A COMPACT DUAL BAND MICROSTRIP PATCH ANTENNA WITH GAIN ENHANCEMENT TECHNIQUE FOR X BAND APPLICATIONS

A Thesis
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A Thesis submitted to the Electrical and Electronic Engineering Department of the Engineering Faculty, **Port City International University** in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

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DECLARATION

This is to certify that this thesis is my original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this thesis has been properly acknowledged.

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APPROVAL

The Thesis titled **"A COMPACT DUAL BAND MICROSTRIP PATCH ANTENNA WITH GAIN ENHANCEMENT TECHNIQUE FOR X BAND APPLICATIONS"** has been submitted to the following respected members of the Board of Examiners of the department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Electrical and Electronic Engineering by the following student and has been accepted as satisfactory.

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MD. AMRANUL HAQUE
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TABLE OF CONTENTS

List of Figures

List of Table

ABSTRACT

In this study, a gain enhancement technique is focused on dual frequencies tree-shaped Microstrip patch antenna (MPA) for X band applications. The antenna is a tree-shaped patch with a stripline around the shape. Multiple dielectric substrate layers have been used to increase the gain in this proposed antenna. This antenna has three substrates where materials are FR4 as “substrate 1” and “substrate 3” and Polyimide as “substrate 2”. Polyimide dielectric substrate 2 is sandwiched between FR4 dielectric “substrate 1” and FR4 dielectric “substrate 3”. Considering the X band satellite applications, the small size of antenna has been used to overcome the problem of narrow bandwidth and low gain. The overall dimension of the antenna is 18 mm $\times$ 16 mm $\times$ 2.45 mm. The 10-dB impedance bandwidths and gains are achieved 184 MHz and 0.38 dBi at lower operating frequency and 420 MHz and 3 dBi at higher operating frequency, respectively. This antenna has been designed and simulated in CST Microwave Studio Suite Software. The simulation shows the impressive result which is utilized for x band (8-12) GHz application.

CHAPTER 1

INTRODUCTION

1.1 Introduction

A Microstrip antenna consist of a radiating patch, substrate and ground. Where substrate is situated between patch and ground. The patch is made of conductor materials like copper, silver, gold, aluminum etc. The ground also made of a same material that are used in patch. While the dielectric material that we used in substrate it varies the lot of parameters of antenna such as- return loss, vswr, input impedance, farfield result etc. The shape of a radiating patch will be rectangular, square, circular, thin strip (dipole), elliptical or any other configuration [1].

Antenna's for satellite application has been playing a vital role for communications, navigations, broadcasting, weather forecasting etc. Still now satellite applications is an ongoing project for demand of modern technology. No doubt that satellite communication application system has essential activates for mandkind. Microstrip patch antenna (MPA) is lightwight, low profile, planner, rugged, low cost, fabrication friendly etc. which can be designed for a dual or multi-frequency operation. MPA can be integrated with circuit element which is suitable for satellite applications [2].

There are so many frequency band for satellite applications. Such as L band (1-2 GHz) which is used in satellite mobile phones and Global positioning systems, C band (4-8 GHz) which is primary used for satellite communications and for satellite TV networks, X band (8-12 GHz) which is initially used for the military purposes , Ku band (12-18 GHz) which is used for mainly direct broadcast satellite service, ka band(26-40 GHz) which is used for Communications satellites and for close-range targeting radars on military aircraft. [3].

The X-band (8-12 GHz) has been assigned merely for military, naval and governmental use. X-band radar is requisite for naval operations including the tracking and searching of surface targets, while X-band communication antenna systems provide email and internet access for operational and crew use. [3].

Previously many researches have been done under satellite application by the researchers. A caterpillar shaped microstrip patch antenna design for S, Ku and K band applications in [4]. A high gain optically transperent microstrip patch antenna reported for K band applications in [5]. A patch antenna loaded with notches and slit has been designed for dual Ku band in [6]. A coaxial feed adidas logo shaped microstrip patch antenna designed for multi band satellite applications in [7]. In [8] a microstrip antenna of defected patch and ground design is used to achieve wide Ku band applications. A shorted pin single layer dual band patch antenna designed for satellite applications in [9]. A rectangular microstrip patch antenna with spiral slot discovered to cover 79% of Ku band in [10].

There are several techniques has been investigated to increase the gain, bandwidth and efficiency by some researcher like using multiple dielectric substrate layers, meta-material, partial substrate methods and using resonator etc. [11-16]. There are several ways to increase the gain of an antenna. Such as, better quality conductor and the good dielectric substrate can increase the gain in microstrip antenna. Gain also can be increased by extending the substrate area also [14-16].

In this paper, a tree shape Microstrip patch antenna (MPA) has been proposed for dual bands applications. The antenna consist of three substrates (two FR4 and one Polyimide), patch and ground. The tree shaped patch is surrounded by a strip-line. The tree shaped patch is connected with a 50 ohm microstrip feed line. Multiple dielectric substrate has been used to increase the gain and bandwidth in this article. Satifactory gain and efficiency have been achieved in the operating bands though antenna size is very small.

Here, a microstrip patch antenna is designed at X-band with the good return loss and worked as a linear polarization. With the help of a CST MICROWAVE STUDIO SUITE we simulated the designed antenna and determined the value of S-Parameter, VSWR, Surface Current, Farfield region etc.

1.2 Objectives

- To design a Microstrip Patch antenna for X band applications
- To keep the frequency range in X band (8-12GHz)
- To increase the bandwidth and gain
- To add multiple dielectric substrates
- Performance analysis of the antenna
- Maintain the bandwidth and gain of the antenna

1.3 Motivation

In recent time, our country is developing in the communication system. In every developed country, the communication system for military purposes is very advanced but our country is that level in communication system. And I always obsessed with military tracking system, searching for surface targets and so on. So, I have interest to know about the wireless communication sector such as- Satellite communication system, Radar communication system, WiMax and LTE etc. I was design an antenna during my course. So, I choose this thesis because it will be easier for me to understand my work and also to know more about this sector.

CHAPTER 2

THEORETICAL BACKGROUND

2.1 Introduction

Operational frequency, bandwidth, front-to-back ratio, radiation property, vswr, input impedance, efficiency, surface current, farfield is described in this chapter.

2.1.1 Operational Frequency

The operational frequency of this antenna is 8.067 GHz and 11.226 GHz which is in X-band with a frequency range of 8 to 12 GHz.

2.1.2 Radiation Property

A proper radiation pattern is expected from the antenna. It is necessary to get correct lobe values. The far field must be calculated as radiation property must not change in the whole frequency band.

2.1.3 Front-To-Back-Ratio

The front to back ratio is a parameter used in describing directional radiation patterns for antennas. If an antenna has a unique maximum direction, the front-to-back ratio is the ratio of the gain in the maximum direction to that in the opposite direction. This parameter is usually given in dB [7]. A high front-to-back ratio of the antenna radiation and low side and back radiation is desired to minimize the antenna coupling and interference to other microwave systems.

