DESIGN OF A MINIATURIZED PLANAR ANTENNA WITH RECTANGULAR CONCAVE STRUCTURE FOR TRIPLE BAND APPLICATIONS

MINOR PROJECT-2 REPORT

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BONAFIDE CERTIFICATE

Certified that this Minor project-2 report entitled **"DESIGN OF A MINIATURIZED PLANAR ANTENNA WITH RECTANGULAR CONCAVE STRUCTURE FOR TRIPLE BAND APPLICATIONS"** is the bonafide work of **"MANINDRA. J (21UEEC0109), ESWARA VENKATA SAI .J (21UEEC0112) and YASWANTH SAI. N (21UEEC0209)"** who carried out the project work under my supervision.

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ABSTRACT

In this project, a planar crossed exponentially tapered slot antenna with a multi resonance function is introduced. The proposed antenna design is ascertained on a FR4 dielectric with a circular schematic. The antenna is designed to support several frequency spectrums of the current and future wireless communications. The configuration of the design contains a pair of crossed exponentially tapered slots intersected by a starshaped slot in the top layer and a bowtie shaped radiation stub with a discrete feeding point extended among the stub parts. The crossed exponential slots exhibit a wide impedance, and the star slot generates an extra resonance at the upper frequencies. For S11 6 dB, the antenna provides a wide operation band of 1.7GHz to 3.5 GHz supporting several frequency bands of 3G, 4G, and 5G in communication. The fundamental characteristics of the proposed slot radiator are studied, and good performances have been achieved. The purpose of designing the antenna in exponentially tapered slot is to increase the performance and to increase the bandwidth for WLAN application

A miniaturized triple band antenna is proposed. The antenna will be designed using CST Microwave studio. FR4 material is chosen as the dielectric substrate to construct the antenna. This triple band antenna is composed of a rectangular ring, a concave ring and a rectangular branch. By adjusting their shapes and sizes, three working frequency bands can be obtained. The antenna operates at 2.4 GHz, 3.3 GHz and 5.9 GHz and it is suitable for wireless local area network (WLAN) applications, World Interoperability for Microwave Access (WIMAX) applications and Bluetooth services.

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LIST OF SYMBOLS

FFT	-	Fast Fourier Transform
$WLAN$	-	Wireless Local Area Network
LAN	-	Local Area Network
WAN	-	Wide Area Network
MAN	-	Metropolitan Area Network
$Wi-Fi$	-	Wireless Fidelity
$WIMAX$	-	Worldwide Interoperability for Microwave Access

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Wireless local area network (WLAN) is commonly utilised nowadays. With the rise in popularity of smart phones and wireless technology, People are paying increasing attention to multiband and tiny antenna designs on the internet. Antennas are a type of antenna. developed with many characteristics in mind, such as low cost and ease of use many bands, construction, tiny size, low weight In Many steps must be taken in order to obtain small multi-band WLAN antennas. Many studies have been conducted, and many researchers have participated. new design methods offered A triple band antenna is proposed in this project. A rectangular ring, a concave ring, and a rectangular ring make up this ring. branch. By tweaking the parameters and altering the form, The antenna is capable of operating in three frequency bands.2.4 GHz, 3.3 GHz, and 5.9 GHz are the relevant frequencies. WLAN apps, WIMAX applications, and Bluetooth services can all use these frequency ranges. This antenna's medium is FR4, which is inexpensive and widely available. The CST programme was used to design and simulate this triple band antenna. The simulation results are promising, and this triple band antenna can handle WLAN and Bluetooth connection. The antenna designs are detailed in more detail below.

1.2 OBJECTIVE

Because wireless devices have become such an important part of most people's life, combining technologies like WLAN, WiMAX, Bluetooth, and others into a single device is a great way to boost commercial progress. Although wide band or ultrawideband antenna might be a viable option. Additional filters are required in systems with such antennas as a solution. Eliminate interfering signals from communication systems that are in use in the vicinity of bands A multiband antenna, for example, would be useful in this situation. proves to be a cost- effective solution because it eliminates the need for by suppressing non-essential bands with the filters and solids in the integration of a variety of wireless communication standards on a single system; effectively enhancing a system's mobility a contemporary wireless terminal device for personal use Because of this, the planar monopole antenna it's appealing Minimal profile and weight, as well as low cost, are some of the qualities. Wide impedance bandwidth, dual- or multitenancy mode, and desired radiation are all intriguing features of this structure.as a result of these attributes, he has become a popular choice among the Prototypes of triple/multiband antennas are known. Antennas, on the other hand When an object's size is reduced, designers have a significant difficulty. The antenna must be achieved as the number of antennas is increased. frequency bands in use

1.3 EXSISTING WORK

The present antenna is made up of two slots that radiate at two separate frequencies: 1.8GHz and 2.4GHz. It takes up a lot of space and achieves isolation of less than -18dB.The antenna's operational bands are created by etching two open-ended slots of varying lengths. The simple decoupling network consists of three open-ended slots, one wide for the larger resonant frequency and two narrow slots for the lower resonant frequency.

