Design and Analysis of a Bow tie Antenna for 1GHz Application

A Thesis submitted in partial fulfillment of the requirements for the Award of Degree of
Bachelor of Science in Electrical and Electronic Engineering

By

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Certification

This is to certify that the thesis entitled, "**Design and Analysis of a Bow tie Antenna for 1GHz Application**" submitted by **Nafis Anjum Ayon (ID No:181-33-688), Md. Tareq Rahman (ID No:181-33-694)** in partial fulfillment of the requirements for the award of Bachelor of Science Degree in ELECTRICAL AND ELECTRONIC ENGINEERING at the Daffodil International university is an authentic work carried out by him under my supervision and guidance. To the best of my/our knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

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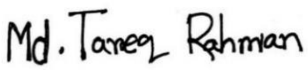

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APPROVAL

The project and thesis entitled **"Design and Analysis of a Bow tie Antenna for 1GHz Application"** submitted by **Nafis Anjum Ayon (ID No:181-33-688)** and **Md. Tareq Rahman (ID No:181-33-694)** Session: Fall 2021 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on December 2021.

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Dedicated to

Our Parents

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LIST OF ABBREVIATIONS

RMPA	Rectangular Microstrip Patch Antenna
MPA	Microstrip Patch Antenna
GHz	Giga Hertz
EM	Electro-Magnetic
GPS	Global Positioning System
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
RF	Radio Frequency
VSWR	Voltage Standing Wave Ratio
PCB	Printed Circuit Board
MP	Microstrip Patch
WiMAX	Worldwide Interoperability for Microwave Access
RFID	Radio Frequency Identification
MIMO	Multiple Input Multiple Output
MHz	Mega Hertz
NASA	National Aeronautics and Space Administration
2D	Two Dimensional

3D	Three Dimensional
Dg	Directivity Gain
Rp	Radiation Intensity for Particular Angle of Antenna
Ra	Average Radiation Intensity
Bw	Bandwidth
Fu	Upper Frequency
Fl	Lower Frequency
Fc	Center Frequency
RL	Return Loss

LIST OF SYMBOLS

λ	Wavelength
π	Pie
f	Frequency
c	Speed of light
Γ	Reflection coefficient
ρ	Magnitude coefficient
R	Resistance
L	Inductance
C	Capacitance
G	Conductance
Z0	Impedance
εr	Relative dielectric constant
ε_{reff}	Effective dielectric constant
tanδ	Loss tangent
h	Height
fr	Resonant frequency
V0	Velocity of light
$Leff$	Effective length
φ	Angle
W	Width

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ABSTRACT

In order to meet rising communications challenges in terms of size, bandwidth, and gain, newer microwave and millimeter-wave systems are in increased demand. As a result, antennas are frequently used to suit the needs of satellite communication. In satellite communication, several frequency bands are available for different uses. Microstrip Patch antennas' bandwidth and gain are continually being improved by researchers. A new optimized MPA (Bow-tie Antenna) is created using the CST Studio Suite simulation program. The suggested antenna is an inset feed partial ground MPA construction with 1 GHz, 1.5 GHz, and 3 GHz resonance frequencies with a bandwidth of 1.7 GHz. It covers the whole X-band and the lower half of the Ku band with frequencies ranging from 1 GHz to 3 GHz. The antenna will be 96 mm in width, lengths are 32 and 47.76 mm, Distance between two parts is 6 mm and angle ratio is 180,0,0 according to X,Y,Z axis The antenna is suitable for terrestrial broadband, satellite uplink and downlink, mobile-satellite service, broadcasting satellite services, secure military communication, military satellite communication, direct broadcast satellite TV relay, fixed satellite service,GPS,GSM,2G,3G,4G,LTE,Public Safety radio ,UHF, amateur radio, weather monitoring, air traffic control, maritime vessel traffic control, and radar applications.

CHAPTER 1

Introduction

1.1 Introduction

In the telecommunications sector, wireless communication has become the fastest growing area, if not the most important technology component. It has grown so pervasive in the realm of communication in the current day that it is inevitable in our daily lives. Furthermore, wireless communication has transformed practically every aspect of our lives, providing us with convenience and an incredible sense of mobility. Long-distance communications, on the other hand, were extremely difficult a few centuries ago, and simply reaching them took considerable time. Long-distance communication, such as optical communication, got simpler as a result of the anticipation. It has been an important part of people's life for several decades and is still evolving. Later in contemporary communication history, the electromagnetic (EM) spectrum has been employed for wireless communication systems, and it is constantly expanding. Wireless communication systems are now being used in a variety of novel applications, including Arduino-based home automation, automated traffic and industries, remote telemedicine, robotic vehicles, and more. Antenna is the most important component of a wireless communication system. An antenna is a collection of conductors or electrical components used to transmit or receive electromagnetic (EM) beam spectrum or radio signals from the space surrounding it. The antenna terminal receives the electric energy and then transmits the signal to the surrounding space as an electromagnetic wave. The Antenna then receives electromagnetic impulses from all horizontal directions or from a single one. The antenna is used to create a wireless connection between two or more devices, particularly in the wireless communication system. Antenna gain, bandwidth, polarization, radiation pattern, and impedance are all concepts that influence the performance of an antenna. The antenna may be used for a variety of applications in the wireless communication system, including mobile phones, GPS receivers, satellites, base station wireless local area network connections (WLAN), radar systems, and so on, based on electromagnetic wave wavelength and radiation frequency. The working frequency range of an antenna, on the other hand, is determined by the materials used, such as steel plate, flex, ceramic, RT duroid, or wire material. The requirement for optimizing the size of an antenna and improving its performance has led to the introduction of a new artificial material called as met material in the modern period. The antenna, on the other hand, is one of the most difficult components of radio frequency (RF) design, and it is also one of the most disregarded. Because the antenna has a significant impact on the range and performance of radio frequency. Antenna design has been a major focus of telecommunications academics over the past decade. The multifunctional system and antenna size reduction have become the most crucial and fascinating aspects. For various frequency ranges, the demand for size optimization and adaptable antennas is rising day by day. Due to its compact construction, the Microstrip Patch Antenna (MPA) has become the most preferred antenna design to meet demand. In comparison to other conventional antennas, MPA has more multilateral design advantages, such as the ability to work at UFH, HF, or a wider frequency range, low manufacturing costs, and ease of assembly in integrated circuit technology . By combining various design strategies, MPA may improve antenna characteristics such as antenna bandwidth, gain, directivity, compact size, adjustable operational frequency, and so on.

1.2 Background

G.A. Deschamps initially proposed the concept of the Microstrip Patch Antenna (MPA) in the 1950s [1-3]. After a 20-year development period, Howell and Munson implemented the MPA idea in the 1970s, following the advancement of printed circuit board (PCB) technology [1-3]. Basic microstrip antenna components and arrays were reasonably well understood in terms of design and modeling by the early 1980s, and engineers were focusing on improving antenna performance attributes (e.g. bandwidth) and expanding the use of MPA technology. The microstrip patch antenna is made up of two substrates, one of which is a conducting patch (metallic patch on a thin, grounded dielectric substrate) with any non-planar or planar shape on one side of the dielectric substrate. The ground plane on the other side is the second. Because of its integration with microstrip technology and planer setup, the MPA is frequently used. Rectangular and circular patches are the most basic and often used microstrip antennas.

The application of MPA is so wide for civilians and military applications such as television broadcasting, Wi-Max, multiple-input multiple-output (MIMO) systems mobile system, radio-frequency identification (RFID), Wi-Fi, global positioning system (GPS), and probably all integrated circuit because of the advantages of being inexpensive, easy to fabricate, and not having difficulty for integration with external circuitry like microwave monolithic integrated circuits (MMICs) and probably all integrated circuit.

MPA's study into design and implementation is a never-ending process. Modified configuration and varied forms such as rectangular or triangular with a varying length (L) dimension might assist get appropriate MPA resonant frequencies. The spacing between the conducting patch and the ground plane has a significant impact on MPA bandwidth. With a narrower distance between the conducting patch and the ground plane, more energy is stored in the patch capacitance and inductance and less energy is radiated. As a result, the antenna's quality factor (Q) rises, signaling a narrower radiation bandwidth. Q may be decreased by increasing the dielectric substrate thickness; however, increasing the dielectric substrate thickness reduces efficiency since a considerable percentage of the input power is lost in the resistor, reducing the available power that can be radiated by the antenna. It can also have an impact on low power gain and the additional radiation emitted by its junction and junction feed points. The substrate permittivity (r) of the microstrip antenna can alter the resonant bandwidth and gain [4]. Getting a standard antenna gain and bandwidth characteristic in the same MPA is quite difficult[3].

