4 GHz (b) 5.2 GHz

7.5.1 Design of Proposed Antenna

In order to improve FBR of the designed antenna two back dielectric reflectors at the back side of the antenna. Back reflectors reflect the back radiations and provides good front to back ratio. The optimum size of the reflector is exactly equal to the ground plane to prevent ground plane edge diffraction and reduce the back lobe levelIn the antenna two 3.2 mm back reflectors are added to it and can be easily seen from the side view of the proposed antenna shown in figure 7.10.

7.5.2 Simulation Results of Proposed Antenna

Figure 7.11 shows the return loss plot of the proposed antenna and radiation pattern of the proposed antenna at 4 GHz and 5.2 GHz is shown in figure 5.12 (a) and (b) respectively.

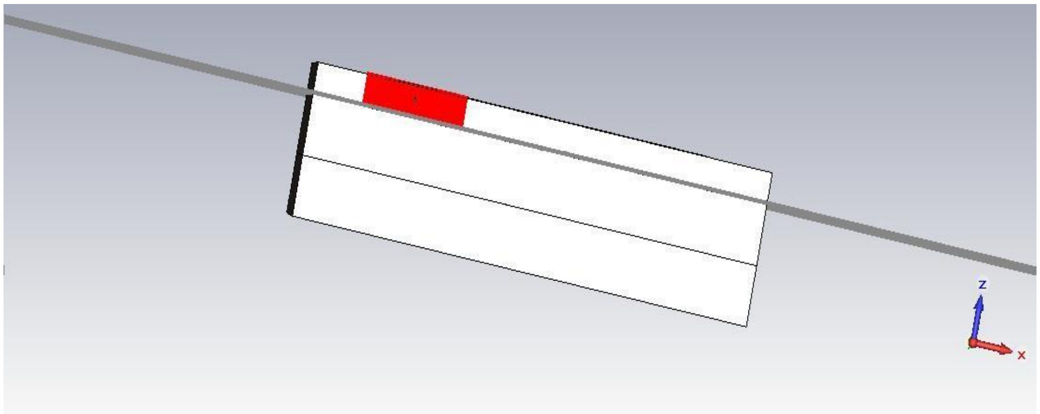


Figure 7.10 Side view of the proposed antenna.

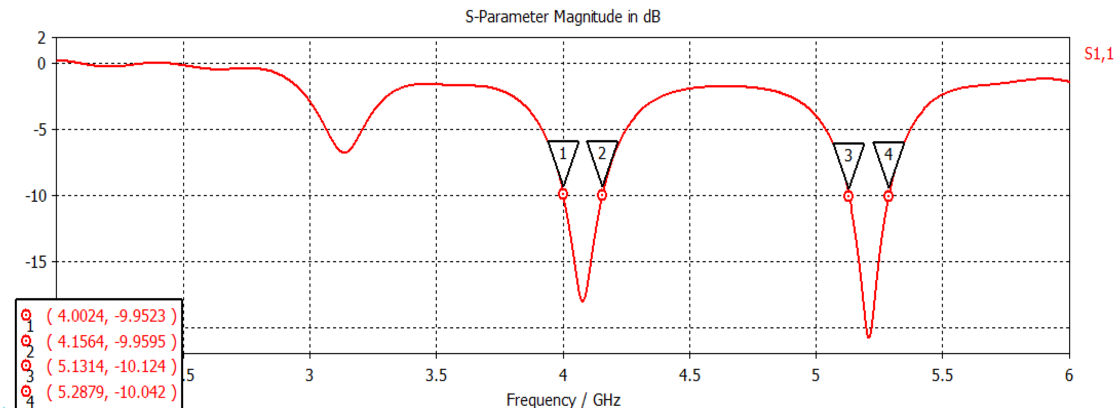
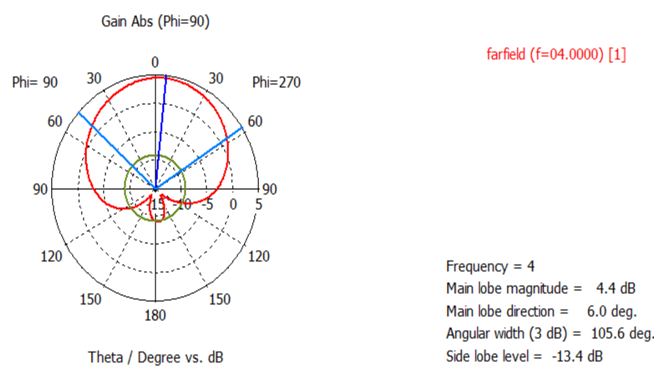
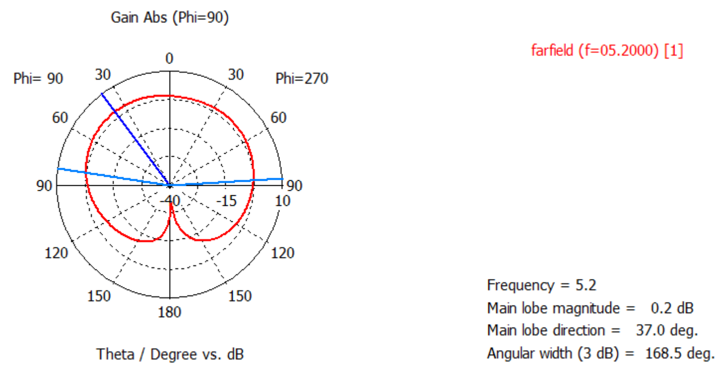


