A Project Report on

DEVELOPMENT OF DUAL-BAND MICROSTRIP PATCH ANTENNA FOR WLAN/MIMO/WIMAX/AMSAT/WAVE APPLICATIONS

Submitted by

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MPA – Microstrip Patch Antenna

Chapter 1
Introduction

1.1 Motivation

Today wireless communication has become more of a dire necessity in various applications. In many scenarios where the wired systems are impractical or almost impossible to be implemented, wireless systems have readily replaced them. Many systems are actually required to actually transmit a message and receive it with minimal error in a wireless systems. Such blocks like transmitter, receiver, coders etc. are required to pass information both over short and long distances.

Now-a-days with the advent of Internet of Things (I.O.T) applications, wireless networking has increased manifold both in terms of number and complexity. Take the example of the unlicensed spectrum of 2.4 GHz for interconnecting Wi-Fi devices such as connecting laptops or mobile devices for people in transit. This spectrum in small range is used for communicating multiple devices in various networks thereby generating requirement of various kinds of specialised antenna for the suitable purpose.

One more use for wireless systems is one that connect the mobile network to connect to the satellites. Take the example of GPS systems where devices need to be within the range of three or more satellites. The location is transmitted from the satellites in range via the communicating channels. So practically the antenna needs to be designed in such a manner that the signals can be detected in any orientation. So a circularly polarised antenna is the requirement for such an application which overcomes the orientation problem

With embedded systems in use at large, antennas have to be integrated into small, portable systems. Small antenna at a particular resonant frequency can be made feasible with various design techniques in the microstrip patch antenna. Recently with the use of metamaterials and dielectric resonators, the antenna size have been drastically reduced to very small sizes for actual practical applications.

1.2 Scope of the Project

Microstrip antenna have a tremendous application potential. Even as of now, these antennas are designed and used in Personal Communication System, Mobile Satellite Communication, Direct Broadcast Satellite, Global Positioning System, Wireless Local Area Network, Intelligent Vehicle Highway System, and also it is receiving attention for Microwave Therapy. Simulators are invaluable tools for microstrip patch antenna. Suitability of these tools depends upon the sophistication of the models used in them.

Microstrip array antennas are actively considered for application, such as satellite communication systems, where thin profile and light weight are important, consideration. The present model can be extended for array of microstrip patch antenna. For this development some additional models will have to be developed.

Many applications in communications and radar required dual frequency. The present work can be extended also for designing of dual frequency patch antenna.

1.3 Methodology

The present work represents a dual-band microstrip-fed patch antenna in which the radiating structure is formed with a pair of inverted L-shaped patches and ground plane is being modified to a shape. Both the radiating patch and modified ground plane are perfect electric conductors. The patch is printed on a readily available Epoxy Glass (FR-4) substrate with thickness 1.6 mm, relative permittivity 4.4,and loss tangent 0.0024. The proposed microstrip patch antenna (MPA) design is capable of generating two distinct operating bands with 10-dB return loss as follows 3.34–3.54 GHz and 4.90–6.26 GHz with adequate bandwidth of 200 MHz and 1.36 GHz, respectively. The impedance bandwidths are wide enough to cover the required bandwidths of 3.3– 3.5 GHz, 5.15–5.35 GHz, 5.725–5.825 GHz for wireless local area network,

3.3–3.5 GHz for multiple input multiple output, 5.25–5.85 GHz for world-wide interoperability for microwave access, 5.650–5.670 GHz for uplinks and 5.830–5.850 GHz for downlinks of Amateur Satellite, and 5.9 GHz wireless access in the vehicular environment (WAVE-IEEE 802.11p). Proposed MPA was simulated using Computer Simulation

Technology Microwave Studio V9 based on the finite integration technique with perfect boundary approximation and effect of using different substrate materials was studied. Finally, the proposed antenna with optimized parameters was fabricated and some performance measurements were taken to validate against simulation results.

1.4 Organization of Project Report

This project report is organized as follows:

- The first chapter discuses on the introduction of the antenna which includes motivation, scope of the project and methodology.