1.3 Literature Review

Light weight, cheap manufacturing costs, mechanical resilience when mounted on hard surfaces, and the ability to operate at dual and triple frequencies are all advantages of microstrip patch antennas [5]. On the other hand, the antenna's narrow bandwidth proved to be its most serious flaw. Many solutions have been explored to solve this challenge, including raising the substrate thickness, inserting parasitic components (co-planar or stack arrangement), and modifying the form of the patch. While reading the literature, We saw that other forms of bowtie antennas have been studied for enhanced performance, such as lower return loss, flatter input impedance, and a more consistent radiation pattern. The next section will go through several shape adjustments recommended in the literature to boost the bandwidth of bow-tie antennas. Oliver Lodge invented the triangular bowtie as a UWB antenna in 1898 [19]. Compton et colleagues [20] proposed a thorough theoretical approach for studying the bow-tie antenna on a dielectric substrate (see figure 1). The simulated findings reveal that the main current for broad bows is a wave traveling down the bow's axis at the dielectric wavenumber. As the bow narrows, the main current becomes an edge current with the quasistatic wavenumber, and the impedances spiral fast toward a quasistatic value described by transmission line theory.A straight-end bow-tie antenna was studied in the frequency domain in [21], and MoM was utilized. The Electric Field Integral Equation (EFIE) is used to solve the antenna issue because of its planar nature. To avoid the "staircase" approximation, the bow tie's surface is modelled using planar triangular patches, and the method of moments is then used to solve the EFIE using the well-known Rao-Wilton-Glisson (RWG) basis function [22]. The results have been shown to agree with Brown and Woodward's well-accepted results for measured impedance and field patterns of bowtie antennas in free space.

Proposes Using the CST Studio Suite simulation program, a new optimized MPA (Bow-tie Antenna) is constructed. An inset feed partial ground MPA antenna with 1 GHz, 1.5 GHz, and 3 GHz resonance frequencies and a bandwidth of 1.7 GHz is offered. With frequencies spanning from 1 to 3 GHz, it covers the whole X-band as well as the lower portion of the Ku band. The antenna will be 96 mm wide, 32 mm long, and 47.76 mm long. The distance between the two pieces will be 6 mm, and the angle ratio will be 180,0,0 on the X,Y,Z axis. The antenna can be used for terrestrial broadband, satellite uplink and downlink, mobile-satellite service, broadcasting satellite services, secure military communication, military satellite communication, direct broadcast satellite TV relay, fixed satellite service, GPS,GSM,2G,3G,4G,LTE, Public Safety radio, UHF, amateur radio, weather monitoring, air traffic control, maritime vessel traffic control, and radar applications.[15].. Ton an air substrate with a total thickness of 7 mm, the patch of the enhanced antenna measured 15 15 mm2, whereas the patch of the basic antenna measured 18 15 mm2. Due to its tiny size, versatility, low cost, and high performance, dual band Microstrip Patch antennas (MPAs) [2] have been widely used in numerous sectors of communication in recent years. They are mostly used for frequency difference operations. They are capable of emitting a variety of patterns. This dual band antenna may boost system performance, and the antenna designer may confidently connect various communication devices to this antenna for sending and receiving signals. Secure transmission, multi-frequency communication, object identification, vehicle speed measurement, and other applications employ dual band E-shape antennas in satellite communication and radar systems. To accomplish dual frequency configuration, various switch states for distinct frequencies of radiation might be employed in advance. For diverse communication reasons, numerous radio frequencies have been designed. The range of microwave frequencies is 3 to 30 GHz. This antenna is designed to work in the C-band and X-band microwave frequency bands. The resonant frequencies are 4.8 GHz with a bandwidth of 167.7 MHz, 6 GHz with a bandwidth of 58 MHz, and 9.2 GHz with a bandwidth of 326 MHz. This antenna's bandwidth is increased by two parasitic layers. The C-band microwave frequency spectrum is used in satellite communications, full-time satellite TV networks, and raw satellite feeds. This C-band is often used in locations with tropical rains because it is less susceptible to rain fade than the Ku band. It uses a frequency range of 4 to 8 GHz to function. The X-band of microwave frequency spectrum is used in military communication systems. It can also be used in radar applications. It has a frequency range of 8-12 GHz.

1 . 4 Aim and Objectives

The purpose of this research is to improve the performance of MPA (Bow-tie) features in the X band. The objectives are shown in the table below.

- Create a microstrip patch antenna that has a higher bandwidth.
- The intended antenna's gain has been improved.
- To cut down on antenna return loss.
- The antenna's application for 1GHz

1 . 5 Methodology

The X and Ku band frequency domains have seen all of MPA's performance enhancements. In MPA, the use of two different types of slots yields a significantly improved result. We've detailed step-by-step plans for reaching our objectives.

Step 1: Establishing the length (L) and width (W) of a basic rectangular microstrip patch antenna (W).

Step 2: Increase the bandwidth of the antenna by using a rectangular form.

Step 3: Improve the widths and lengths of the inset slot and partial ground by modifying and optimizing them.

Step 4: Analyze the performance of each designed antenna in terms of antenna characteristics, particularly antenna gain, return loss, and bandwidth.

Step 5: For best results, adjust the widths and lengths of the inset slot and partial ground.

Step 6: Talk about the programs that run on 1 GHz.

1.6 Thesis Orientation

There are five primary chapters in this thesis, as well as a reference section.

- The introduction, literature review, thesis objectives, and scope are all discussed in **Chapter 1**.

- The basic concepts of the microstrip antenna are explained in **Chapter 2** through brief literature reviews. It also reviews the literature on designing a slotted wideband microstrip patch antenna.

- The design approach for a wideband high gain Microstrip patch antenna employing the microstrip feed line technology is described in **Chapter 3**. This chapter goes over a number of antenna configurations and how to optimize them. It has been introduced to boost the gain of the suggested antenna array arrangement.

- Results, analysis, discussion, and the proposed antenna's 1GHz application are all covered in **Chapter 4**.

- Finally, **Chapter 5** brings the work to a close and discusses the possibilities for future work.

CHAPTER 2

Literature Reviews

2.1 Antenna Parameters

An antenna, like a transducer, transforms electrical energy into electromagnetic (EM) energy (vice versa). Some quantifiable characteristics should be considered while developing an antenna in order to understand the device's strength and weaknesses. An antenna contains a variety of metrics that may be used to determine whether it is performing well or poorly, and the parameters are interdependent. Furthermore, it should be checked that all of the parameters are better suited for antenna design. For instance, the return loss should be less than -10dB and the VSWR should be less than 2.

2.2 Antenna Field regions

Understanding antenna field regions is important for establishing how far away from the antenna the antenna actually radiates, even though it is not an antenna characteristic in and of itself. There are three primary sections in which the fields that surround an antenna are divided:

- ❖ Near Field Radiation or Fresnel Region
- ❖ Fraunhofer Region or Far Field
- ❖ Near-Field Reaction

The far field area is the most important since it affects the antenna radiation pattern as well as the majority of other factors. Antennas, on the other hand, are used to communicate over large distances. As a result, for most antenna types, this is the critical operating range.

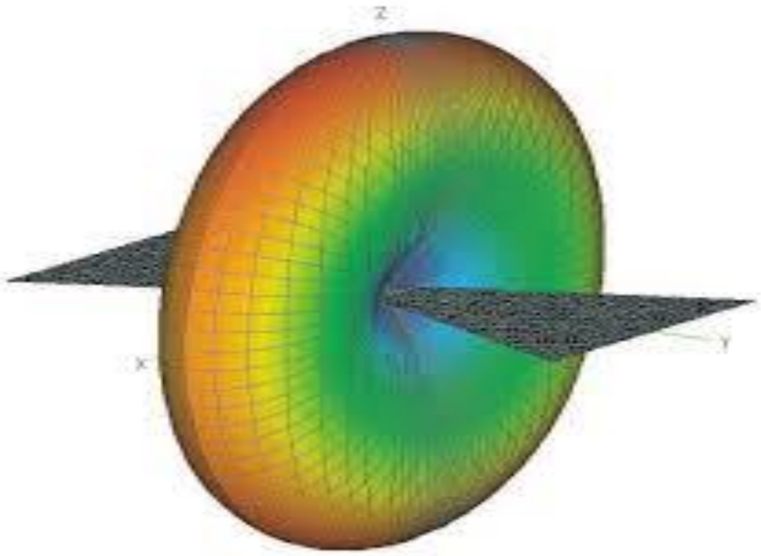

Figure 2.1(a) Antenna Radiation flow

In the electric field and magnetic field equations, an antenna has two field components. Radiative and reactive fields are the terms for these two types of fields. The reactive field components in the denominator of the equation frequently have a distance 'r' on the order of two or greater. There is also a distance component with 'r' of the first order in the radiative component. When a result, as distance increases, the reactive component of the field dies, but the radiative component survives, dying at a far larger distance than reactive fields. Because the reactive field is greater, there isn't much radiation accessible in the near field. However, this distance, which is measured in mm and cm at microwave frequencies and is on the order of R0 (Wavelength at the operating frequency), is too tiny for us to perceive.
As a result, every parameter of an antenna is addressed in the far field region unless it is asked to be done in the near field zone, because radiation only exists there.