1.4 PROPOSED WORK

The suggested antenna radiates at three distinct frequency points: 2.4 GHz, 3.3 GHz and 5.9 GHz with mutual coupling between the antenna parts less than 18 dB over the whole frequency spectrum, making it appropriate for portable applications. The antenna is fabricated using FR4 dielectric substrate for better mechanical strength and DGS which increases gain and provides low capacity loss. Reflection coefficient of less than -6dB, VSWR less than 1.5 and impedance of 50Ω will be obtained using this antenna. The 3-3.5 GHz frequency range is used for LTE band 42 and 43 with high data rate speed. The suggested antenna has a broad operating frequency range of 1.8 – 3.5 GHz. The antenna is constructed with acceptable dimensions of 35 mm $\times$ 21 mm $\times$ 1.5 mm and an antenna element is a microstrip-line feed with two quarter wavelength slots. These slots reduce the electromagnetic coupling energy between the ports, resulting in good isolation. The operating frequency spectrum offers S11 6 dB, which is sufficient for wireless applications such as WiMAX and other commercial networks.

CHAPTER 2

LITERTAURE SURVEY

2.1 LITERTAURE SURVEY

J. R. Costa, C. R. Medeiros and C. A. Fernandes, "Performance of a Crossed Exponentially Tapered Slot Antenna for UWB Systems," in *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 5, pp. 1345-1352, May 2009, doi: 10.1109/TAP.2009.2016727.
Time domain analysis of the XETS revealed low pulse distortion effects, which were comprehensively quantified using the pulse fidelity parameter (varying from 70% to 95% over the solid angle) and the breadth of the 90% energy window (ranging from 0.21 ns to 0.41 ns). The worst outcomes are associated with the plane that contains the printed antenna, which is unavoidable. These results are consistent with the anticipated data speeds of several hundred Mbit/s. A balanced meal would produce better outcomes. It's worth noting that the planned antenna arrangement still leaves opportunity for advancement. The inclusion of correctly designed slots in the XETS can result in a notch in the antenna transfer function, preventing interference with WLAN bands and avoiding the need for additional specialised filtering.

D. Sarkar, K. V. Srivastava and K. Saurav, "A Compact Microstrip-Fed Triple Band-Notched UWB Monopole Antenna," in *IEEE Antennas and Wireless Propagation Letters*, vol. 13, pp. 396-399, 2014, doi: 10.1109/LAWP.2014.2306812.
In this letter, an elliptic complementary split ring and a rectangular split ring are embedded in an antenna framework to create a compact triple band-notched UWB monopole antenna. The suggested antenna has an impedance bandwidth that spans the whole UWB range (3.1–10.6 GHz) and includes notch-bands. WiMAX (3.3–3.8 GHz), WLAN (5.15–5.85 GHz), and X-band are all available (7.9–8.4 GHz) frequency range. The design standards and pertinent information HFSS simulations are used to describe and validate equations. A The prototype antenna is built in a PCB lab using low-cost FR4 wire substrate.

H. Zhai, Z. Ma, Y. Han and C. Liang, "A Compact Printed Antenna for Triple-Band

WLAN/WiMAX Applications," in *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 65-68, 2013, doi: 10.1109/LAWP.2013.2238881.

A unique small triple-band printed antenna has been conceived and implemented in this study. Three bands can be efficiently obtained for WLAN/WiMAX operations by appropriately tuning the three circular-arc-shaped strips, as demonstrated by measured and simulated results. It could be a better contender for multimode terminal design in integrated wireless communication systems due to its small size and good electromagnetic properties. The proposed small antenna may efficiently span three separated impedance bandwidths of 400 MHz (2.38– 2.78 GHz), according to measured results.