2.1.4 Microstrip Patch Antenna

Microstrip antenna is one of the most popular types of printed antenna. It plays a very significant role in today’s world of wireless communication systems. Microstrip antennae are very simple in construction using a conventional microstrip fabrication technique. Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate (FR4) that has a ground plane (Cu) on the other side as well.

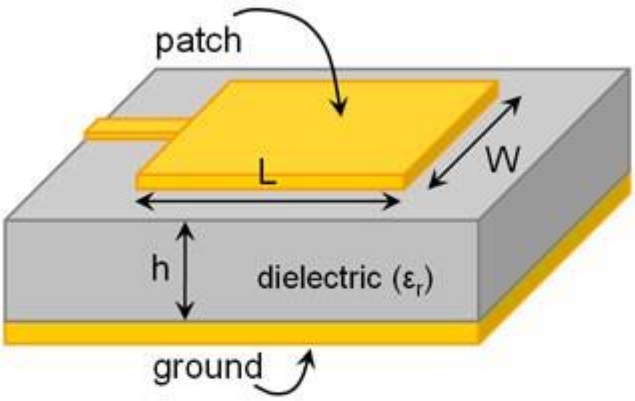

Figure 1: Microstrip Patch Antenna

The patch is generally made up of a conducting material such as copper or gold and can take any possible shape like rectangular, circular, triangular, and elliptical or some other common shape. The radiating patch and the feed lines are usually photo-etched on the dielectric substrate.

Microstrip patch antennae radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant (<6) is desirable since it provides higher efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size [1].

2.2 Advantages of Microstrip Patch Antenna

- They operate at microwave frequencies where traditional antennas are not feasible to be designed.
- This antenna type has smaller size and hence will provide small size end devices.
- The microstrip based antennas are easily etched on any PCB and will also provide easy access for troubleshooting during design and development. This is due to the fact that microstrip pattern is visible and accessible from

top. Hence they are easy to fabricate and comfortable on curved parts of the device. Hence it is easy to integrate them with MICs or MMICs.

- As the patch antennas are fed along centerline to symmetry, it minimizes excitation of other undesired modes.
- The microstrip patches of various shapes e.g. rectangular, square, triangular etc. are easily etched.
- They have lower fabrication cost and hence they can be mass manufactured.
- They are capable of supporting multiple frequency bands (dual, triple).
- They support dual polarization types viz. linear and circular both.
- They are light in weight.
- They are robust when mounted on rigid surfaces of the devices [3].

2.3 Basic Parameters

The basic parameters which are used in antenna is very much important for antenna designing. From the parameter value we can know how much suitable the antenna is and how perfectly the antenna will work. We may change our design by observing the results of parameters.

2.3.1 Radiation Pattern

The energy radiated by an antenna is represented by the Radiation pattern of the antenna. Radiation Patterns are diagrammatical representations of the distribution of radiated energy into space, as a function of direction.

The energy being radiated is represented by the patterns drawn in a particular direction. The arrows represent directions of radiation. The power when radiated from the antenna has its effect in the near and far field regions.

- Graphically, radiation can be plotted as a function of angular position and radial distance from the antenna.
- This is a mathematical function of radiation properties of the antenna represented as a function of spherical co-ordinates, E (θ, Ø) and H (θ, Ø).

2.3.2 Input Impedance

The input impedance of an electrical network is the measure of the opposition to current flow (impedance), both static resistance and dynamic reactance, into the load network being that is external to the electrical source. The input admittance (1/impedance) is a measure of the load's propensity to draw current. The source network is the portion of the network that transmits power, and the load network is the portion of the network that consumes power. If the load network were replaced by a device with impedance equal to the input impedance of the load network, the characteristics of the source-load network would be the same from the perspective of the connection point. And so, the voltage across and current through the input terminals would be identical to the original load network.

2.3.3 Directivity

The ratio of maximum radiation intensity of the subject antenna to the radiation intensity of an isotropic or reference antenna, radiating the same total power is called the directivity. An antenna radiates power, but the direction in which it radiates matters much.

Its radiation intensity is focused in a particular direction, while it is transmitting or receiving. Hence, the antenna is said to have its directivity in that particular direction.

- The ratio of radiation intensity in a given direction from an antenna to the radiation intensity averaged over all directions is termed as directivity.
- If that particular direction is not specified, then the direction, in which maximum intensity is observed, can be taken as the directivity of that antenna.
- The directivity of a non-isotropic antenna is equal to the ratio of the radiation intensity in a given direction to the radiation intensity of the isotropic source.

2.3.4 Antenna Gain

Gain of an antenna is the ratio of the radiation intensity in a given direction to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropic. Gain of an antenna takes the directivity of antenna into account along with its effective performance. If the power accepted by the antenna was radiated isotropic (In all directions), then the radiation intensity can be taken as a referential.

- The term antenna gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source.
- Gain is usually measured in dB.
- Unlike directivity, antenna gain takes the losses that occur also into account and hence focuses on the efficiency.

2.3.5 Antenna Efficiency

Antenna Efficiency is the ratio of the radiated power of the antenna to the input power accepted by the antenna. An Antenna is meant to radiate power given at its input, with minimum losses. The efficiency of an antenna explains how much an antenna is able to deliver its output effectively with minimum losses in the transmission line. This is otherwise called as Radiation Efficiency Factor of the antenna.

2.3.6 Polarization

An Antenna can be polarized depending upon its requirement. It can be linearly polarized or circularly polarized. The type of antenna polarization decides the pattern of the beam and polarization at the reception or transmission.

When a wave is transmitted or received, it may be done in different directions. The linear polarization of the antenna helps in maintaining the wave in a particular direction, avoiding all the other directions. Though this linear polarization is used, the electric field vector stays in the same plane. Hence, we use this linear polarization to improve the directivity of the antenna.

When a wave is circularly polarized, the electric field vector appears to be rotated with all its components losing orientation. The mode of rotation may also be different at times. However, by using circular polarization, the effect of multi-path gets reduced and hence it is used in satellite communications such as GPS.

Horizontal polarization makes the wave weak, as the reflections from the earth surface affect it. They are usually weak at low frequencies below 1GHz. Horizontal polarization is used in the transmission of TV signals to achieve a better signal to noise ratio.

The low frequency vertically polarized waves are advantageous for ground wave transmission. These are not affected by the surface reflections like the horizontally polarized ones. Hence, the vertical polarization is used for mobile communications.

Each type of polarization has its own advantages and disadvantages. A RF system designer is free to select the type of polarization, according to the system requirements.

2.3.7 Beam Width and Side Lobes

Beam width is the aperture angle from where most of the power is radiated. The two main considerations of this beam width are Half Power Beam Width (HPBW) and First Null Beam Width (FNBW).

2.3.8 Half-Power Beam Width

The angular separation, in which the magnitude of the radiation pattern decreases by 50% (or -3dB) from the peak of the main beam, is the Half Power Beam Width. Beam width is the area where most of the power is radiated, which is the peak power. Half power beam width is the angle in which relative power is more than 50% of the peak power, in the effective radiated field of the antenna.