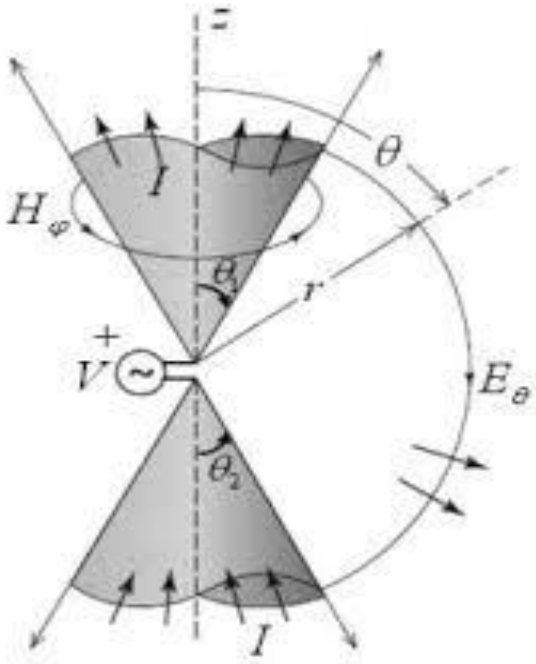

Figure 2.1(b) Field Regions

2.3 Radiation pattern:

The radiation pattern of an antenna is a graphical representation of the strength of the antenna's radiation in proportion to space co-ordinates, commonly in a spherical co-ordinate system. Based on their emission pattern, antennas are classed as directional or omnidirectional. An omnidirectional antenna is one that transmits equally throughout the azimuthal angle while fluctuating sinusoidally with respect to elevation angle. An antenna, on the other hand, is considered to be directional if it radiates at a certain angle with more directivity than at other angles. The word "directivity" is used to characterize the directionality of an antenna. A radiation pattern can be depicted using a 3D plot, 2D plot, or Polar plot. The use of 2D and

Polar graphs is required for analytical purposes. In these diagrams, the pattern of the antenna radiating in different directions may be viewed graphically.

2.4 Directive Gain:

The directional antenna is another antenna that radiates differentially at different angles. The ratio of an antenna's radiation intensity at a certain angle to the average radiation intensity in all directions is known as directive gain. It is abbreviated as dBi.

$$Directive\ Gain\ at\ an\ Angle = \frac{Radiation\ Intensity\ at\ That\ Particular\ angle}{Average\ radiation\ intensity}$$

2.5 Directivity:

A directional antenna has a radiation angle where the radiation strength is higher than in all other directions. The directed gain of a directional antenna in the direction of greatest radiation is known as an antenna's directivity.

2.6 Antenna Efficiency:

An antenna is usually associated with at least two types of losses. One is caused by a mismatch in impedance between the feed line and the antenna, while the other is caused by a mismatch in impedance between the antenna and the free space. Another issue is that the antenna suffers losses since it is a conductor. As a result, the antenna will be unable to transmit the full amount of input power. The ratio of an antenna's output power to its input power is its efficiency.

$$Antenna\ Efficiency = \frac{Output\ Power}{Input\ Power} \times 100\%$$

2.7 Antenna Gain:

When the antenna efficiency is taken into consideration, the antenna gain is the directivity of the antenna. The ideal scenario for an antenna is its directivity, but the practical situation is its gain. As a result, the gain and directivity of an antenna will be the same if all of its input powers are radiated. In the actual world, there will always be losses associated with antennas; gain will always be less than directivity.

$$Antenna\ Gain = Antenna\ Efficiency \times Directivity = Antenna\ Efficiency\ Directionality$$

2.8 Voltage Standing Wave Ratio

It is impossible to match the impedance exactly, there will always be some mismatch between the antenna and the generator. Some of the signal is reflected back to the generator from the antenna due to the impedance mismatch. Both the forward and reflected waves to and from the antenna are contained in the waveguide. These two voltages combine to form a 'Standing Wave' inside the waveguide. This wave has a high point and a low point. The ratio of the maximum and minimum voltages inside the waveguide is called the Voltage Standing Wave Ratio (VSWR).

$$VSWR = \frac{Maximum\ Voltage\ Of\ Standing\ wave}{Minimum\ Voltage\ Of\ Standing\ wave}$$

The VSWR value is 1 when there is no mismatch between the generator and the antenna. It denotes a wave that is completely emitted and completely reflected. A VSWR of 2 is considered a good match for most cases since it represents around 10% of the reflected power.

2.9 Return Loss / S11 Parameter:

Return loss is another metric that communicates information about impedance mismatch. It is the most often used measure in antenna literature to quantify impedance mismatch and resonance, despite the fact that it gives the same information as VSWR. The reflection coefficient is the ratio of reflected power to incident power. It is calculated using the following equation:

$$\textit{Reflection Coefficient}, \tau = \frac{zA-zo}{zA+zo}$$

Where, zA = Antenna impedance

zo = Transmission Line impedance

The reflection coefficient is 0 when the antenna and line impedances are exactly matched, indicating that there is no reflection. The reflection coefficient's decibel value is the return loss. The link between the Reflection Coefficient and the VSWR is as follows:

$$VSWR=\frac{1+\tau}{1-\tau}$$

The return loss is calculated using the following equation in dB. The negative sign ensures that the return loss value remains positive, as required by the IEEE specification. The minus value of the return loss is represented by the s11 parameter.

$$\textit{Return Loss}= -20\log\frac{VSWR-1}{VSWR+1}dB$$

2.10 Input Impedance

Input impedance is the impedance presented by an antenna at its terminals, or the ratio of voltage to current at a pair of terminals. When the transmission line and antenna input impedances are matched, maximum power transfer is achieved. If it is not matched, the efficiency of the entire system will suffer. This is the case because a reflected wave is created at the antenna terminal and travels back to the energy source.

The input impedance for this parameter must match the transmission line's characteristics impedance in order to enable maximum energy transfer between transmission line and patch. A reflected wave is created at the antenna terminal if the input impedances are not equal, and it returns to the energy source. As a result of energy reflection, the overall system efficiency is diminished. Only if the antenna is used to broadcast or receive energy will its efficiency be lost.

2.11 Antenna Bandwidth:

Antennas are available in a wide range of bandwidths, each with its own set of characteristics. A frequency range with a return loss of less than -10dB is specified by the s11 parameter bandwidth. A radiation pattern's bandwidth is the range of frequencies throughout which the pattern remains constant. An antenna bandwidth is a frequency range in which all antenna characteristics are within an acceptable range.

2.12 Advantages and Disadvantages:

Microstrip patch antennas are becoming more popular in wireless applications due to their low-profile design. As a result, integrated antennas in portable wireless devices such as cellular phones and pagers are excellent. Because telemetry and communication antennas on missiles must be small and conformal, microstrip patch antennas are widely utilized. Another area where they've excelled is satellite communication.

The following are some of their most significant advantages:

- When installed on hard surfaces, it is mechanically robust.
- The volume is small and the weight is modest.
- Planar arrangement with a low profile that is easily conformable to the host surface.
- It can be produced in massive quantities because to the inexpensive cost of production.

- There is support for both linear and circular polarization.
- Microwave integrated circuits are simple to put together (MICs).
- It's feasible to use two or three frequencies at the same time.

When compared to conventional antennas, microstrip patch antennas have more flaws. The following are some of their key drawbacks, as highlighted by [9] and Garg et al [10]:

- Low Gain
- Narrow Bandwidth
- Low Efficiency
- Radiation from feeds and connections that isn't needed
- With the exception of tapered slot antennas, end fire radiators are poor.
- Power handling capacity is limited.
- Excitation via surface waves

Microstrip patch antennas have a high antenna quality factor (Q). The antenna losses are depicted, with a large Q resulting in a narrow bandwidth and low efficiency. To minimize Q, the dielectric substrate thickness might be raised. However, as the layer thickness increases, a higher proportion of the source's total power is transformed to a surface wave. This surface wave contribution might be regarded an unwanted power loss since it is dispersed at the dielectric bends and causes the antenna characteristics to deteriorate. Other difficulties can be addressed by arranging the parts in an array, such as lower gain and power handling capacity.

CHAPTER 3

DESIGN OF THE PROPOSED PATCH ANTENNA

The main goal of this thesis is to create a wideband microstrip patch antenna (Bow-Tie) that can function in the entire X band as well as a section of the Ku band. It is difficult to construct a wideband MPA that can deliver the requisite bandwidth due to the lack of a succinct mathematical formula. This chapter presents the inset feed partial ground wideband MPA design methodologies and the entire process of iteratively modifying the antenna design while gradually increasing the bandwidth.

3.1 Basic Parameters

The antenna is designed using three major parameters, which are displayed below. These characteristics are selected to achieve a certain design purpose, which will be explained later in this chapter. For design optimization, certain parameters are not subject to change.

- MPA has been set to operate in the X band frequency domain.
- FR-4 is an insulating material with a high dielectric constant. As the dielectric material for MPA, an epoxy substrate with a dielectric constant of 4.4 has been used.
- Because MPAs are often small devices, a standard thickness has been chosen for the basic layout of MPAs.