- In the second chapter, a brief introduction to microstrip patch antennas is provided. Here in this chapter, various advantages and disadvantages of such antennas have been discussed. Further, a brief introduction to the various models used for the study of microstrip patch antenna has been provided. After introducing the antenna and knowing its basic features more stress has been laid on the antenna parameters. Finally a basic simulation of a rectangular microstrip patch antenna has been simulated and explained in detail using HFSS Software.

- In the last chapter we will discuss about the result analysis and conclusion of the project.

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Chapter 2

DEVELOPMENT OF DUAL-BAND MICROSTRIP PATCH ANTENNA FOR WLAN/MIMO/WIMAX/AMSAT/WAVE APPLICATIONS

2.1 Introduction

The design of a microstrip patch antenna (MPA) is one of the most exciting developments in electromagnetic history because of its salient features which are not commonly exhibited in other antenna configurations including ease of fabrication, good radiation control, low cost of production, low profile, lightweight, simple, and inexpensive to fabricate using modern day printed circuit board technology, compatible with microwave and Electric field lines millimeter-wave integrated circuits, and ability to conform to planar and non planar surfaces. Microstrip patch antennas (MPA) are a class of planar antennas which have been researched and developed extensively in the last four decades. They have become favorites among antenna designers and have been used in many applications in wireless communication systems, both in the military sector and in the commercial sector. The aim of this book is to provide a coherent account of the theory, analysis, and design of these antennas, as well as some recent developments. Since the authors have been involved with the research and development of MPAs from the early 1980's, this book can also be regarded as a partial record of their personal journeys in this field. A significant fraction of the material is drawn from their own work in the last three decades.

2.2 Advantages and Disadvantages

The low-profile nature and its compatibility with embedded systems in wireless devices like mobile phones, PDAs etc. has immensely popularised microstrip patch antennas. In warfare antennas need to be placed over missiles for communication and telemetry. Such antennas need to be thin and conformal which can be only made possible by microstrip patch antenna. Apart from many advantages Microstrip patch antennas suffer from far more drawbacks in comparison to conventional antennas. Some of the advantages and disadvantages are compared in the table below

Sl. No.	Advantages	Disadvantages
1.	Light weight & low volume	Narrow bandwidth.
2.	Low profile planar configuration that can be easily made conformal to host surface	Low efficiency
3.	Low fabrication cost, hence can be manufactured in large quantities.	Low Gain
4.	Supports both, linear as well as circular polarization.	Extraneous radiation from feeds and junctions.
5.	Can be easily integrated with microwave integrated circuits (MICs).	Poor end fire radiator except tapered slot antennas
6.	Capable of dual and triple frequency operations.	Low power handling capacity.
7.	Mechanically robust when mounted on rigid surfaces	Surface wave excitation.

TABLE 1: Advantages and Disadvantages of Microstrip Patch Antenna

Microstrip patch antennas suffer an increasing loss in radiated wave with increasing substrate thickness. Substrate is expected to be thick for larger bandwidth. This unwanted surface wave power loss gets scattered and causes degradation of antenna radiation. Some other problems like low power gain and low power handling capacity can be overcome by other methods.

2.3 Transmission Line Model

The transmission line model represents the microstrip antenna by two slots each of width (W) and height (h), separated by the transmission line of length (L). Microstrip is generally a non-homogenous line of two dielectrics, generally the substrate and the air as seen in figure 1.

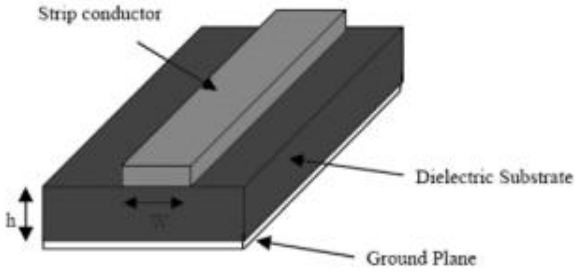


FIGURE 1: Microstrip Line

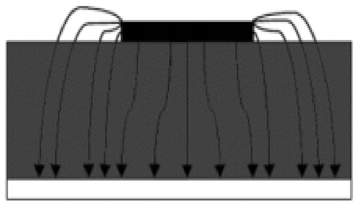


FIGURE 2: Electric Field Lines

We can see in figure 2 that most of the electric field lines lie inside the substrate and very few of them lie outside in air. Thus pure TEM mode cannot be supported, and instead of that the quasi-TEM mode would be the dominant mode of propagation. So to account for the fringing effects and wave propagation an effective dielectric constant (εreff) must be obtained. This value will be slightly smaller than the relative permittivity (εr) since the fringing fields around the perimeter of the patch are not confined in the substrate but are also spread as shown in the figure 2 above. The εreff equation is stated as:

If $\frac{w}{h} < 1$

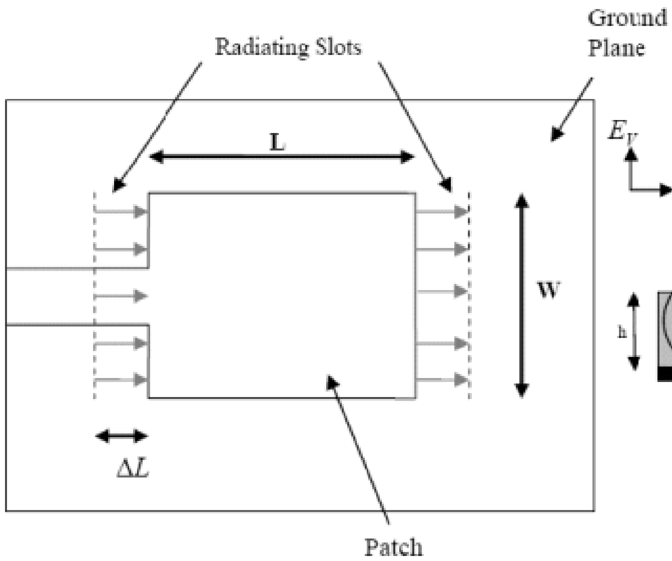
$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \left(\frac{\varepsilon_r - 1}{2}\right)\left[\frac{1}{\sqrt{\left(1 + \frac{12h}{e}\right)}}\right] + 0.04\left(1 - \frac{w}{h}\right)^2 \quad \text{.................................. (2.1)}$$

If $\frac{w}{h} >= 1$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \left(\frac{\varepsilon_r - 1}{2}\right)\left[\frac{1}{\sqrt{\left(1 + \frac{12h}{e}\right)}}\right] \quad \text{.................................. (2.2)}$$

where, εreff = Effective Dielectric Constant
εr = Dielectric Constant of the Substrate
h = Height of the electric substrate
W = Width of the Patch

It can be seen that we need to operate in TM10 mode, and hence the length of the patch must be slightly less than λ/2 where λ is the wavelength in the dielectric medium and is equal to λo/√εreff where λo is the free space wavelength. Also the normal components of the electric field along the two edges of the width are in opposite directions and thus out of phase. On the other hand the tangential components are in phase. It actually means that the resultant fields combine to give maximum radiated field normal to surface of the structure.



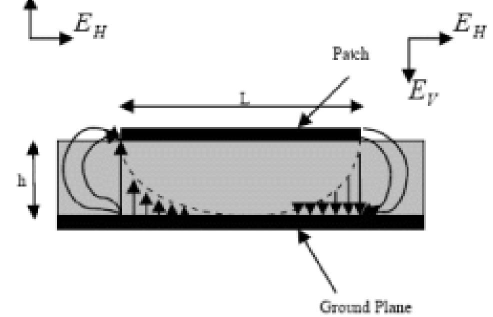


FIGURE 3: Top View of Antenna **FIGURE 4: Side View of Antenna**

Hence the fringing fields along the width can be modeled as radiating slots and thus the electrical length of the patch becomes greater than its physical length. So there is an increase in the length of the patch by the factor ΔL defined by

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad \text{..................................} (2.3)$$

Thus the effective length now becomes: Leff = L + ΔL
Hence for a given frequency fo, the effective length is given by

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \qquad \text{..................................} (2.4)$$

For a rectangular Microstrip patch antenna, the resonant frequency for any TM010 mode is as defined by

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} \qquad \text{..................................} (2.5)$$

where m and n are modes along L and W respectively For efficient radiation, the width W is given by

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \qquad \text{..................................} (2.6)$$

2.4 Performance Parameters

A number of parameters can be taken into consideration while judging the performance of an antenna. The following parameters are the critical ones for microstrip patch antenna.