2.3.9 First Null Beam Width

The angular span between the first patterns null adjacent to the main lobe, is called as the First Null Beam Width. FNBW is the angular separation, quoted away from the main beam, which is drawn between the null points of radiation pattern, on its major lobe. The main beam is the region around the direction of maximum radiation.

The side lobes are smaller beams that are away from the main beam. These side lobes are usually radiation in undesired directions which can never be completely eliminated.

2.3.10 Return Loss

Return loss is the loss of power in the signal reflected by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in decibels (dB). Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss.

2.3.11 Bandwidth

Bandwidth is a fundamental antenna parameter. Bandwidth presents the range of frequencies over which the antenna can properly radiate or receive energy. Often, the desired bandwidth is one of the determining parameters used to decide upon an antenna. Many antenna types have very narrow bandwidths and cannot be used for wideband operation.

2.3.12 Farfield

The field, which is far from the antenna, is called as far-field. It is also called as radiation field, as the radiation effect is high in this area. Many of the antenna parameters along with the antenna directivity and the radiation pattern of the antenna are considered in this region only. In this region, the radiation pattern does not change shape with distance (although the fields still die off as 1/R, the power density dies off as 1/R^2). Also, this region is dominated by radiated fields, with the E- and H-fields orthogonal to each other and the direction of propagation as with plane waves.

2.3.13 E-Field

Electromagnetic waves are made up of Electric Fields (Known as E-Field) and magnetic fields (Known as H-Field). The E-field at a point in space is a measure of how strong the force would be on a unit point charge (a small sphere with an electric charge of 1 Coulomb on it).

Hence, the units of the E-field are Newton's/Coulomb [N/C]. These units are equivalent to Volts/meter [V/m], which is what the E-field is commonly quoted in (for instance, 10 V/m). The E-field is a vector quantity, this means at every point in space it has a magnitude and a direction.

2.3.14 H-Field

Electromagnetic waves are made up of Electric Fields and Magnetic fields. The H-field is a vector quantity has a magnitude and direction and is measured in Amps/Meter [A/m]. H-field wraps around a wire of moving charge. H-fields are associated with moving electric charges.

There are no isolated magnetic charges, so H-field can't be defined as a force per unit magnetic charge in the way an E-field can be defined. Magnetic dipoles do exist (magnets) which have a positive and negative end (or North and South). The magnetic field lines travel away from the North side and terminate on the south side.

2.3.15 Voltage Standing Wave Ratio (VSWR)

The ratio of the maximum voltage to the minimum voltage in a standing wave is known as Voltage Standing Wave Ratio. If the impedance of the antenna, the transmission line and the circuitry do not match with each other, then the power will not be radiated effectively. Instead, some of the power is reflected back.

The key features are −

- The term, which indicates the impedance mismatch is VSWR.
- VSWR stands for Voltage Standing Wave Ratio. It is also called as SWR.
- The higher the impedance mismatch, the higher will be the value of VSWR.
- The ideal value of VSWR should be 1:1 for effective radiation.
- Reflected power is the power wasted out of the forward power. Both reflected power and VSWR indicate the same thing.

2.3.16 Resonant

Resonant is a phenomenon in which a vibrating system or external force drives another system to oscillate with greater amplitude at specific frequencies.

Frequencies at which the response amplitude is a relative maximum are known as the system's resonant frequencies or resonance frequencies. At resonant frequencies, small periodic driving forces have the ability to produce large amplitude oscillations, due to the storage of vibrational energy.

2.4 Summary

It is easier to work on antenna having the knowledge of antenna parameters. This chapter contains the basic idea of antenna parameters. Introducing with basic parameters of antenna helps to design more efficient antenna.

CHAPTER 03

Antenna Design and Software

3.1 Introduction

Considering high penetration property and fine range of resolution, it is mandatory to design the antenna such a precise way that fulfills the both criteria with a least size as well. Lower operating frequency provides high penetration which is directly proportional to the width of the antenna that depends on the effective wavelength as well. Theoretically, antenna with such properties refers us such a large antenna size to construct which is a major obstacle for the medical diagnosis and imaging array so far. So, beside the performance, antenna size is also an important thing that to be considered as well.

3.2 Antenna Designing Software

In order to design high frequency (HF) devices such as antennas, filters, couplers, planner and multi-layer structures, there are some well renowned software available. Depending on various applications, analysis mechanism, user friendly interface CST MICROWAVE STUDIO® (CST® MWS®) is used in this thesis.

3.2.1 CST MICROWAVE STUDIO® (CST® MWS®)

CST MICROWAVE STUDIO® (CST® MWS®) is a specialist tool for the 3D EM simulation of high frequency components. CST® MWS® enables the fast and accurate analysis of high frequency (HF) devices such as antennae, filters, couplers, planar and multi-layer structures and SI and EMC effects' software makes available Time Domain and Frequency Domain solvers, CST® MWS® offers further solver modules for specific applications. Filters for the import of specific CAD files and the extraction of SPICE parameters enhance design possibilities and save time.

3.3 Antenna Design Procedure

Using CST® MWS®, the antenna is designed and simulated in free space first and placed on human phantom model for further simulation and result.