3.2 Substrate Selection

When building patch antennas, the two most important factors to consider are substrate permittivity and loss tangent. The microstrip patch antenna's main drawbacks are its limited bandwidth and low gain. As a result, selecting the appropriate substrate permittivity lowers surface wave losses and improves antenna performance, especially impedance bandwidth and radiation efficiency [22]. In addition to being structurally stronger, a thicker substrate will increase radiated power, reduce conductor loss, and improve impedance bandwidth. It will, however, increase weight, as well as dielectric loss, surface wave loss, and undesired probe feed radiation. The fringing field at the patch perimeter will be enhanced by a substrate with a low dielectric constant. As a result, the radiated power of the antenna will be increased. As a result, a lower dielectric constant is desirable; however, because this would increase antenna size, the substrate material should be selected correspondingly. With a substantial dielectric loss, the antenna's dielectric loss rises.

Depending on the application, the permittivity of the most often used dielectric substrate materials for printing patch antennas ranges from 2 to 10. As the permittivity lowers, the antenna gain rises. This is because a greater permittivity substrate's traveling wave slows down as it goes through the antenna.

3.3 Bow-tie Antenna Dimension

The antenna's resonance frequency and radiation pattern are both influenced by patch width. It has a bigger influence on input resistance and bandwidth, though. A greater patch width increases the amount of power radiated, resulting in decreased resonance resistance, increased bandwidth, and increased radiation efficiency. In antenna arrays, the creation of grating lobes is a barrier to a greater patch width. The length to breadth ratio of the route should be between one and two in order to obtain optimum radiation efficiency. Because of the patch's limited bandwidth, the patch length has an impact on the resonant frequency and is an important design element. A microstrip patch's length (L) can be estimated.

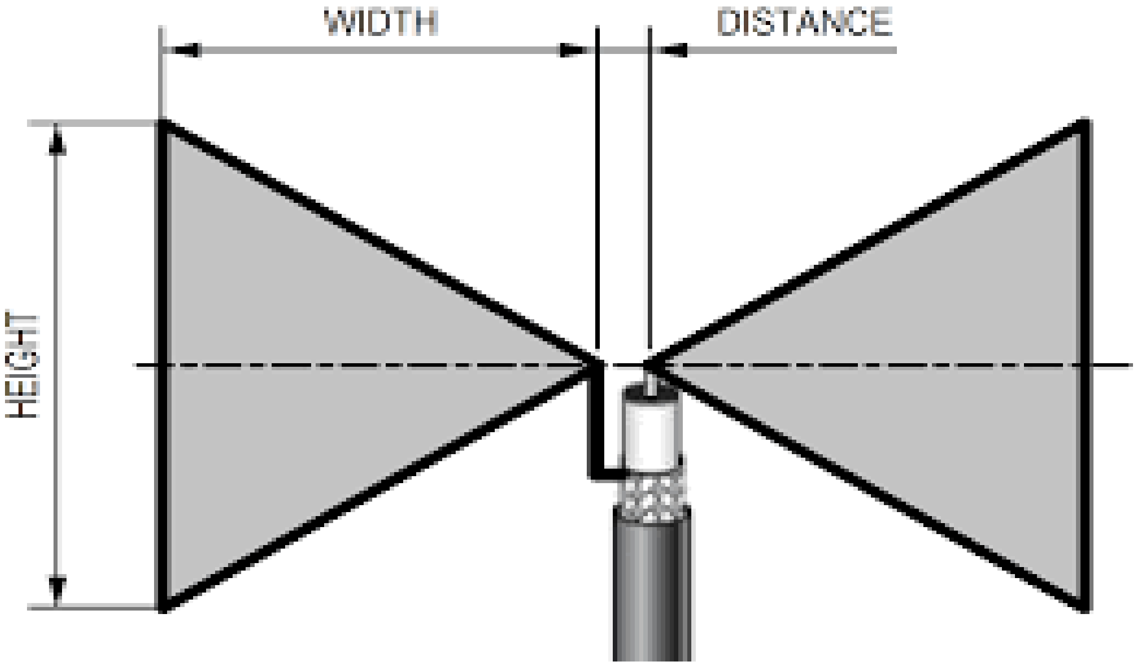

Figure 3.1 Bow-tie Antenna Dimension

Fields are not restricted to the patch in practice. As seen in figure 3.3, a component of the fields lies outside the patch's physical boundaries (LW). The fringing field is how it's known. Practical considerations necessitate the existence of a limited ground plane. Similar results may be obtained for finite and infinite ground planes if the ground plane dimensions are larger than the patch dimensions by about six times the substrate thickness all around the periphery.

3.4 Design of Bowtie Antenna

This section depicts the Bow-Tie antenna's design process and bandwidth increase. The S1/return loss, VSWR, Bandwidth, Directivity, and Gain are the most important parameters to consider. A 1.5 - 3 GHz antenna design is presented in figure 3.3 to give you a better sense of MPA specifications.

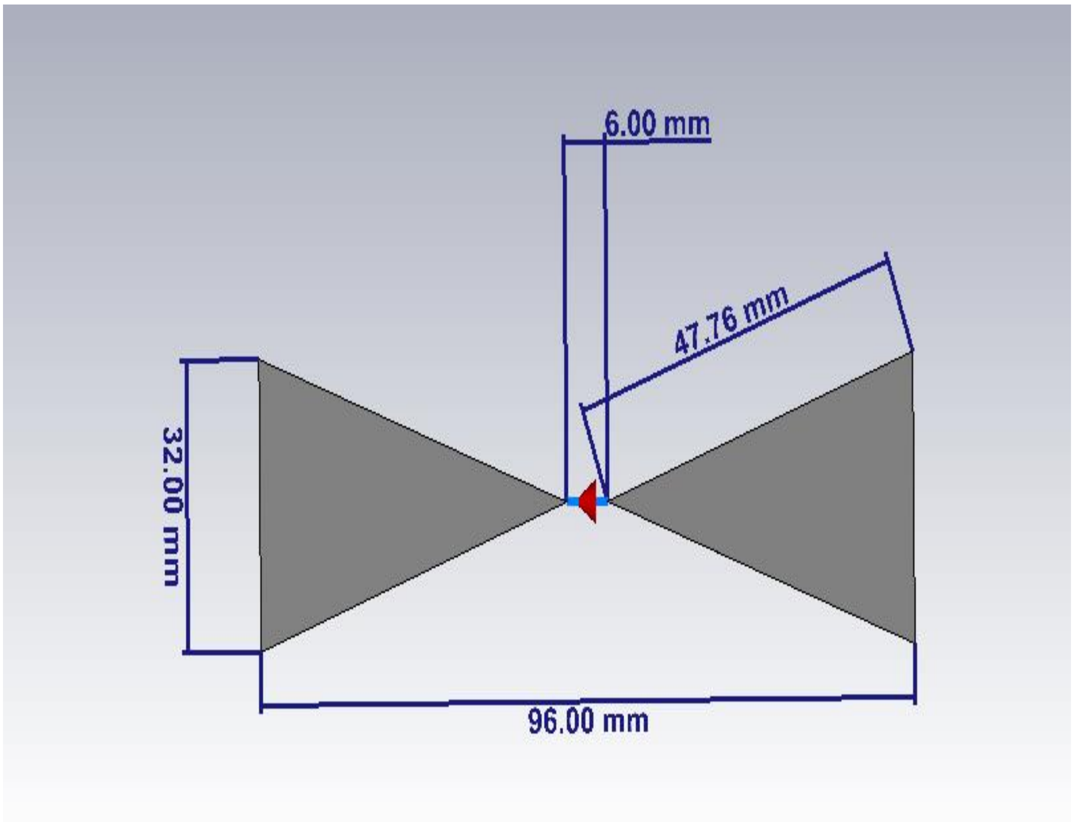

Figure 3.2: Simple Bow-tie Antenna

Finally, the best dimensions for the suggested modified bowtie antenna design are: L1=32mm, L2=47.76 mm, W=96mm, D=5 mm, and Rotation angle (x,y,z) =(180,0,0).

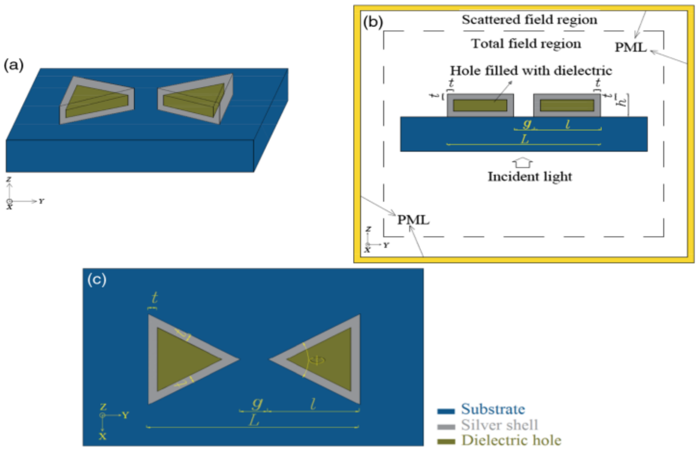

Figure 3.3: Designed Bow-tie Antenna

The resonant frequency obtained differs significantly from that predicted. Because the empirical equations are inaccurate, there is a mismatch between estimated and simulated resonance frequency. Although the resonance frequency is not in the X band, it is fairly near and serves as a starting point for the antenna we want to build. To produce the antenna with the desired performance, iterative design optimization can be used.