2.4.1 Radiation Pattern

The radiation pattern is a three dimensional graphical representation of the radiation of the antenna as the function of direction. It is actually the plot of power radiated from an antenna per unit solid angle. If we consider the total power radiated by an isotropic antenna to be P, with a spread over a sphere of radius r then the power density S at this point in any direction is given as:

$$S = \frac{P}{4\pi r^2} \qquad \text{.................................. (3.1)}$$

Isotropic antennas do not exist in reality but are generally used as an reference to compare the performance of other antennas. For an isotropic antenna, the radiation intensity can be calculated as

$$Ui = \frac{P}{4\pi} \qquad \text{.................................. (3.2)}$$

The radiation pattern provides all the required information on antenna beam-width, sidelobes and resolution of the antenna.

2.4.2 Gain

The ratio of the maximum radiation intensity at the peak of the beam to the radiation intensity in the same direction produced by an isotropic radiator having same input power is known as the Gain of the Antenna. The gain of the isotropic radiator is considered to be unity. The gain is defined as

$$G(\theta,\emptyset) = \frac{P(\theta,\emptyset)}{\frac{Wt}{4\pi}} \qquad \text{.................................. (3.3)}$$

Where, $P(\theta, \emptyset)$ is defined as the power radiated per unit solid angle in direction $(\theta, \emptyset)$ Wt is the total radiated power.
Due to poor radiation efficiency microstrip patch antennas have poor radiation efficiency. Research is being conducted at several levels to obtain high gain antennas.

2.4.3 Return Loss

Return loss or reflection loss is the signal power's reflection from the insertion of a device in a transmission line. It is expressed as ratio in decibels (dB) relative to the transmitted signal power. The return loss is expressed by

$$RL(dB) = 10\,log\frac{Pr}{Pi} \qquad \text{.................................. (3.7)}$$

Where Pi is the supplied power from the source

Pr is the power reflected back

Let Vi be amplitude of incident wave and Vr be that of reflected wave, then return loss can be written in terms of reflection coefficient г as

$$Rl = -20log|\Gamma| \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

And the reflection coefficient г can be expressed as: г = Vr /Vi.
The return loss should be restricted to less than -10 db, so that the antenna can radiate effectively.

2.4.4 VSWR

Voltage Standing Wave Ratio (VSWR) is the wave in the transmission line where distribution of electric parameters like current, voltage or field strength is formed by superposition of two waves of same frequency that propagate in the opposite direction. This voltage standing wave along the line produces a series of nodes and anti-nodes at fixed positions. The VSWR is defined as

$$VSWR = \frac{Vmax}{Vmin} = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.9)$$

VSWR should lie between 1 and 2 for efficient antenna performance.

2.5 Simulation of Rectangular Microstrip Patch Antenna

A rectangular microstrip patch antenna was simulated using HFSS Software. The simulation of any antenna requires to go through three basic steps. Firstly, all the unknown parameters are calculated from the list of known parameters. Then port is created and basic simulation is done to find the S11 parameters. The more simulation is done for further analysis of the patch antenna