CHAPTER 4

ANTENNA DESIGN AND PERFORMANCE ANALYSIS

4.1 Antenna Design

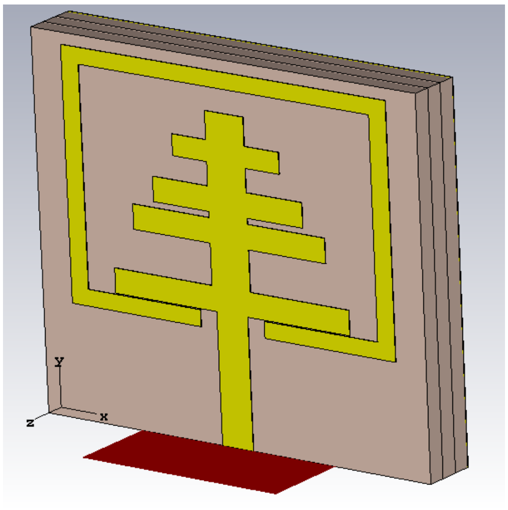

Figure 2: Prospective view of antenna

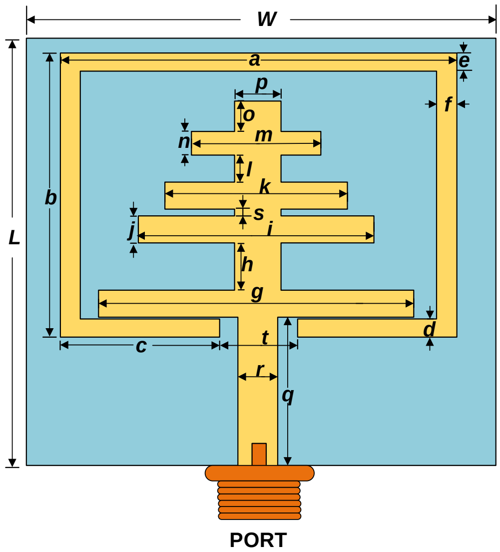

Figure 3: Front view of antenna

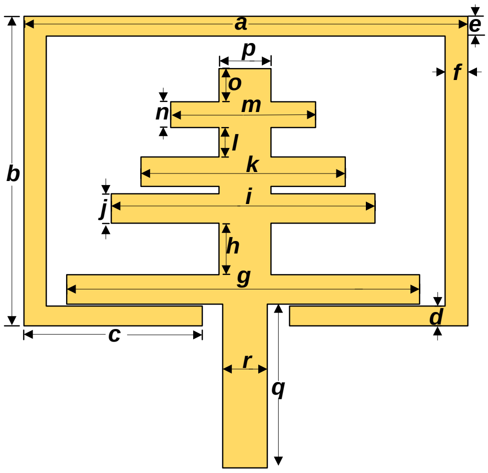

Figure 4: Radiating patch of antenna

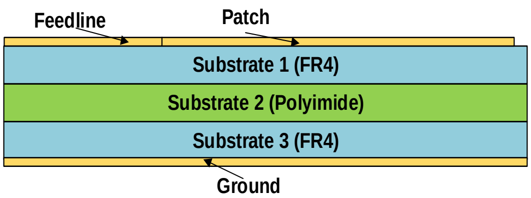

Figure 5: Side view of antenna

Figure 2 represents the prospective view of the proposed antenna. This antenna's patch is designed like Chrismas tree shape with rectangular strip line and plane ground. The Chrismas tree shape has four branches. Each one has been designed one after one to improve the result. The patch and ground are designed with the material copper having a thickness of 0.025mm. The antenna has three substrates. These are two FR4 substrate and one Polyimide substrate having a dielectric constant of 4.3 and 3.5, respectively. The thickness of each substrate is 0.8 mm. A different substrate is used for improving gain. The overall size of the antenna is *18* mm $\times$ 16 mm $\times$ 2.45 mm. This antenna is fed by a microstrip feed line.

4.2 Antenna Parameters

The parameters which are used to design the antenna are given below:

Parameter	Dimension(mm)	Parameter	Dimension (mm)
W	18	*i*	9
L	16	*j*	1.5
a	15.2	*k*	7
b	10.7	*l*	1
c	6.1	*m*	5
d	0.7	*n*	0.9
e	0.7	*o*	1.2
f	0.8	*p*	1.8
g	11	*q*	5.55
h	1.75	*r*	1.45
s	0.25	*t*	3

Table 1: Antenna Parameters

4.3 Performance Analysis

After the completion of geometric design of the antenna in CST® MWS®, the simulation procedure gave some basic parameter calculation which are given below.

4.4 Design Stages of Proposed Antenna

Figure 6, 7 and 8 represent the cross-section view of the different design stage. Figure 9 shows the corresponding simulation result of S_{11} and Figure 13 shows the parametric change of gain.

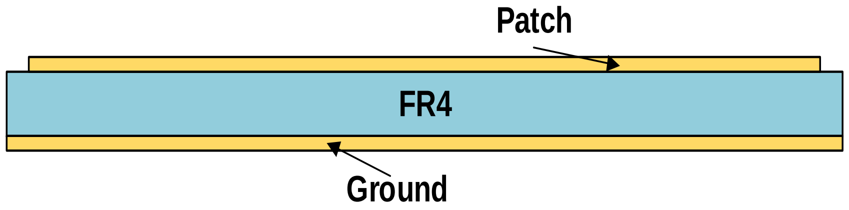

Figure 6: Cross-section view with substrate 1 of the antenna

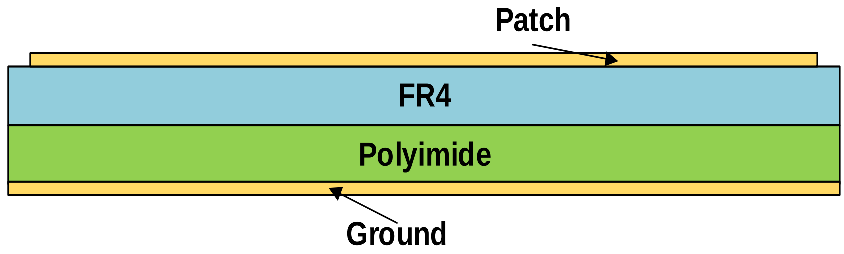

Figure 7: Cross-section view with substrate 2 of the antenna

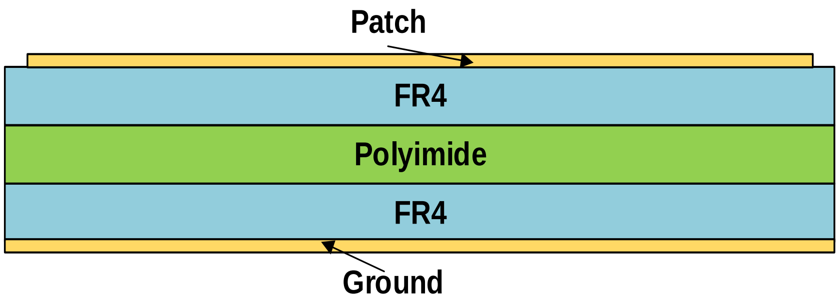

Figure 8: Cross-section view with substrate 3 of the antenna

With the one substrate (FR4) at design stage 1, Figure 9 shows impressive reflection co-efficient but gain is very low. The antenna has return loss of −51.50 dB & −44.30 dB at resonated frequencies at 8.07 GHz & 11.87 GHz, respectively. But the gain is attained -5.34 dBi and -0.87 dBi. Therefore gain enhancement technique has been applied.

For adding a new substrate (Polyimide), along the previous substrate. It is noticed that there is a noticeable improvement in gain as shown in Figure 13. The antenna has achieved return loss of −26.02 dB & −17.96 dB at resonated frequencies at 8.27 GHz & 9.57 GHz, respectively. The gain is improved to −1.24 dBi and −12.48 dBi. Still the gain is not acceptable for practical applications. Therefore, for reaching the intending result, gain improvement technique has been applied again in the previous way which is mentioned. This time, an FR4 dielectric substrate is designed as the third substrate with the same height again. At this stage, the resonance shifted to the previous frequency and increase the gain which is suitable for x band applications. After some optimization, the reflection coefficient and gain increased simultaneously. The reflection coefficient is achieved −21.81 dB and −30.86 dB at resonated frequencies 8.06 GHz and 11.22 GHz, respectively.

4.4.1 S-Parameters for Substrate 1, 2 and 3

According to Substrate, S-Parameters show some changes.