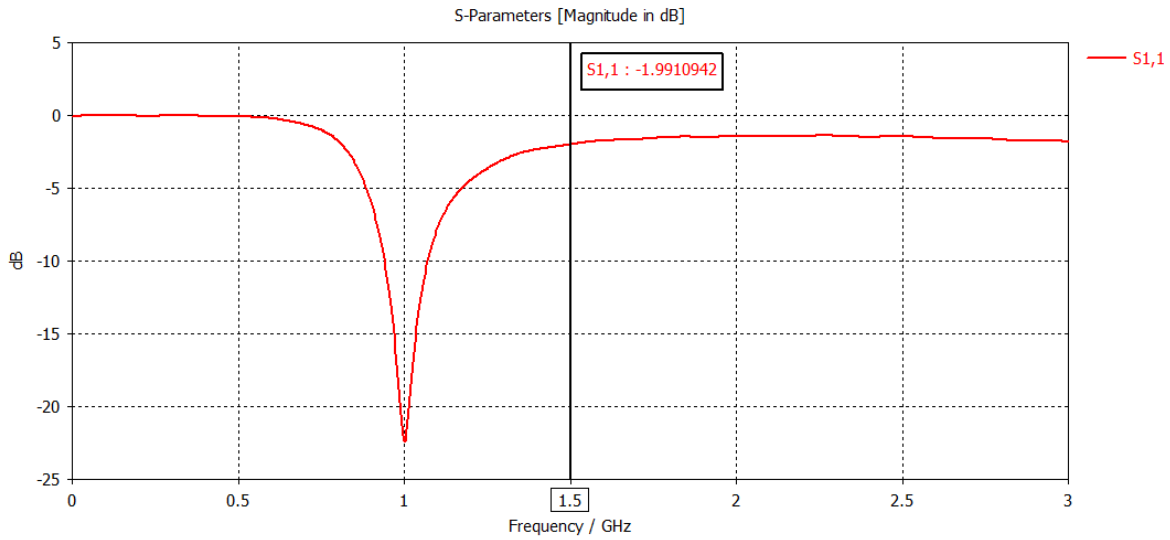

Figure 3.4: S parameter of Designed Bow-tie antenna

3.5 Optimization

We start the antenna optimization process with a trial-and-error stage to see how different parameters impact the antenna's behavior. It has been proved that a first feasible approach may be utilized to place a resonant frequency at a different operating frequency. The values of numerous parameters or components must be determined when using an optimization approach.

Traditional search and optimization approaches have a number of limitations when working with complex situations. The biggest obstacle arises when one method is utilized to solve a range of problems. This is due to the fact that each classical technique is optimized for a certain set of issues. As a result, these techniques are unable to handle the vast variety of issues that designers and practitioners encounter. Furthermore, most traditional techniques lack a global perspective and often result in a locally optimum solution.

Among the several ways provided, there wasn't much of a theory or equation presented to determine an ideal antenna shape. A variety of random shapes with varying lengths and widths were shown. Equations were tried by designers of rectangular-shape patch antennas. The simplest technique to discover the best MPA solution, according to the situation, is to employ a trial and error or optimization process.

In comparison to the earlier findings, the addition of an inset slot and partial ground with changing dimensions resulted in a very satisfactory conclusion. The S1/Return loss figure now shows a broad response with frequencies spanning from 1.5 to 3 GHz. The antenna now covers a large amount of the X band, thanks to the current optimization. More optimization is required to cover the entire X band.

Different techniques have the advantages of being simple to build, needing no new components to be added to the device, and reducing the device's size. A quarter wave monopole theory was devised in one of the works, in which a slit was carved in the edge so that it might behave as a monopole when connected to free space.

We must first pick our estimations for numerous aspects or variables before we can apply an advancement method. It also needs the employment of a fitness function to compare the fitness of several solutions and determine the optimum result. The goal of this research is to create a fitness function that allows the antenna to achieve the necessary bandwidth. The following Bow-tie antenna was created using the above equations and techniques, which was initially unoptimized.

A number of parameter combinations were explored using the previously mentioned criterion as a guideline to position the resonant frequencies in the best location while balancing the other design parameters, as described in "First optimization."

Our final design is shown below after we completed all of the design optimization utilizing a number of parameter combinations.

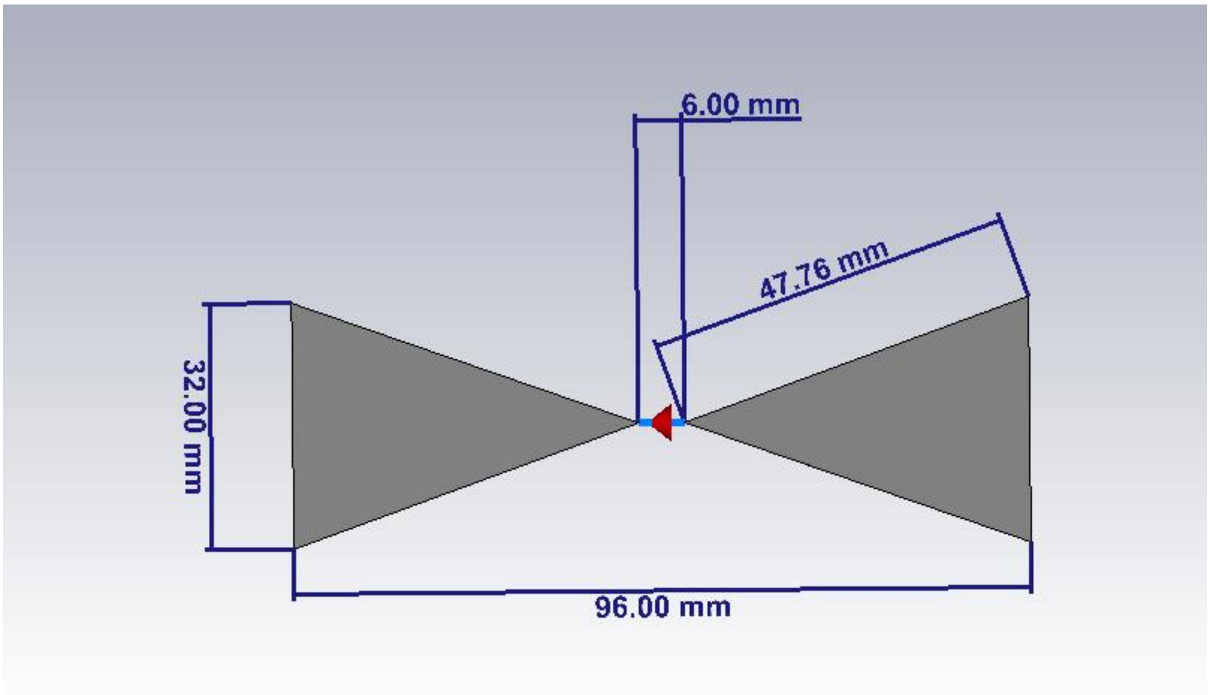

Figure 3.5: Designed Bow-tie antenna

Table: Dimensions of the Proposed Bow-tie Antenna

Parameters (f0=3 GHz)	Optimized Dimensions
L1	32mm
L2	47.76mm
D	6mm
W	96mm
Rotation Angle(x,y,z)	(180,0,0)