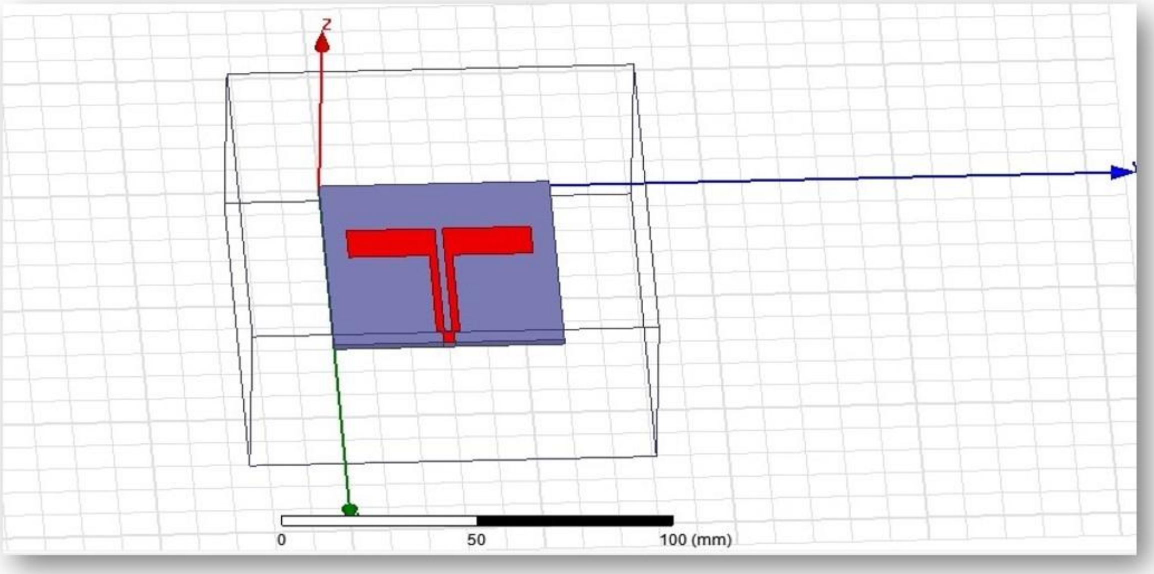


FIGURE 5: Rectangular Micro- strip Patch in HFSS

Parameters	W_s	L_s	L_1	L_2	L_3	W_1	W_2	L_{g1}	W_{g1}	g	d
Unit (mm)	60	70	11.7	33.5	5	23	3	8	31	2	2

TABLE 2: Optimal Parameters of the Proposed MPA

2.6 Hardware and Software Requirements

<u>Hardware Requirements</u>: Microstrip Patch Antenna, inverted L-shaped patches, ground plane, Epoxy Glass (FR-4) substrate.

<u>Software Requirements</u>: HFSS Software.

Chapter 3

Simulation and Experimental (if any) Results

3.1 RESULT ANALYSIS

After the simulation all the parameters were analyzed to check for the desired output of the antenna design. As we can see in figure 6, the S11 curve has been plotted. As we can see the curve just crosses below -10 db at the resonant frequency marked on the plot.

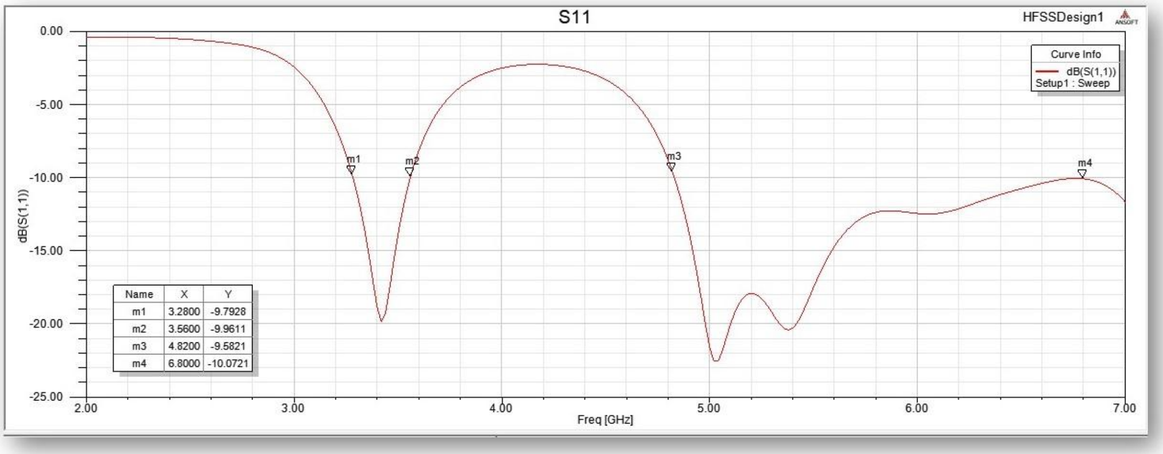


FIGURE 6: Simulated return loss curve of proposed Antenna

The E-plane and H-plane has also been shown. The E-plane is bi-lobed in nature keeping axial angle constant and varying the equatorial angle whereas the H-Plane is circular for a constant equatorial angle and varying axial angle. We can also visualize the 3-D radiation pattern where the areas in red represent directions having higher antenna gain as compared to area having green color. The areas having blue color have no directivity in the direction indicated.