Figure 7.11 Return loss plot of proposed antenna.



(a)

From figure 7.11 it can be seen that proposed antenna exhibits return loss and of -17.5 dB and -21 dB and bandwidth 163.3MHz and 165.5 MHz at 4 GHz and 5.2 GHz respectively.



(b)

Figure 7.12 Radiation pattern of proposed antenna at (a) 4 GHz and (b) 5.2 GHz

Figure 7.12 shows the radiation pattern of proposed antenna. From the radiation plot given in figure 7.12 it can be easily seen that proposed antenna shows much better performance in terms of back radiations as compared to the conventional radiation pattern of which is given in figure 7.9. Radiation performances of both the antennas at both the frequencies is compared in Table 7.4

Table 7.4 - Comparison of conventional and proposed antenna.

Frequency (GHz)	Conventional Antenna				Proposed Antenna			
	Gain (dB)	Bandwidth (MHz)	BLL (dB)	FBR (dB)	Gain (dB)	Bandwidth (MHz)	BLL (dB)	FB R
5.2	2.71	166	-16.7	19.4	2.43	165.5	-25.7	28.3
4	5.06	157	-5.4	9.4	4.4	163.3	-9.2	13.6

Proposed antenna with two back reflectors shows better performance than conventional one and that can be seen in Table 7.4. Conventional antenna exhibits gain of 5.06 dB and 2.71 dB at 4 and 5.2 GHz bands respectively, while proposed antenna exhibits 4.4 dB and 2.43 dB at these frequencies respectively. Bandwidth of conventional and proposed antenna is 157 MHz, 163.3 MHz and 166 MHz, 165.5 MHz at 4 GHz and 5.2 GHz respectively. BLL of conventional and proposed antenna is -5.4 dB, -9.2 dB and -16.7 dB and -25.7 db at 4 GHz and 5.2 GHz respectively.

7.6 Conclusion

Double reflector used at the back side of the MSA minimize the departure of radiations in undesired direction and provides reduction of 11.6 dB in the back lobe and 7.8 dB in FBR over conventional antenna.

Proposed multiband antenna shows an improvement of -3.8 dB and -9 dB in back lobe level at 4 GHz and 5.2 GHz respectively over the conventional antenna. There is an improvement 6.3 MHz in bandwidth at 4 GHz frequency band and at 5.2 GHz bandwidths are almost equal to 166 MHz. Proposed antenna shows an improvement of 4.2 dB and 8.9 dB in FBR over the conventional antenna. The more thick the reflectors the more is the improvement, but this improvement is limited upto the 6 times the thickness of the upper substrate and after that back lobe is getting worse.