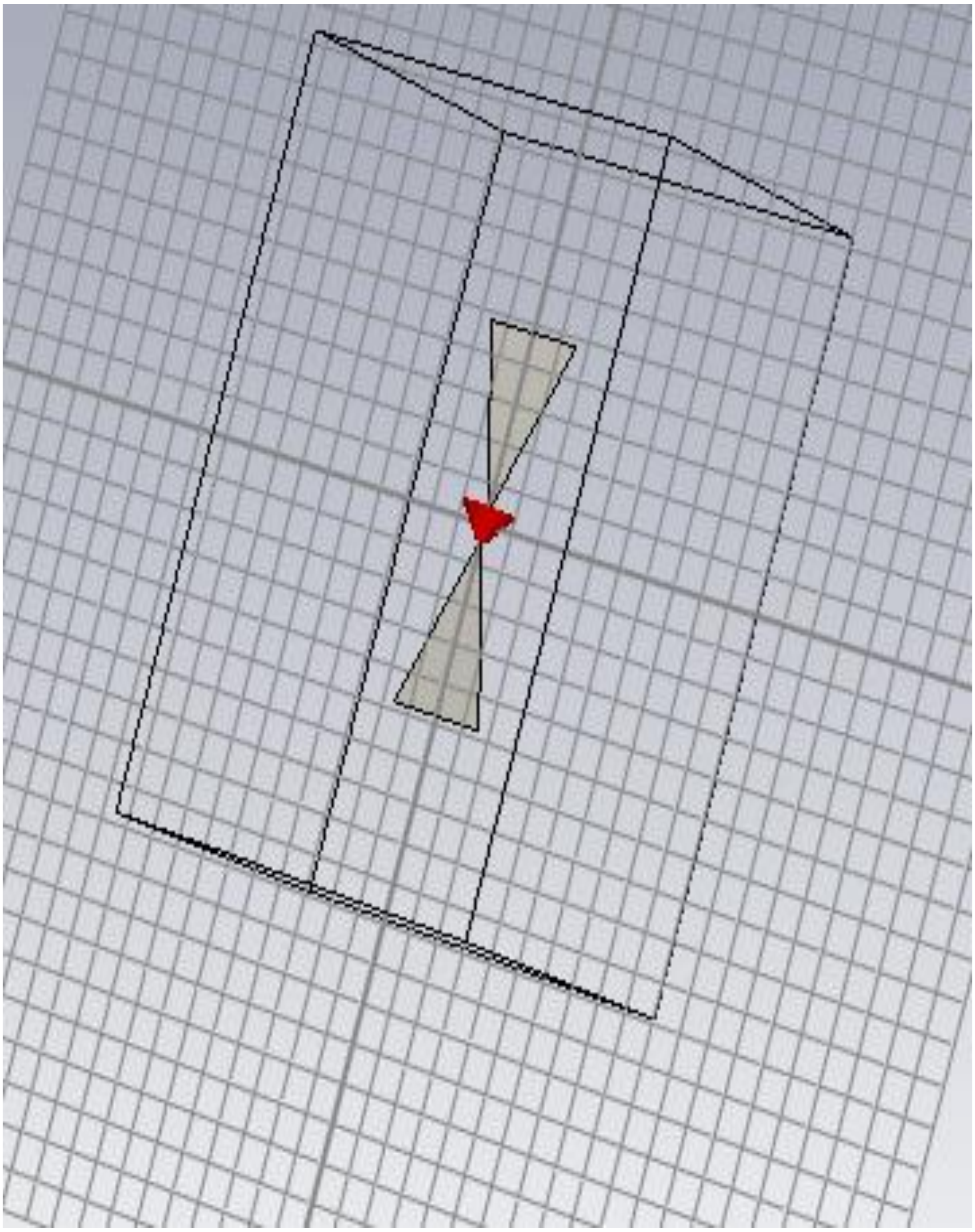

Figure 3.6: Simulated 3D view of the proposed Bow-tie antenna in CST

CHAPTER 4

Result and Analysis

4.1 Results and Discussion of the Proposed Antenna using CST

Extensive simulations were done to find the best optimal antenna for X band operation, which was the thesis's major purpose. Many antennas and array combinations were invented, and the bandwidth gradually increased. The suggested antenna inset slots cutting and partial ground technique has been used to improve antenna attributes. The bandwidth has increased tremendously due to the properties of inset slots and partial ground. The proposed antenna has a 1.7 GHz bandwidth and covers the entire X band frequency range as well as the 1.5-3 GHz portion of the Ku band, allowing it to support terrestrial broadband, satellite uplink and downlink, mobile-satellite service, broadcasting satellite services, secure military communication, military satellite communication, direct broadcast satellite TV relay, fixed satellite service, amateur radio, weather monitoring, air traffic control, and maritime vessel traffic control.

CST Studio is used to simulate antenna performance parameters such as bandwidth, return loss, average current distribution, vector current distribution, 2D, 3D gain and directivity radiation patterns. For comparison, the same performance metrics are simulated using the CST Studio Suite 3D EM simulation tool, which will be explained later in this section.

The current distribution shows the antenna structure and helps determine the density and direction of current flow inside the patch at different frequencies. It also shows how various components of the antenna react to different operating frequencies. The power emitted by an antenna is plotted as a function of distance from the antenna.

graphical representations of 2D and 3D radiation patterns In both polar and cartesian form, a 2D radiation pattern provides a 3D rotatable view of antenna directivity and gain with emission style in terms of axial ratio, azimuth, and elevation, whereas a 3D radiation pattern provides a 3D rotatable view of antenna directivity and gain with emission style in terms of axial ratio, azimuth, and elevation. Simulations were run for recommended design antennas at various resonance frequencies, providing for a better understanding of antenna parameters.

4.2 Port Signals

With regard to time, port signal offers us the incident (i1) and reflected signal (o1,1) on a certain port.

For your antenna to exhibit substantial resonance, the port signal should begin at zero and gradually decrease to zero after some resonance.

The following is the port signal:

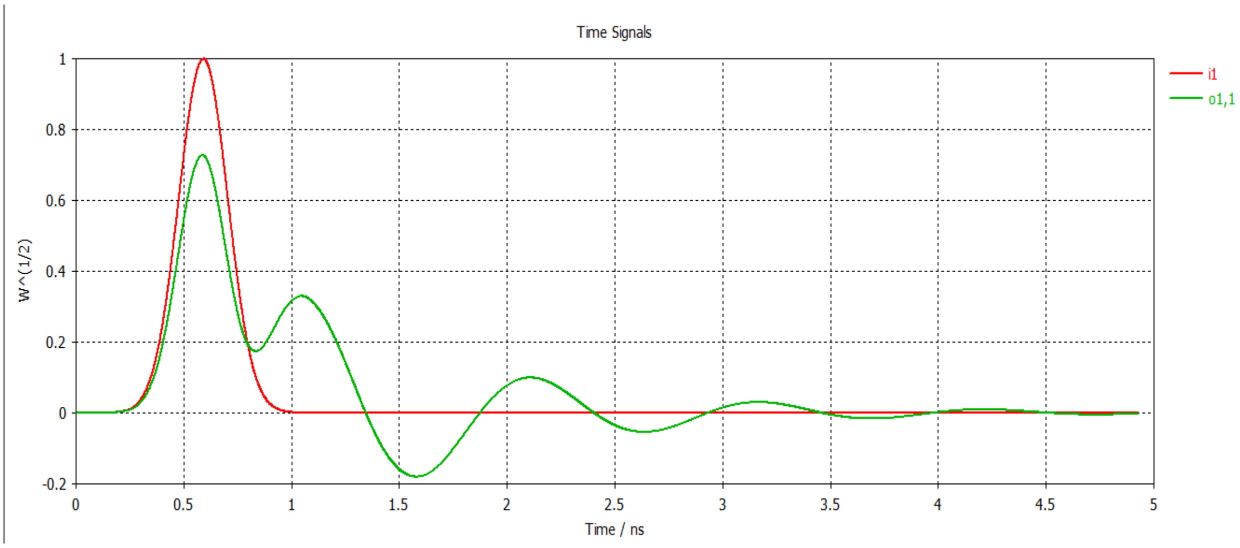

Figure 4.1: port signals of proposed MPA

4.3 Power accepted per port

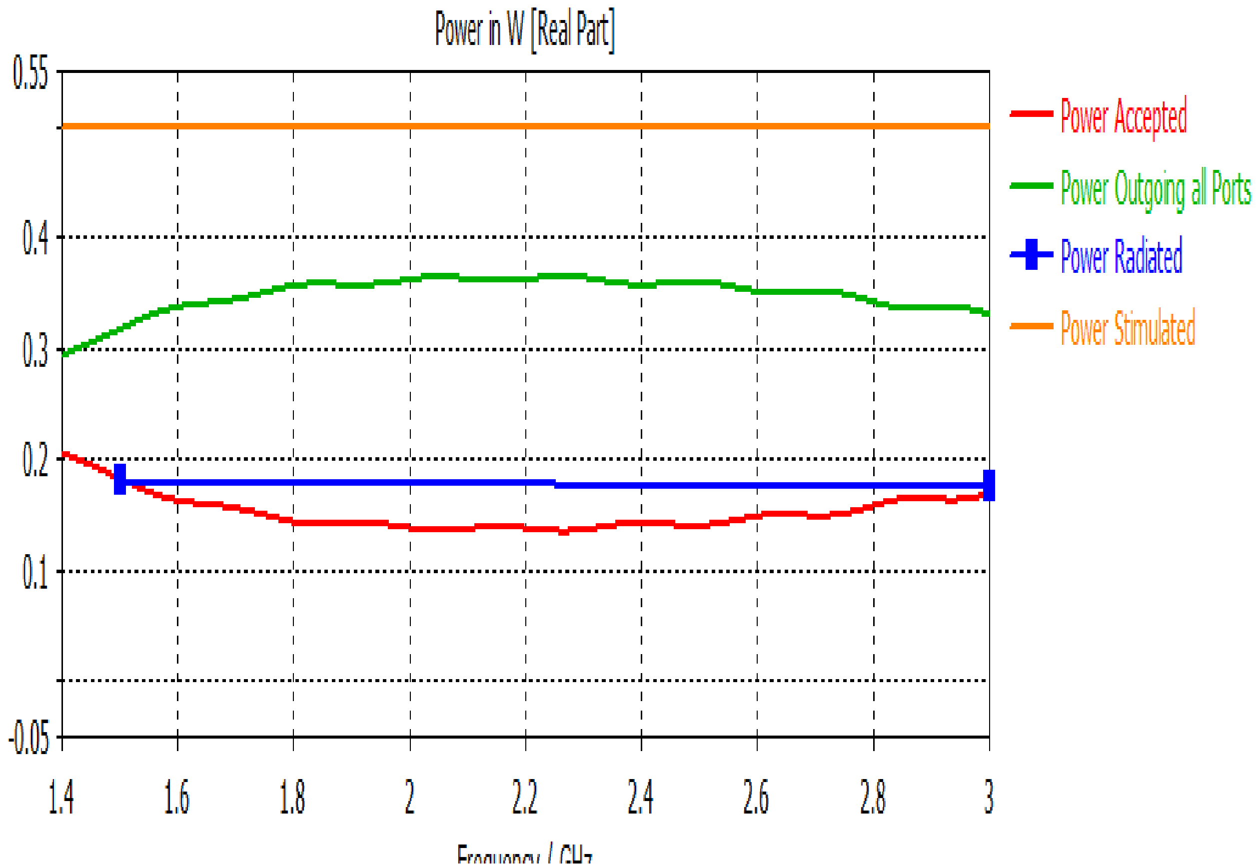

Figure 4.2: power accepted per ports

4.4 2D/3D result

Understanding how the antenna radiates in 3D is aided by the 2D radiation pattern. The 2D radiation pattern is used for analytical reasons due to the difficulties of presenting a 3D pattern on a 2D surface. A good antenna should maintain a consistent radiation pattern over the whole frequency range it covers. At 1.5 and 3 GHz, the proposed antenna's radiation pattern is depicted below.

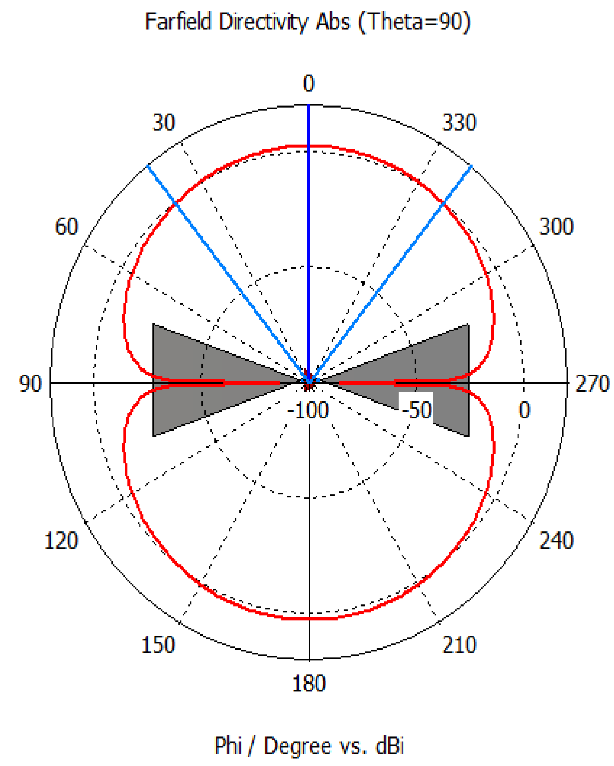

Figure 4.3(a): Farfield (f=1.5GHz)

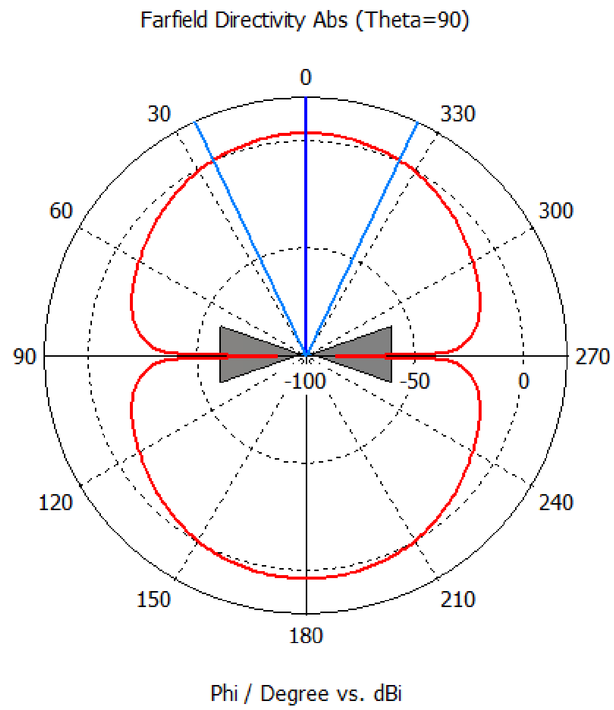

Figure 4.3(b): Farfield (f=3GHz)

Despite the fact that the 3D radiation pattern cannot be utilized to derive much information, it is included in the book to aid understanding of the 2D patterns. A 3D radiation pattern can be used to acquire a better knowledge of antenna power radiation direction. @ 1.5 GHz and 3 GHz, shows actual 3D radiation patterns of the planned single element inset feed MPA. They show the pattern in three dimensions. The size of the pattern from the origin represents the strength of the field at a certain (theta, phi) angle.