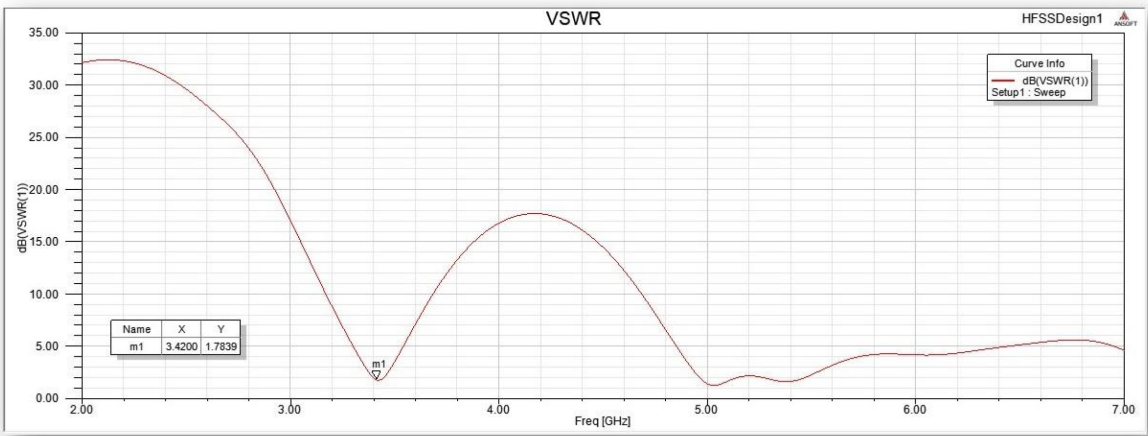


FIGURE 7: VSWR (Voltage Standing Wave Ratio)