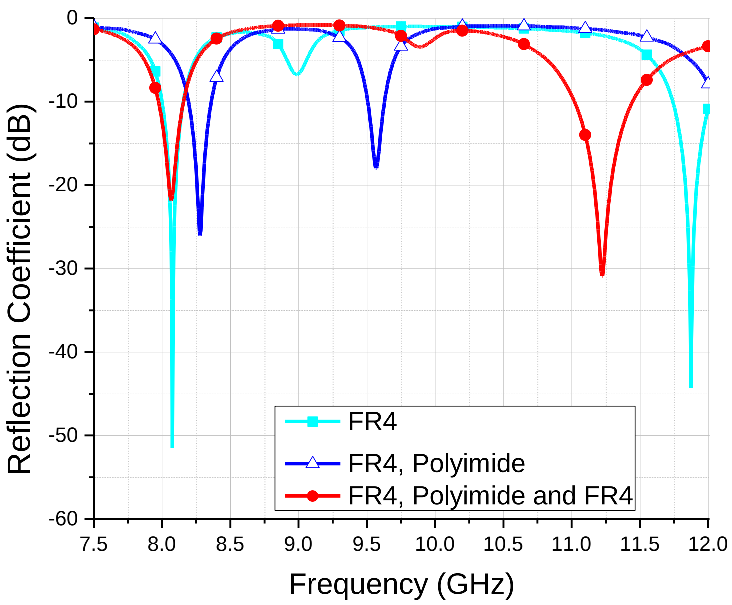

Figure 9: Reflection Coefficient for Substrate 1, 2, 3

Here, frequency and return loss both are changing according to different substrates. Adding second substrate, it shifted the frequency to the right side and decrease the return loss while adding third substrate, it shifted the frequency to previous position and increase the return loss.

4.4.1.1 Reflection Coefficient Result for Different value of *f*

Figure 10 shows the impact of the width (*f*) along the major axis of the stripline on the reflection coefficient. The resonant frequencies move to the lower frequency and increase the S_{11} when the width of *f* is 1.2 mm. The resonant frequencies move to the higher frequency and decrease the S_{11} when the width of *f* is 0.2mm.

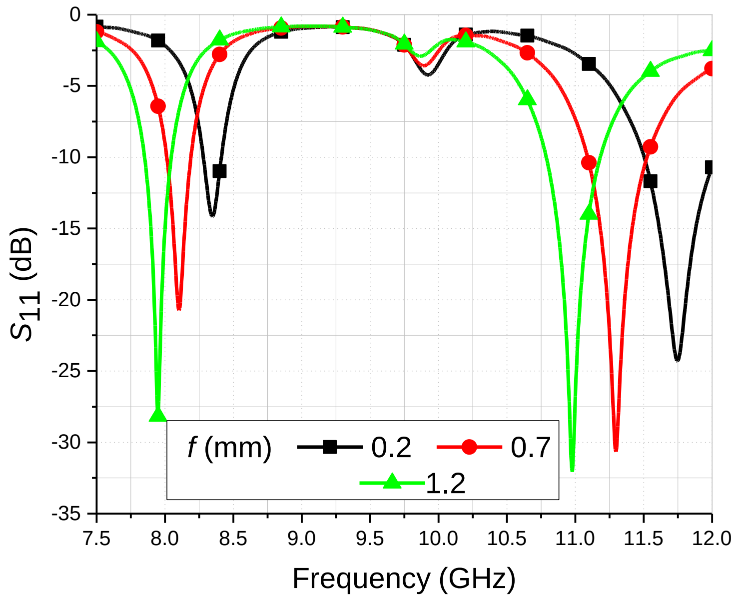

Fig. 10: Reflection coefficient result for the different values of *f*

4.4.2 Efficiency for Substrate 1, 2 and 3

According to substrate1, 2 and 3 efficiency show some changes.

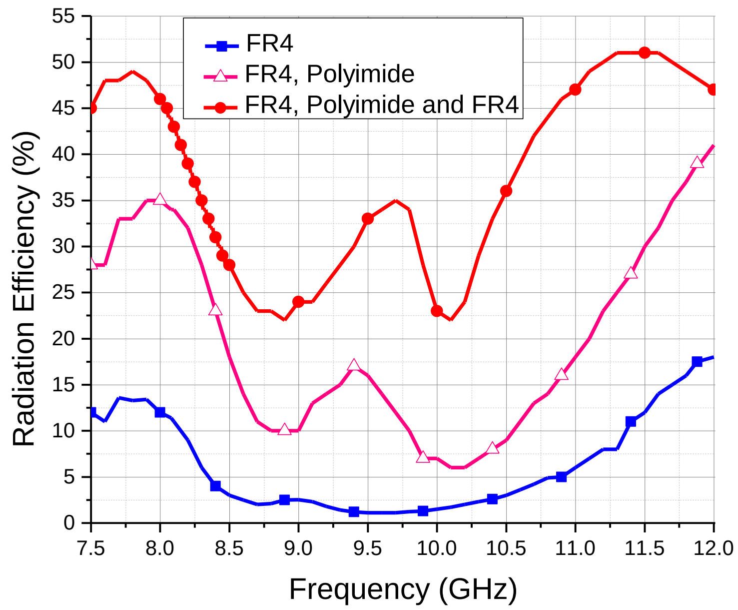

Figure 11: Radiation Efficiencies for Substrate 1, 2, 3

Figure 11 and Figure 12 show the result of the efficiencies of the designed antenna. The antenna achieved 44% and 52% of radiation efficiency and total efficiency, respectively. Moreover, the total efficiency is the same as radiation efficiency at resonating frequencies.

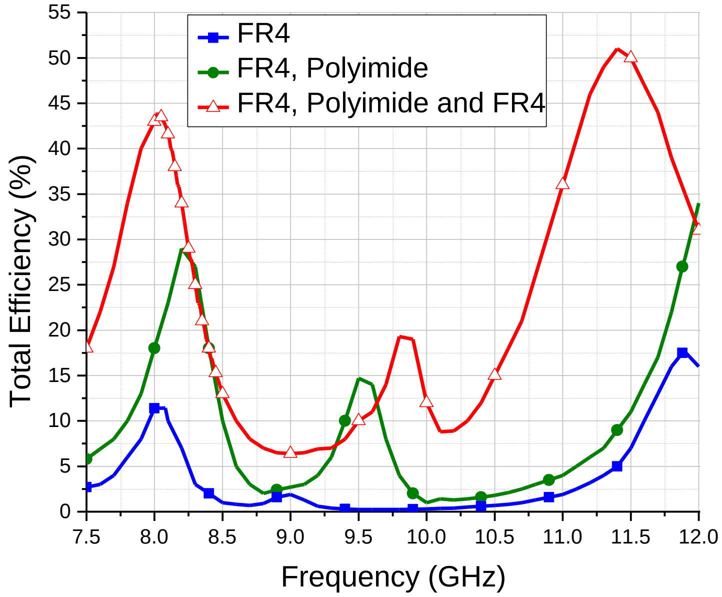

Figure 12: Total efficiencies for Substrate 1, 2, 3

4.4.3 Gain for Substrate 1, 2 and 3

According to Substrate, gain show some changes.