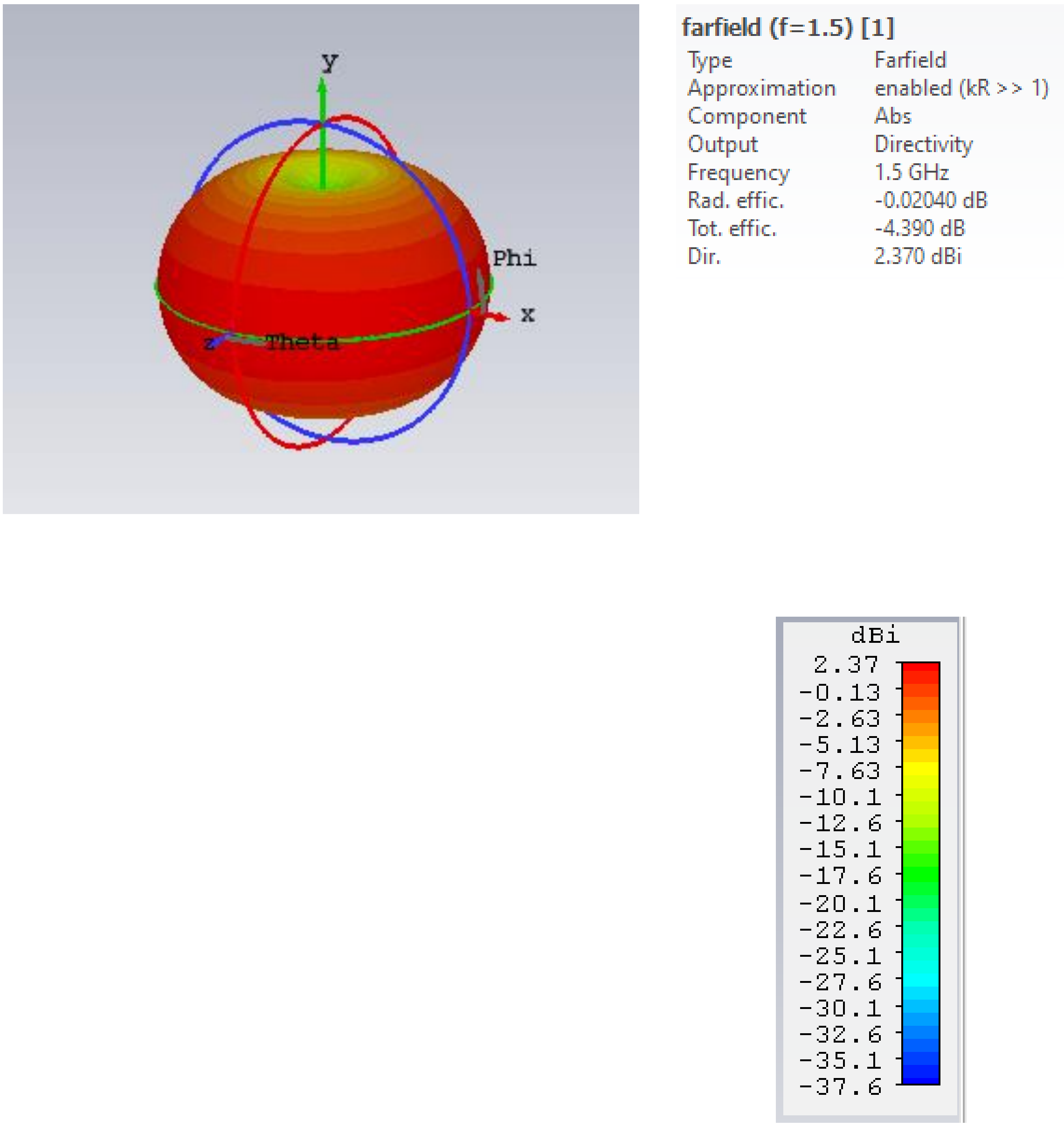

Figure 4.4(a): Farfield (f=1.5GHz)-3D

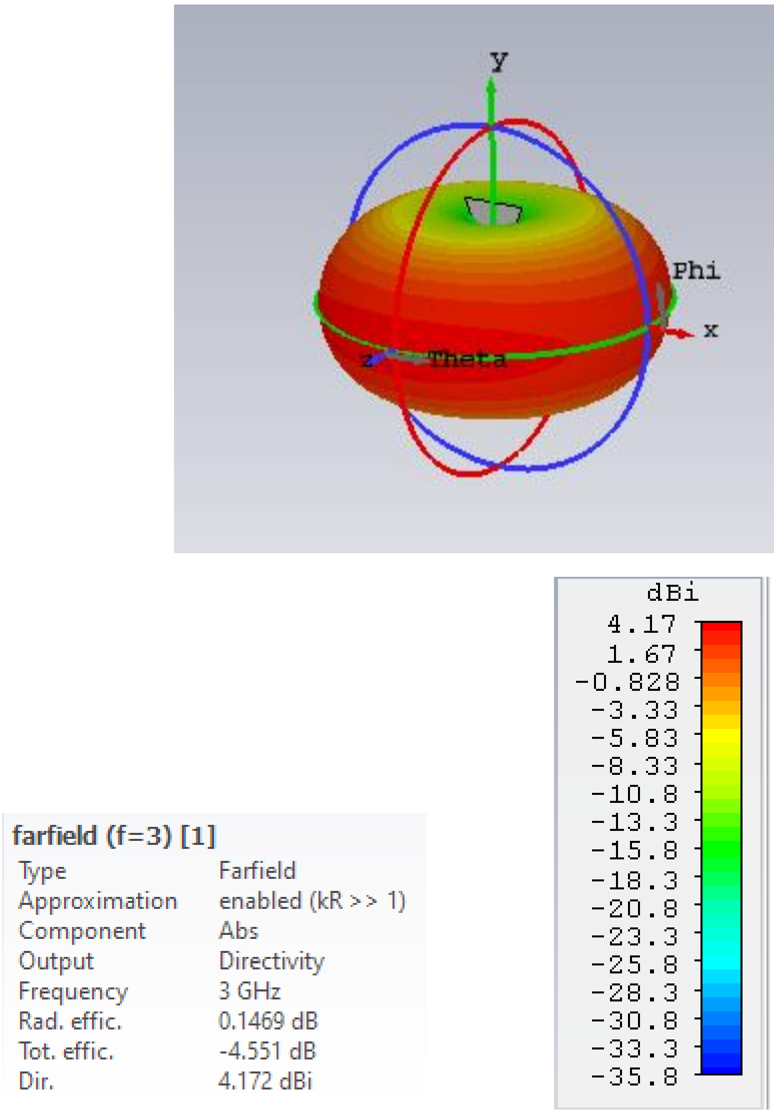

Figure 4.4(b): Farfield (f=3GHz)-3D

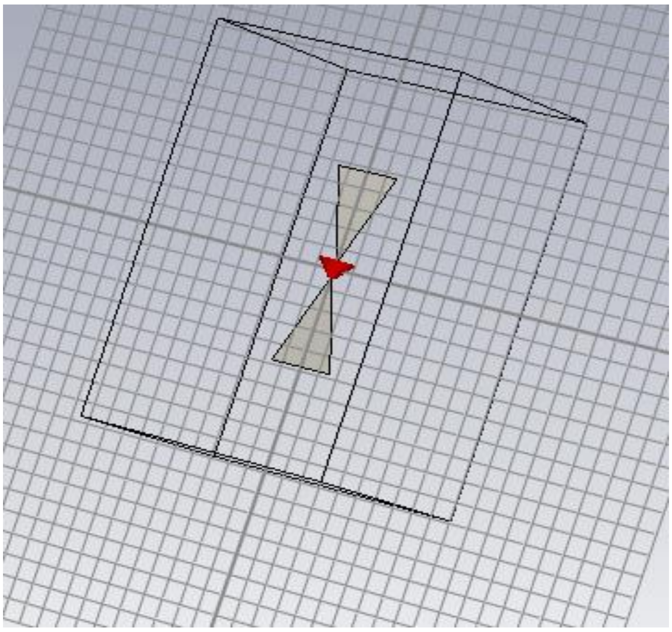

Figure 4.5: Simulated 3D view of proposed MPA using CST

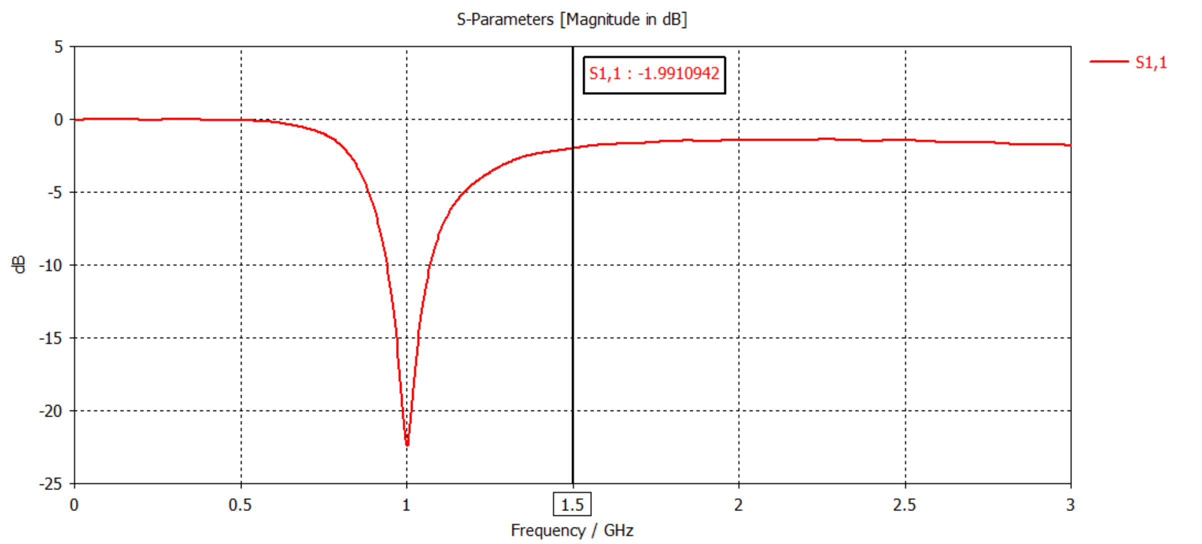

Figure 4.6: S- parameter of proposed antenna using CST

The electrical behavior of linear electrical networks when subjected to varied steady state stimuli by electrical signals is described by scattering parameters or S-parameters (the elements of a scattering matrix or S-matrix).According to the diagram above, the antenna radiates optimally around 1 GHz.

4.5 Applications (for 1 GHz):

The patch antenna is most useful at microwave frequencies, when the wavelengths are short enough to keep the patches tiny. Because it is simple to fabricate on printed circuit boards, it is commonly utilized in portable wireless devices.

Here are some examples of 1 GHz designed antenna (Bow-tie) applications:

- GSM
- GPS
- Bluetooth
- 2G,
- 3G,
- 4G,
- LTE
- DTH
- Public safety radio systems
- UHF etc.

CHAPTER 5

Conclusion & Future Works

5.1 Major Contributions of the Thesis

Patch antennas are popular because of their low profile, light weight, and low cost. They have several advantages over regular antennas. However, there are two major issues: limited bandwidth and poor gain.

This thesis looks at the difficulty of a single band patch microstrip antenna with a small bandwidth and low strength. To boost bandwidth, partial ground and inset slot cutting techniques were applied. Because slot has an influence on the host media's electromagnetic characteristics, it has the ability to increase antenna bandwidth and gain.

We suggested a preliminary design of a reconfigurable antenna based on the entire geometry morphing technique in this paper, with the goal of mimicking the behavior of 1.5–3 GHz bow-tie antennas in GPR applications. First, we demonstrated the antenna's design in free space, followed by the half-space situation. In addition, we have reported some preliminary results on the ability of the reconfigurable structure to achieve S-parameter invariance against varied values of the examined medium's dielectric permittivity. The influence of the switches and the related DC network on the radiation properties of the reconfigurable antenna will be addressed in future advancements. the entire implementation of the antenna thanks to the feed-line and absorption case designs; numerical characterization of the antenna's behavior in the presence of the other; hardware implementation of the suggested solution

The conclusions of the findings are encouraging and pleasing. In terms of bandwidth coverage and gain characteristics, the proposed antenna shows potential when compared to existing antennas.

5.2 Future Scope of Work

This thesis looked at the effect of slot and rectangular slots on the bandwidth of a rectangular patch antenna. Experimenting with alternative slot structures and changing the antenna type might be part of future development (including antenna form and substrate dielectric). An impedance matching network might be used to enhance impedance bandwidth.

In the future, a variety of strategies can be employed to construct optimal antennas, including the following:

- Electromagnetic Band Gap Structure (EBG)
- Metamaterials
- Split-Ring Resonator Structure (SRRS)

Fabrication of the antenna can be done in the future to monitor its performance in real time. The antenna construction is fairly basic, and the FR-4 Epoxy substrate is very common. As a result, it is incredibly simple to produce at a low cost. On the provided antenna, other frequently used techniques might be utilized to further improve antenna properties.

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