L. Li, X. Zhang, X. Yin and L. Zhou, "A Compact Triple-Band Printed Monopole Antenna for WLAN/WiMAX Applications," in *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 1853-1855, 2016, doi: 10.1109/LAWP.2016.2539358.

The paper presents a small printed monopole antenna for WLAN and WiMAX systems. The antenna may produce three resonant modes for desired applications by etching a rectangular slot in the ground plane and inserting a fork-shaped strip in a modified rectangular ring. The antenna is a good contender for WLAN/WiMAX applications because of its omnidirectional emission patterns, reasonable gains, small size, and ease of construction. The current node on the microstrip line has been relocated down, and the antenna's impedance has been altered.

W. Liu, C. Wu and Y. Dai, "Design of Triple-Frequency Microstrip-Fed Monopole Antenna Using Defected Ground Structure," in *IEEE Transactions on Antennas and Propagation*, vol. 59, no. 7, pp. 2457-2463, July 2011, doi: 10.1109/TAP.2011.2152315.

With simulated and measured results, a novel microstrip-fed antenna design based on the patch monopole for a triple-frequency operation has been presented. The proposed antenna can excite triple-resonances and has a suitable radiation performance to cater to the operation requirements of both the 2.4/5.2/5.8 GHz WLAN and the 3.5/5.5 GHz WiMAX communication systems, thanks to the skills of defecting the ground plane, protruding the patch with dual protruding strips, and feeding the patch with a cross-shaped stripline. The antenna prototype has been built and tested, and it matches the numerical prediction very well. The effects of the DGS, cautious strips, and cross-shaped stripline, as well as changing the diameters of these structures, on antenna resonant frequencies and impedance bandwidths, have also been investigated

Z. Tang, X. Wu, J. Zhan, S. Hu, Z. Xi and Y. Liu, "Compact UWB-MIMO Antenna with High Isolation and Triple Band-Notched Characteristics," in *IEEE Access*, vol. 7, pp. 19856-19865, 2019, doi: 10.1109/ACCESS.2019.2897170.

This paper presents a four-element small UWB-MIMO antenna. Miniaturization and excellent performance are achieved by combining symmetric layout, orthogonal structure, separated four-directional staircase-shaped decoupling, and multi-slot and multi-slit techniques in an organic way. Simulating and measuring some critical parameters, such as S-parameters, gain, radiation patterns, isolation, and MIMO diversity, is also done. The measured and simulated findings are very close to one another.

S. Priya and S. Dwari, "A Compact Self-Triplexing Antenna Using HMSIW Cavity," in *IEEE Antennas and Wireless Propagation Letters*, vol. 19, no. 5, pp. 861-865, May 2020, doi: 10.1109/LAWP.2020.2982533.
The HSS system is similar to an airbag in a car. Hopefully, it will never be required to operate throughout the duration of the equipment's life, but if it is, it must do so immediately. It is unacceptable to engage in a nuisance operation. In regular operation, the device cannot be tested. It must be believed. HSS designs haven't been around in a very long time. More success stories confirming the switch's, light sensors', and electronics' robustness are expected to emerge as time goes on. HSS systems should be seriously examined for medium-voltage switchgear installation. There are other ways to safeguard your equipment from arc flash risks. Along with plant safety, switchgear size, importance, cost, complexity, growth needs, and architectural concerns should be considered.

Zhai, Huiqing; Liu, Lu; Ma, Zhihui; Liang, Changhong (2015). A Printed Monopole Antenna for Triple-Band WLAN/WiMAX Applications. International Journal of Antennas and Propagation, 2015(), 1– 7. doi:10.1155/2015/254268
Two band-notches have been used to create and construct a new compact triple- band printed antenna in this work. based on the use of a broadband antenna The first appearance of the tiny engraved paper clip structure can help you save time and money. the dimension zones that have been etched At this time, the antenna is Three distinct operating bands are well-suited to triple band WLAN/WiMAX systems, as demonstrated by the architecture. Results were simulated and measured. Furthermore, the parameters the investigation of the two etched paper clip architectures to change the two's centre placements and bandwidths Stop- bands are used to divide the three operating bands. Multimode programmes have been redesigned to be more flexible.