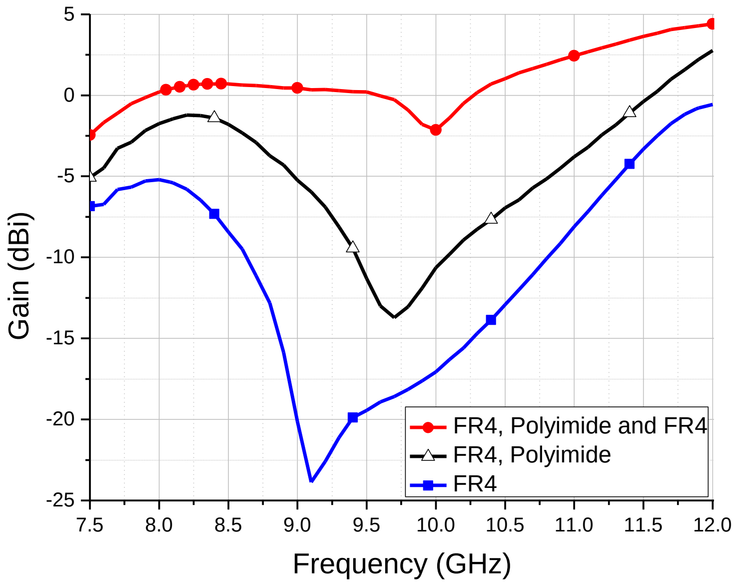

Figure 13: Gain for Substrate 1, 2, 3

Adding second substrate, it increase the gain but which is not acceptable for practical applications while adding third substrate, it increase the gain in suitable position which is acceptable for practical applications.

4.5 S-Parameters

S-Parameter which is known as reflection co-efficient shows the amount of power radiated and reflected from the antenna. For low dielectric loss and high-power transmission rate, waveguide port was selected rather than others.

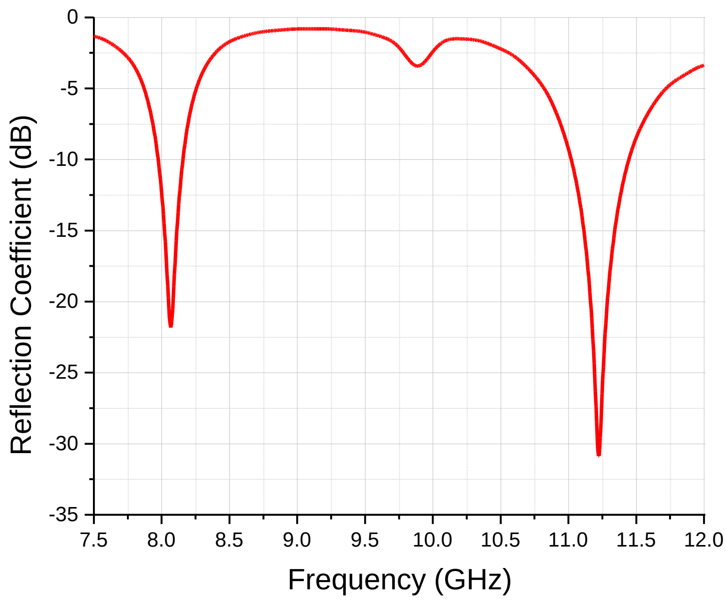

Figure 14: Simulated S_{11} of the antenna

Figure 14 demonstrates the reflection coefficient. The antenna resonates on dual frequencies within the band of interest. The resonating frequencies are obtained at 8.06 GHz and 11.22 GHz having reflection coefficient of -21.84 dB and-30.86 dB, respectively. Which is in between X-band (8 to 12 GHz). Here, designed antenna gives a good return loss.

4.6 Bandwidth

Bandwidth represents the range of a frequency spectrum. 10-dB impedance bandwidth is found 184 MHz (7.97 GHz - 8.15 GHz) and 420 MHz (11.02 GHz - 11.44 GHz), correspondingly. Figure 15 shows this result.

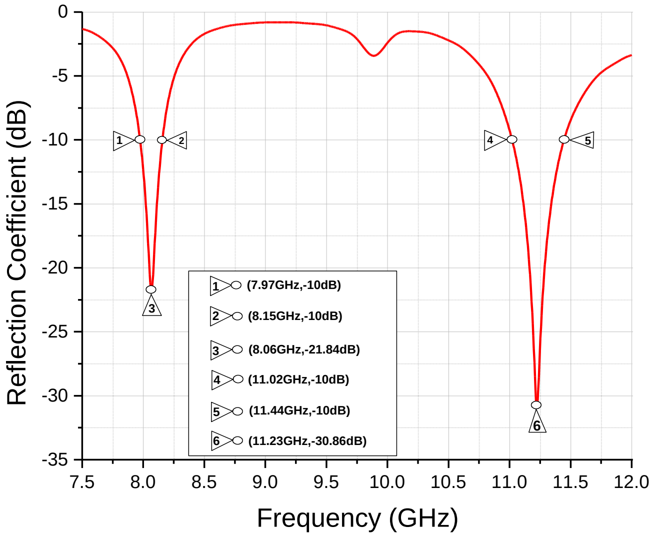

Figure 15: Bandwidth of antenna

4.7 Input Impedance

The Input Impedance of an amplifier defines its input characteristics with regards to current and voltage looking into an amplifiers input terminals [11].

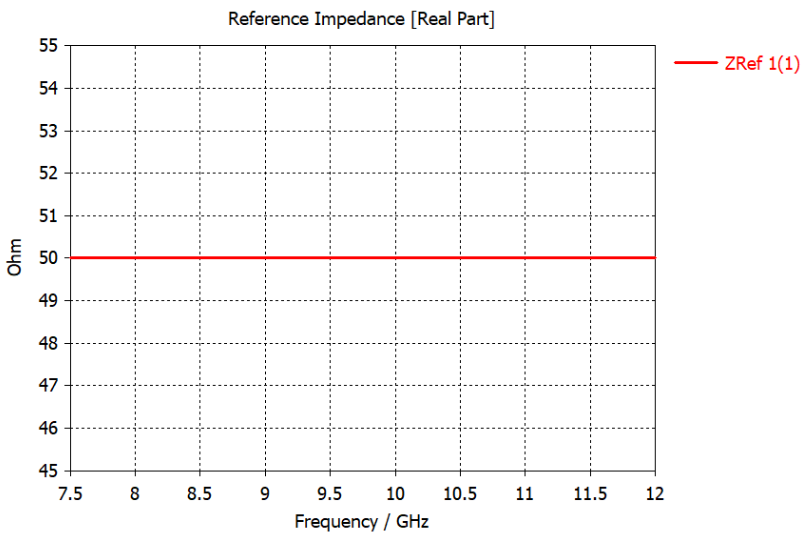

Figure16: Input Impedance of the antenna

Here, input impedance of this designed antenna is 50 ohm which is meet the requirement of the antenna desired value.

4.8 VSWR

VSWR is such a parameter which shows the impedance matching quality of the antenna. Impedance matching with transmission line is an important property that an antenna must have. VSWR must be less than 2 and not equal to 1 for suitable output. In this designed VSWR is 1.175 and 1.059.