CHAPTER 8

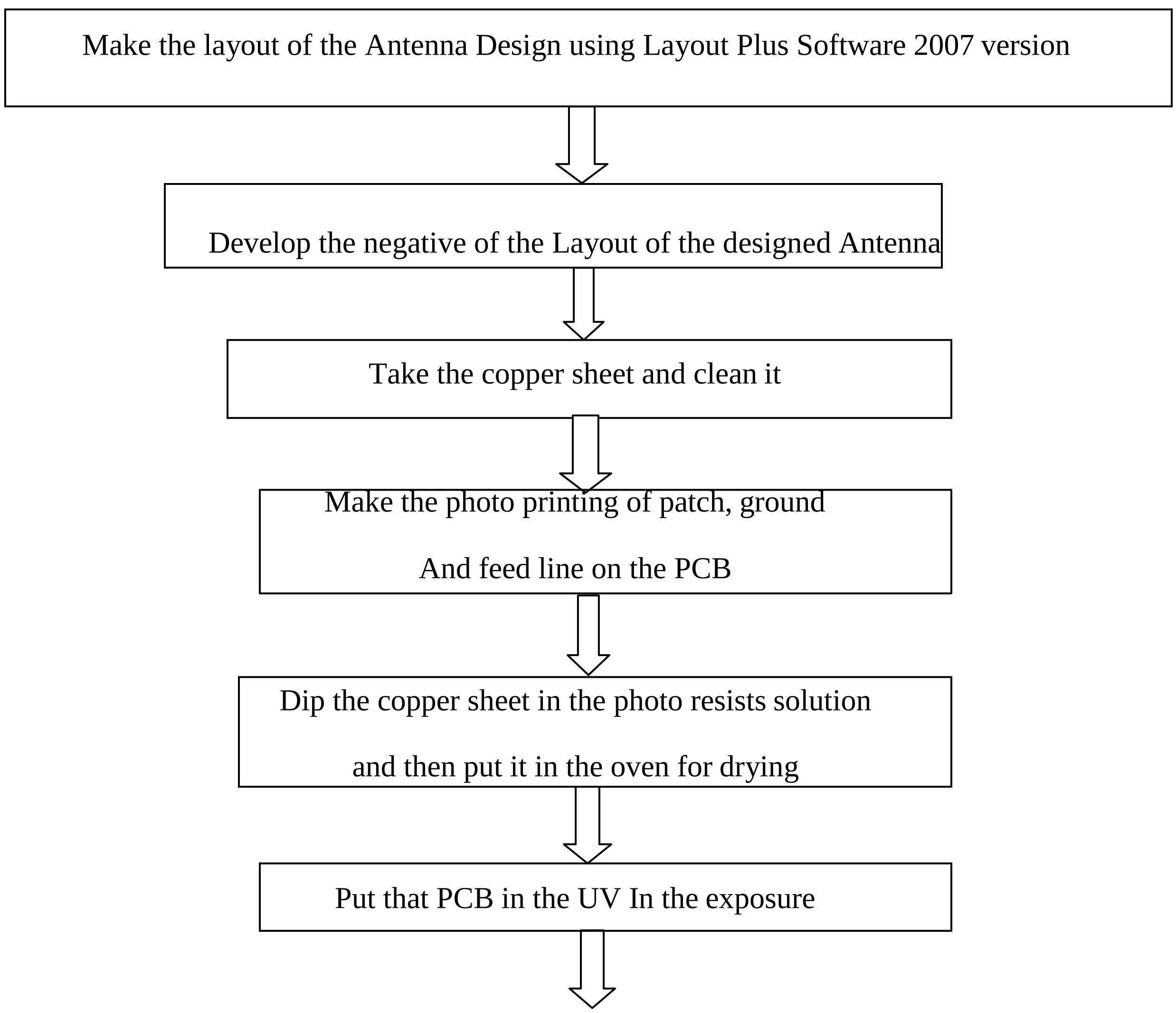
Fabrication and Testing of Antenna

8.1 Introduction

This chapter presents the fabrication and tested results of MSA with double reflector and validation of results in practical usage of the antenna. Comparison between simulated and tested results is also presented.