Ellis, Mubarak Sani; Zhao, Zhiqin ; Wu, Jiangniu; Nie, Zai-Ping; Liu, Qing Huo (2014). A NEW COMPACT MICROSTRIP-FED MONOPOLE ANTENNA FOR TRIPLE BAND WLAN/WIMAX APPLICATIONS. Progress In Electromagnetics Research Letters, 48(), 129– 135. doi:10.2528/pierl14061004
In this paper, a tri-band microstrip fed monopole antenna for WLAN/WiMAX applications is given. Three inverted L-shaped strips are used to create the triple band. The antenna may also be rearranged in a variety of ways without impacting its function, according to the findings. This demonstrates that the suggested antenna is simpler, more compact, easier to tune, and more adaptable than other triple band antennas that have been proposed. The results of the experiments show that it has stable radiation qualities and wide bandwidths, making it appropriate for real WLAN/WiMAX applications.

CHAPTER 3

ANTENNA THEORY

Antennas are an indispensable part of any wireless communication system. In today's scenario, although, antenna as a device is not new to common man, but understanding the background concept involved in the working of this device will certainly help in designing new versatile antennas, in order to meet the stringent requirements of wireless communication engineers.

3.1 ANTENNA PARAMETER

It is necessary to understand several terms associated with antenna which is formally known as antenna parameters. Important parameters need to be considered to characterize the antenna are return loss, radiation patter, half – power beam width, VSWR, antenna efficiency, bandwidth, directivity and gain.

3.2 ANTENNA GAIN (DBI/NUMERIC) EFFICIENCY

Antenna gain is a relative quantity that quantifies the amount of power transmitted by an antenna in its primary direction in relation to an isotopically radiating source. An antenna with a 6 dB antenna gain, for example, would receive 6 dB more power than an isotropic antenna in the same position. Antenna gain can be expressed in terms of dBi, which is dB relative to an isotropic antenna, or dBd, which is dB compared to a dipole antenna (2.15 dBi).

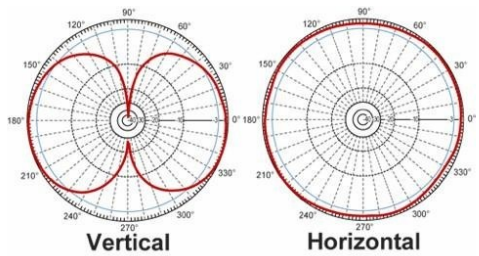

Figure 3.1: Antenna Gain Efficiency

3.3 ANTENNA DIRECTIVITY

A fundamental antenna parameter is directivity. It is a measure of how 'directional' the radiation pattern of an antenna is. An antenna that radiates evenly in all directions would have effectively zero directionality, and its directivity would be one (or 0 dB).

$$D = \frac{1}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}|F(\theta,\phi)|^2 \sin\theta d\theta d\phi}$$

Figure 3.2: Antenna Directivity Formula

3.4 ANTENNA EFFICIENCY

Radiated efficiency compares the power radiated as an electromagnetic wave by the antenna to the power delivered to the antenna terminals. If an antenna could be designed to be a completely perfect electrical component, it would convert all of the power provided to its terminals to a radiating signal. Electromagnetic energy that spreads over the surrounding space This is only possible inAs a result, in practise, some of the power delivered to the antenna terminals is constantly lost. For example, a mismatch between the antenna element and the feeding network results in power loss.

$$Antenna\ Efficiency = \frac{P_{RAD}}{P_T}\ \%$$

3.5 ANTENNA EFFECTIVE AREA

The effective area or effective aperture of an antenna is a helpful statistic for determining its receive power. Assume a plane wave with the same polarisation as the receive antenna strikes the antenna. Assume that the wave is travelling towards the antenna in the direction of maximum radiation from the antenna (the direction from which the most power would be received). The effective aperture parameter, on the other hand, defines how much power is captured from a given plane wave. Let p denote the plane wave's power density (in W/m2). If P t represents the power (in Watts) available to the antenna's receiver at the antenna's terminals, then:

$$Pd = SA_{eff}$$

3.6 STRIP LINE

Strip line is a type of printed circuit transmission line in which the signal trace is sandwiched between upper and lower ground planes, as depicted in three- dimensional and cross-sectional views. There are several advantages to this configuration, the most prominent of which is that the electromagnetic radiation is completely encased within a homogeneous dielectric, limiting emissions and providing natural shielding against incoming spurious signals. It is also worth noting that, while the two ”ground” planes represent AC grounds, they can be at different DC potentials, allowing for convenient DC power distribution.