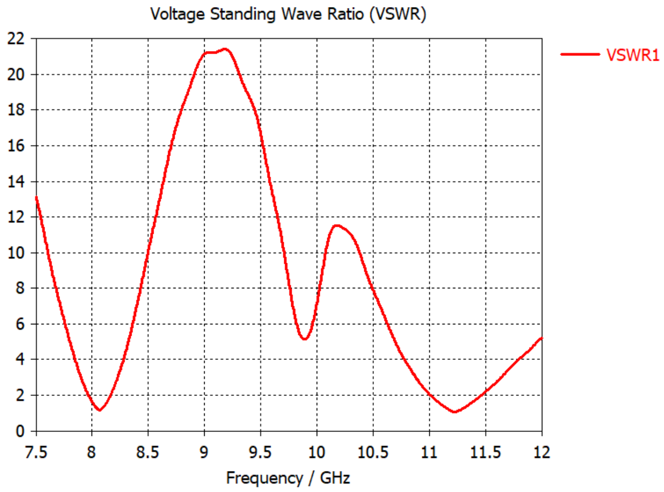

Figure 17: VSWR

4.9 Efficiency

Efficiency should be greater than 50%, if it less than this that means this antenna have more loss than gain. Here, both radiated and total efficiency is 44% and 52% at 8.067 GHz and 11.226 GHz, respectively.

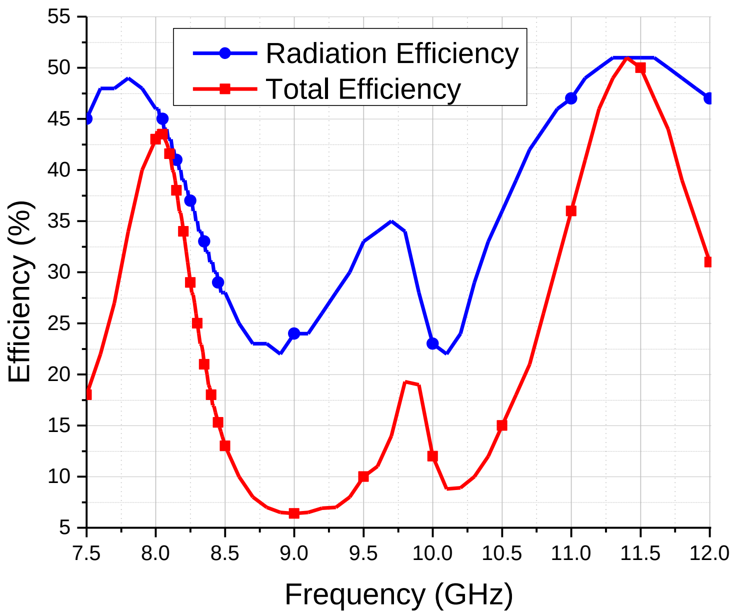

Figure 18: Efficiency of the antenna

4.10 Surface Current

Due to electromagnetic field there is induces a current. In surface current it shows the direction of the current that which way it flows from the feedline to the antenna.

The surface current distributions of the antenna at 8.06 GHz and 11.22 GHz is studied, and the results are shown in Figure 19 and 20, respectively. When the antenna is excited, it is noticed that the maximum current is around the rectangular strip line. Figure 19 shows that there are four null points which is the second fundamental mode for the antenna. Figure 20 shows that there are six null points which is the third fundamental mode for the antenna.

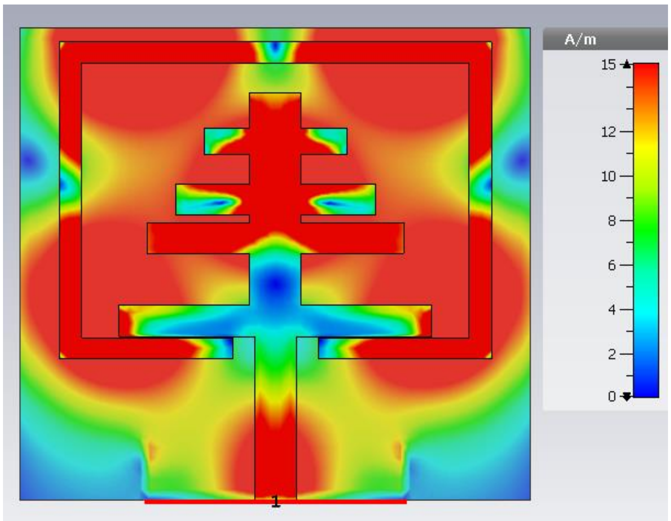

Figure 19 : surface current at 8.067GHz

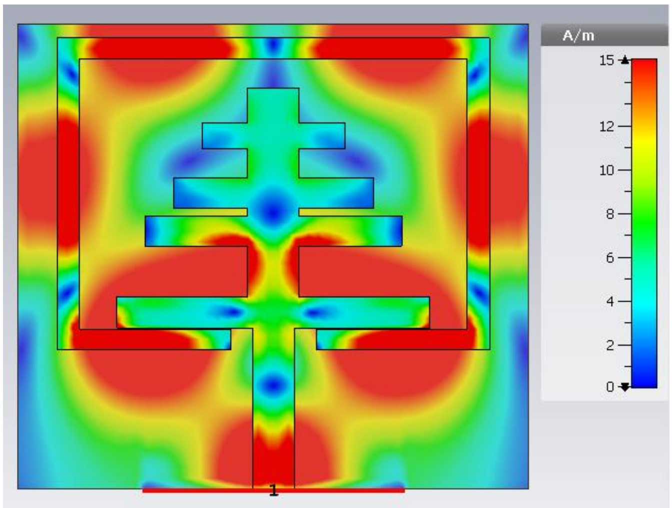

Figure 20: Surface Current at 11.227 GHz

4.11 Gain

Figure 21 represents the gain of the proposed antenna. Basically, gain indicates how much power is transmitted in the direction to an isotropic region. The gain is achieved 0.38 dBi and 3 dBi at 8.06 GHz and 11.22 GHz, respectively. . Which should be positive and greater than 1 is considered as a good result.

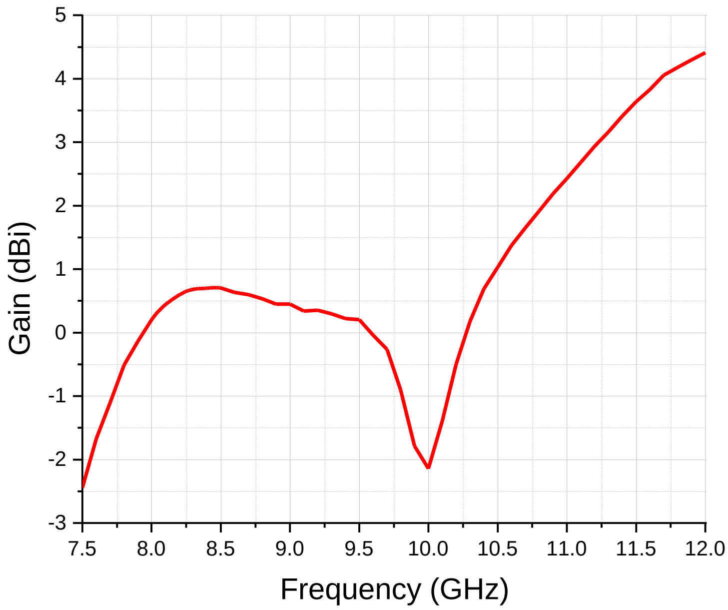

Figure 21: Gain of the antenna

4.12 Far-Field Radiation Pattern

Basically, it indicates the direction of the radiated power to the antenna.