8.2 Fabrication Process Steps:

The different steps incorporated in the fabrication process are shown in the fig 8.1.



Wash the PCB and put it into the etching solution

which contains ferric chloride solution.

Take it out and wash it.

Figure 8.1 Flow chart of antenna fabrication process

Initially in Layout Plus software 2007 version, layout of proposed antenna is prepared. Negative of this layout is designed using the above software. In order to fabricate an antenna on copper sheet, copper sheet is cleaned. Photo printing of each component of antenna is made on PCB. Then PCB is dipped into a photo resist solution. This PCB is made dry in Oven. Then this PCB is placed in UV exposure. At last this PCB is placed in an etching solution containing ferric chloride.

8.3 Equipment Used

The testing of the antenna is done using VNA (Vector Network Analyzer) MS46322A which analyses one or two port networks. The frequency range of VNA is from 9 KHz to 20 GHz.

Figure 8.2 Vector network analyzer for testing

8.4 Fabricated Antenna Design

Fabricated MSA with two back dielectric reflectors is shown in the figure 8.3.

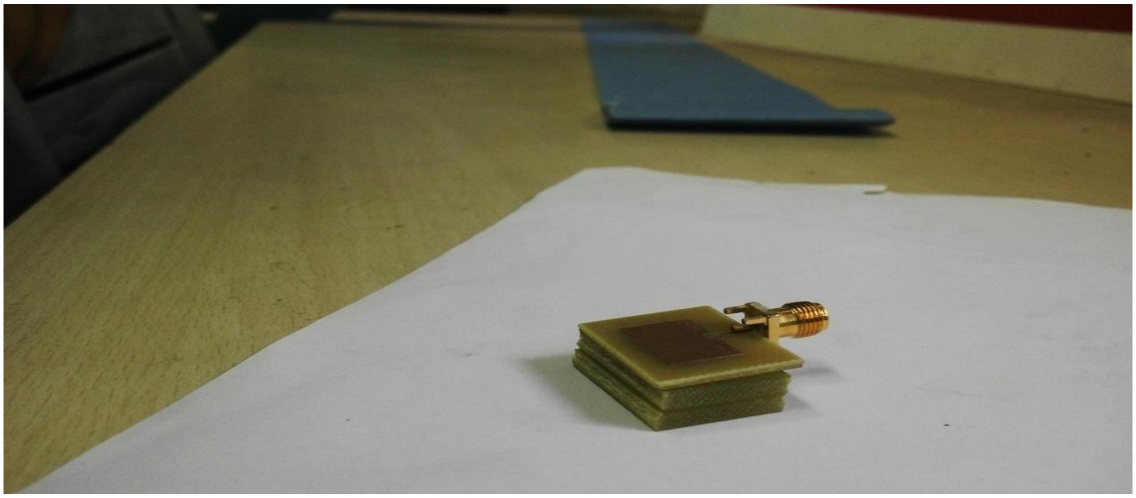


Figure 8.3 Fabricated antenna design

8.5 Simulation and Testing results

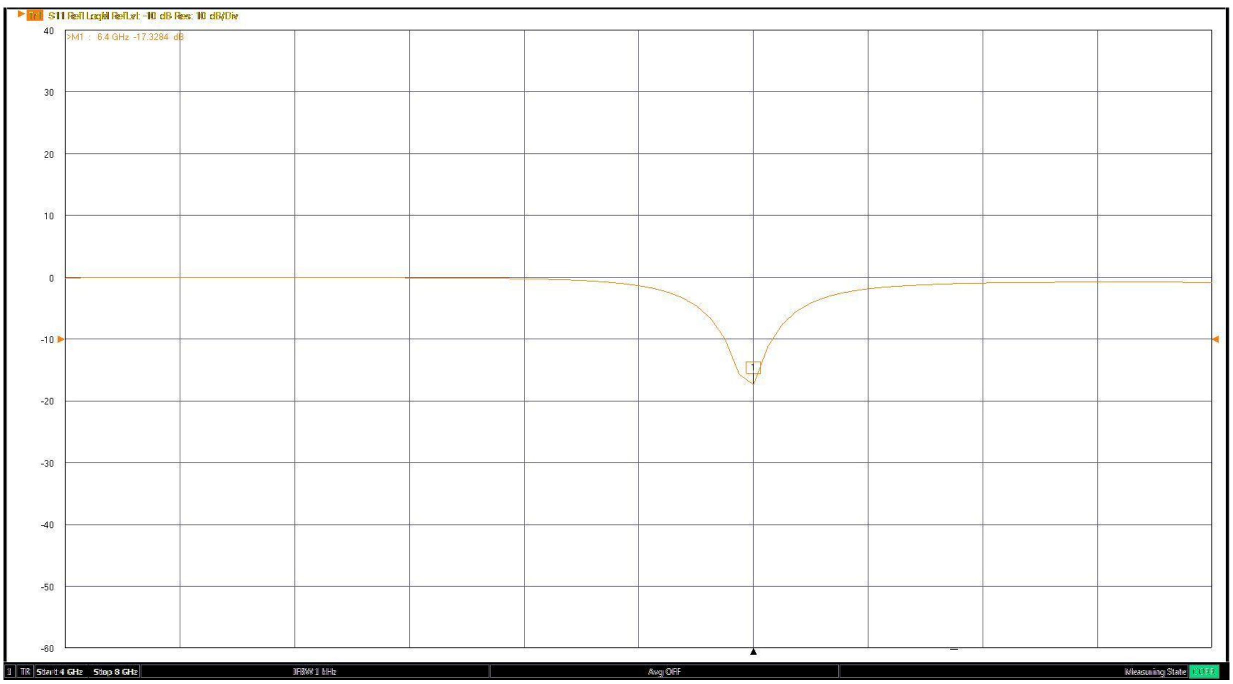
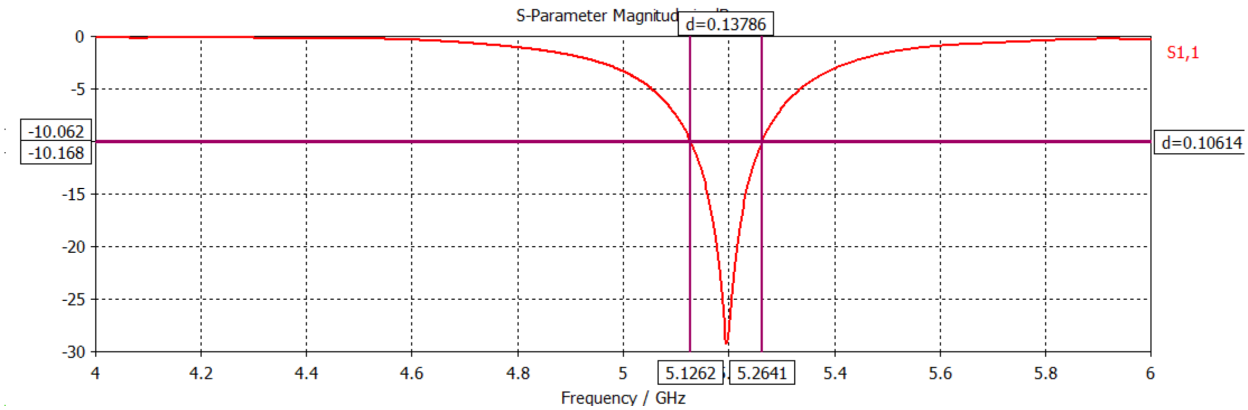


Figure 8.4 Measured return loss using network analyzer



8.4 Simulated antenna return loss

8.6 Comparison of Simulated and Tested Antenna Results

Table 8.1 shows the comparison between simulated and tested results. Return loss of the simulated antenna is -29 dB and of tested antenna is -17.34 dB. There is around 11 dB downfall in tested antenna return loss. Resonating frequency of simulated antenna is 5.8 GHz and of tested antenna is 6.4 GHz and there is 0.6 GHz deviation in resonating frequency. Deviation occurs due to fabrication error and testing error.