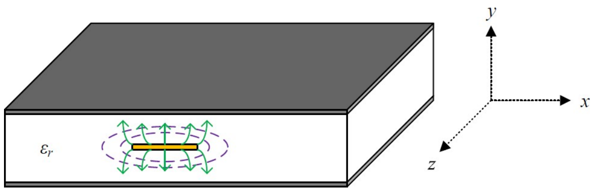

Figure 3.3: Antenna Strip Line

3.7 ANTENNA LENGTH AND WIDTH

At the lowest frequency of operation, the antenna length should be higher than a free space wavelength. This criteria ensures adequate gain and beam width performance. The lowest frequency of operation, and hence the bandwidth, is also affected by antenna length, with longer antennas providing a broader bandwidth. When the requirements for gain and beam width are not as stringent, an antenna length of the order of the 0 will suffice to obtain the appropriate bandwidth. To achieve the necessary radiation performance, the antenna width must be bigger than one-half wavelength at the lowest frequency of operation, 0/4. Reduced antenna width below this value reduces the lowest frequency of operation and consequently the antenna bandwidth significantly.

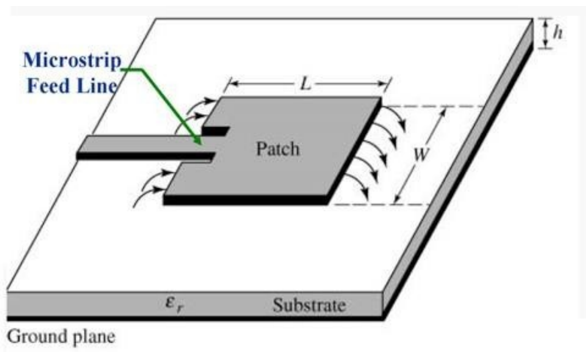

Figure 3.4: Antenna Microstrip

3.8 ANTENNA BEAM WIDTH

Beamwidth is the angle from which the majority of the antenna’s power emanates, as shown on the main lobe of the radiation pattern. It is the distance between two places where the power is less than half of the maximum and can be measured in either the horizontal or vertical planes.
Beamwidth changes with an antenna’s physical and electronic parameters, such as type, design, direction, and frequency. It might be horizontal (azimuth) or vertical (elevation), or it can be around

360 degrees horizontally in the case of omni-directional antennas.

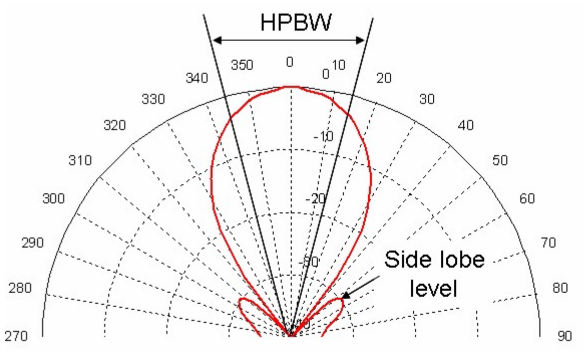

Figure 3.5: Antenna Beam Width

3.9 BEAMWIDTH AND SIDELEVELS

Aside from directivity, antenna radiation patterns are distinguished by beamwidt hs and sidelobe levels. The primary beam is the area surrounding the maximum radiation direction (usually

$$R(\theta) = \sin\theta \frac{\sin\left(4(\theta - \frac{\pi}{2})\right)}{4(\theta - \frac{\pi}{2})}$$

the region that is within 3 dB of the peak of the main beam). The primary beam is centred at a 90-degree angle. Sidelobes are tiny beams that are separated from the main beam. These sidelobes are typically radiation in unfavourable directions that can never be totally eradicated. The sidelobes are located at approximately 45 and 135 degrees. The angular separation at which the magnitude of the radiation pattern decreases by 50

3.10 ANTENNA BANDWIDTH

Bandwidth is simply defined as a frequency range over which an antenna meets a certain set of specification performance criteria. A significant issue to consider about bandwidth is the performance tradeoffs between all the performance properties. Many definitions are there to define bandwidth. In this research the bandwidth is considered at -10dB at lower and upper frequency at center frequency from the return loss graph. 11 Fig. 3.2 Return loss Vs Bandwidth It all situations, the required performance properties of an antenna are achieved only the limited frequency bandwidth. Bandwidth range is the significant aspect to the performance requirements, selected antenna type and its size relatives to the operating wavelength. Normally, optimum antenna performance is achieved at the center frequency of the operating hand.