The polarization senses are cross-polarization and co-polarization in the linear directional radiation pattern. Far-Field radiation is taken at 8.067 GHz and 11.226 GHz frequency. Figure 22 and Figure 23 show the radiation pattern of linear polarization at resonating frequencies of the proposed antenna. The antenna has maximum radiation in theta = 0° and phi = 0° in the both bands. Moreover, the cross-polarization level is more that 40 dB in both 10-dB impedance bands. Which are described below

4.12.1 Far-Field Radiation Pattern at 8.067

From Figure 22 it can also be observed that the cross-polar is -111.54 dB and co-polar is 0.38 dBi.

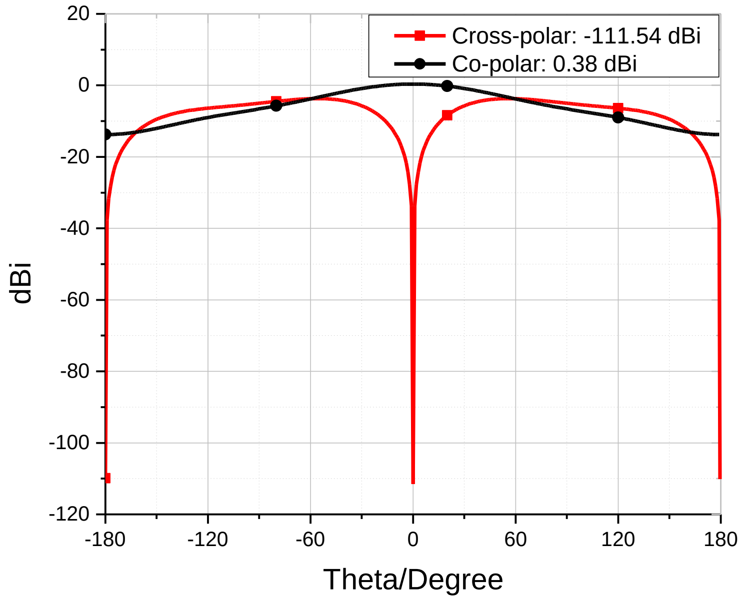

Figure 22: Radiation pattern at 8.067 GHz

4.12.2 Far-Field Radiation Pattern at 11.227 GHz

From Figure 23 it can also be observed that the cross-polar is -104.92 dB and co-polar is 3 dBi.

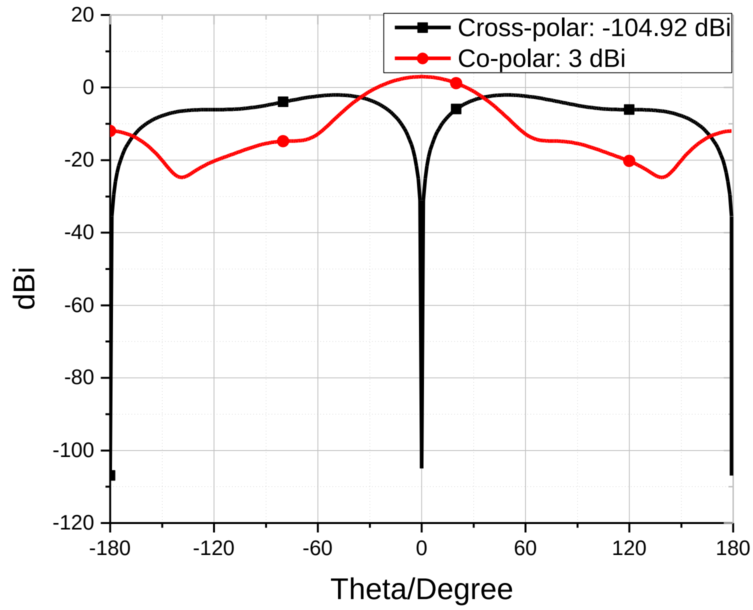

Figure 23: Radiation pattern at 11.226 GHz

4.13 Comparison Table between Proposed Antenna and Previous Work

A comparison between proposed antenna and previous works has been shown in table 2. The proposed antenna has comparatively smaller size than other mentions work and also satisfactory result comparing with others.

Ref. No.	Size (m^2)	10-dB impedance bandwidth	Gain (dBi)	Efficiency		
[17]	20×20	30 MHz , 110 MHz	3.2, 1.2	22%, 75%		
[18]	38×38	500 MHz	2.8	68%		
[19]	47×35	460 MHz	2.3	-----------		
[20]	10.12×8.7	490 MHz	2.6	-----------		
[21]	77×36	All are around 200 MHz	1.7, 1.1, 2.3	-----------		
This work	18×16	184 MHz 420 GHz	0.38, 3	44%, 52%		

Table 2: Comparison table between proposed antenna and previous works

CHAPTER 5

FUTURE WORK AND CONCLUSION

5.1 Future Work

The designed antenna can be improved in future by doing further research. It can be improved in several aspects which are described below.

5.1.1 Reduction of Antenna Size

Antenna size can be reduced for more fruitful use. By reducing the size of the antenna fabrication cost will be reduced.

5.1.2 Better Return Loss

By changing parameters, making more slots in ground and patch; there is also a possibility to get better return loss from the recent result.

5.1.3 Increase in Gain

Antenna gain can be increased by changing in patch and ground. By increasing the gain antenna performance will be better than the recent result.

5.1.4 Fabrication

Designed antenna is now perfect for fabrication. By fabricating this designed anyone will be able to use it in practical life.

5.2 Conclusion

In this study, a dual-band MPA is presented and demonstrated the result for X band applications. Multiple substrates are added for improving gain. Return loss -21.84 dB and -30.86 dB, gain 0.38 dBi and 3 dBi, bandwidth 184 MHz and 420 MHz is obtained at resonant frequencies 8.06 GHz and 11.22 GHz, respectively. Moreover, the cross-polarization level is more than 40 dB in both 10-dB impedance bands. The simulation result is quite satisfactory to work in the desired bands. These radiation patterns, impressive gain, efficiency is made the antenna quite compatible for X band applications. This advocate that the antenna can be used in satellite communications, aircraft communication and radar communications. Improving the lower band frequency, improve the efficiencies and find out the more effective value of this proposed antenna will be future modifications of the research.

Initially the antenna prototype is designed at free space using CST MW studio where copper used as radiating material, two FR4 lossy and one polyimide as substrate. Performance analysis is shown here using important antenna parameters like return loss, farfield, radiation pattern, vswr, efficiency and surface current.

Overall achievements that can be drawn from this antenna design and measurement are:

- Enormous bandwidth and good return loss that refers to a wide range of performance window
- Good efficiency compared with low input power and small size of the antenna.
- Good VSWR result meet the requirement of that result.

In Conclusion, fulfilling the criterion of X-band antenna, this proposed design shows promising performance for the practical implementation. It gives well balanced performance considering its overall size and design. By fabricating this it can be used in practical life.

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