Table 8.1 Comparison of tested and simulated results

Parameter	Tested results	Simulated results
Return loss (dB)	-17.34	-29
Resonating frequency (GHz)	6.4	5.8

8.7 Conclusion

Results of tested antenna varied slightly from simulation results and this deviation is due fabrication and testing errors.

CHAPTER 9

Conclusion and Future Scope

9.1 Conclusion

- SLL and BLL of radiation pattern of a directional antenna are disastrous for antenna performance in wireless communication field. These cause interference to other signals and decrease the directivity of the antenna. So, these parameters should be as low as possible. There are various designs proposed in this thesis work to minimize these parameters.
- A MSA was designed at 5.2 GHz frequency and partial ground plane with edge shaping is employed to increase FBR. This technique best suited in terms of fabrication and an improvement of almost -17 dB in back lobe and 16 dB in FBR has been achieved using this technique.
- Technique of fractal shaped ground plane is employed in the previous designed MSA at 5.2 GHz and it provides improvement of -10 dB in back lobe and 8 dB in FBR over conventional antenna.
- Another MSA was designed at 5.8 GHz and partial ground plane with edge shaping along with corrugated back dielectric reflector was used to increase FBR of antenna. Back reflector with corrugation gives best result when grooves are exactly placed below the edge shaped part of the ground plane and this technique gives 10 dB of improvement in back lobe and 9 dB in FBR of single band MSA.
- Technique of a metal reflector of dimensions same as the ground plane was used to divert back rediations in front side and thus increase FBR. This technique gave 13.5 dB improvement in back lobe and and 13.7 dB improvement in FBR.
- Single Band antenna at 5.8 GHz and Multiband Microstrip patch antenna at 4 GHz and5.2 GHz were designed and simulated with inset feed line. Inset feed line has been proved to be the best in terms of bandwidth and return loss. Bandwidth of more than 250 MHz and return loss almost -50 dB has been achieved. Two dielectric reflectors were used at the back side of the antenna to increase FBR. Dielectric reflectors at back side of the antenna give improvement upto when height of back reflectors is less than or equal to

six times the height of upper substrate and improvement of -14 dB in back lobe and 13 dB in FBR in single band MSA and 3.8 dB and 9 dB in BLL and 4.2 dB and 8.9 dB in FBR at 4 GHz and 5.2 GHz was achieved respectively.

- Designed antennas with high FBR are suitable for WLAN and WiMAX applications as they gave high directivity in these wireless communication applications.

9.2 Future Scope

- Fabry Parot can be used to increase gain of the multiband antennas. Multiband antennas generally exhibits low gain at lower frequencies, so this technique can be used to provide high gain and improved front radiations.
- Microstrip antenna generally exhibit low bandwidth, modified aperture coupling techniques can be used to provide high bandwidth.
- Techniques like electromagnetic band gap (EBG) and defective ground structure (DGS) can be proved very useful in increasing both gain and bandwidth of the microstrip antenna.
- Microstrip antennas with very high front radiations provided by split ring resonator (SRR) can be used in satellite communication.

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List of Publications

- Baljinder Singh, Amanpreet Kaur. **Improvement in FBR using partial ground plane with edge shaping and corrugated Dielectric reflector** STM journal (unpaid) of Electronics Design Technology.
- Baljinder Singh, Amanpreet Kaur. **Improvement in Front to Back ratio using aperture coupled MSA with corrugated ground plane** National Conference in recent in Electronics and Computer Engineering. IIT Roorkee, 2015.