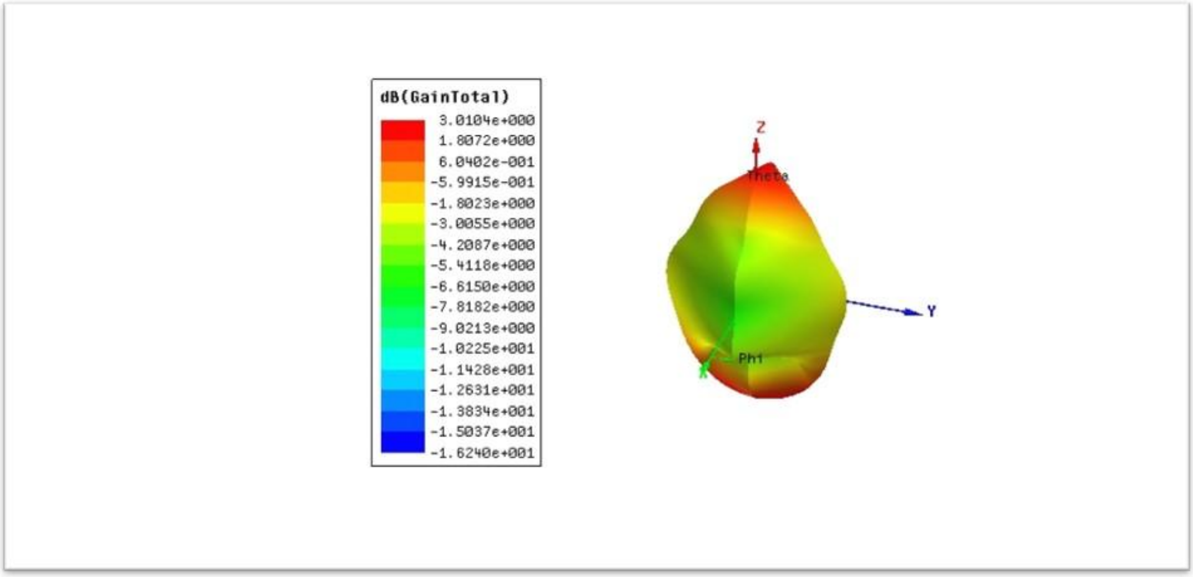


FIGURE 8: 3D Gain plot

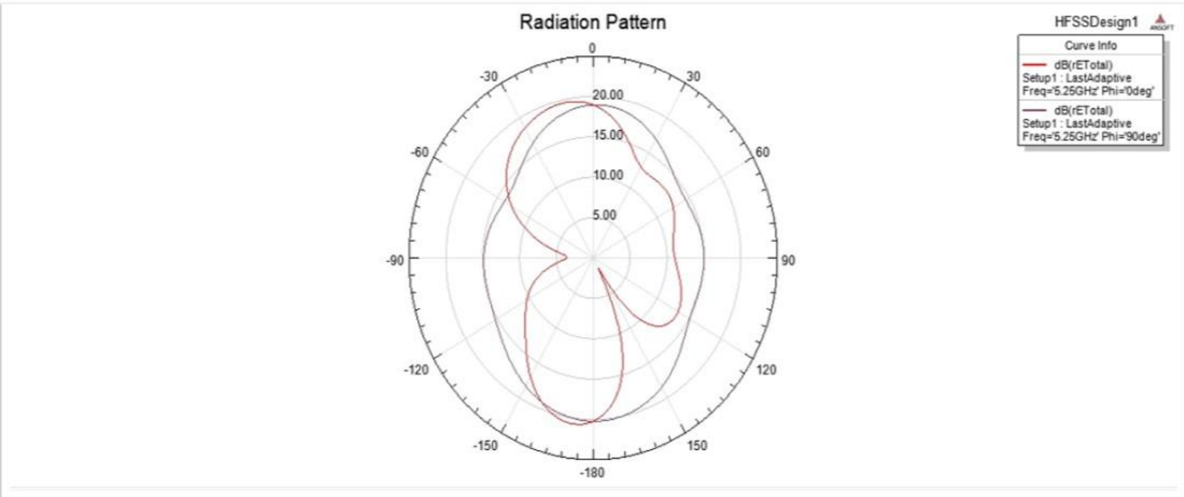


FIGURE 9: 2D Radiation Pattern

3.2 CONCLUSION

In this article, a compact, high-gain and dual-band MPA formed with a pair of inverted L-shaped patches and -shaped ground plane is presented that is suitable for WLAN/MIMO/WiMAX/ AMSAT/WAVE and other long-distance communication applications. The frequency bands with return loss below 210 dB cover 3.34–3.54 and 4.90–6.26 GHz with maximum gain values of 6.1 and 8.0 dB in the lower and higher frequency bands, respectively, thus making the proposed antenna appropriate for high-gain applications. The microstrip line feeding method enables direct feeding of the structure without using complicated impedance transformer or microstrip taper. The fabricated prototype on measurement shows reasonable impedance band widths of around 200 MHz (3.34–3.54 GHz) and 1.36 GHz (4.90–6.26 GHz) in two operating bands. Slight discrepancies between simulated and measured results are observed which may be mainly due to errors in fabrication process and possible presence of interference and noise. In this specific antenna struc ture, DGS has been incorporated which is actually responsible for the wide impedance bandwidth of 24% from 4.90 to 6.26 GHz. Taken as a whole, the performance of the antenna meets the desired requirements in terms of return loss, high gain, and VSWR at the two operating frequencies. From this article, it can be concluded that the performance of the micro strip antenna depends heavily on the dimensions of the inverted L-shaped patches and DGS been used. The type, thickness, and dielectric constant of substrate also contribute in the antenna performance. The proposed antenna production costs are reduced because of using a FR-4 substrate. It is seen that the proposed antenna having simple structure achieved very good perform ance and can be constructed with a lower cost. Hence, the pro posed dual-band design will meet the requirements of various wireless communication standards with smaller size and can be easily integrated to microwave circuits for practical wireless applications.

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