$$\text{Bandwidth} = \frac{f_2 - f_1}{f_0} \text{ x } 100\%$$

Where

f2 is upper frequency

f1 is lower frequency and f0 is center frequency

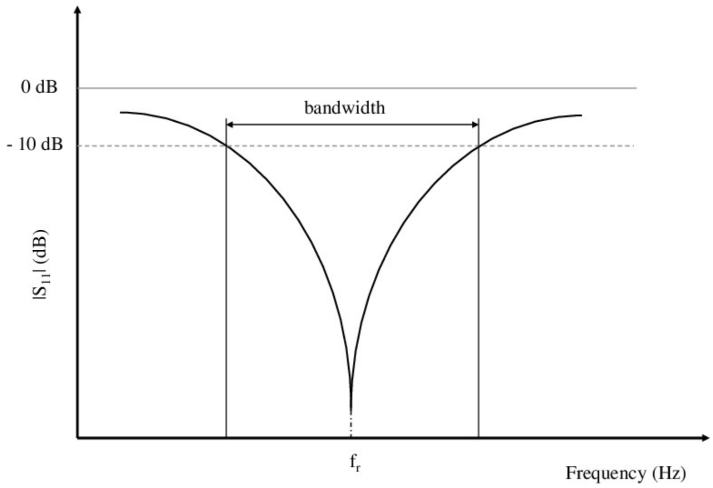

Figure 3.6: Antenna Bandwidth

Another important antenna characteristic is bandwidth. The bandwidth of an antenna indicates the frequency range over which it can adequately emit or receive energy. The intended bandwidth is frequently one of the determining parameters used to select an antenna. Many antenna types, for example, have extremely narrow bandwidths and cannot be used for wideband operation.

CHAPTER 4

DESIGN OF ANTENNA

4.1 SUBSTRATE MATERIAL

The use of FR-4 substrate as a potential candidate for X-band antenna design Single element microstrip antennas with frequencies ranging from 2 to 10 GHz have been designed for this purpose. The effects of frequency increase on antenna performance have been investigated. S-parameters were used as a metric for comparing simulated and fabricated antennas. Low dielectric constant substrates also lower the scattering along the antenna and consequently spurious fields. FR-4 offs, bus bars, washers, arc shields, transformers and screw terminal strips Losses in FR4 increase with frequency and become significant for frequencies above 1 GHz, becoming progressively more significant as frequency increases. The dielectric constant is not as tightly controlled as in 'proper' (job-specific and more expensive) microwave materials.

4.2 SUBSTRATE THICKNESS

Planar microstrip antennas are becoming increasingly popular as communication systems progress from 3G to 5G. They play an important role in increasing bandwidth and making it available. Slimmer and more fashionable in order to fit in with communication Lines with microstrips or microstrip antennas are essentially a component used to develop the Planar geometry is a concept. Microstrip antennas are more common. Useful and in being used solely for the ease of fabrications well as the ability to change its structure as needed use. Patch antennas, also known as microstrip patch antennas, are widely used. are in high demand in the age of WiFi and WiMax Researchers are working hard to make it slick, thin, and durable. Suitable for use in these ranges It has a lot of benefits with certain limitations,

4.2.1 THIN SUBSTRATE AND THICK SUBSTRATE COMPARISON

Firstly, as the mathematical expressions for the components of the Green's function necessarily contain both space and surface wave components, the electric surface current model is valid for

THIN SUBSTRATE	THICK SUBSTRATE
High dielectric	Low dielectric constant
constant Less efficiency	Better efficiency
Smaller element	Larger bandwidth
size Lighter in weight	Larger element size
Smaller bandwidth	Increase in weigh
Minimum dielectric loss	Increase in dielectric loss

Table 4.1: Difference between Thin and Thick Substrate

electrically thick substrates, whereas the variational approach is applicable only to antennas with electrically thin substrates. The wider bandwidth is usually accomplished by using a thick substrate with low permittivity; yet there is a limit on the maximum useable substrate thickness such that surface waves will not be radiated. Here increasing the substrate thickness increases the excitation of surface waves, resulting in lowered efficiency and also bandwidth. The design of the antennae is complicated by the added matching structures, diodes, shorting pins and their associated biasing structures. When a frequency greater than 10 GHz is used, the size of antenna elements becomes small, hence it is not

4.3 ANTENNA STRUCTURE

The geometry of the proposed antenna has been shown in fig. 5(a) and specifications of the design have been given in Table I. A microstrip feed line of width 1.04 mm has been used in order to achieve a characteristic impedance of 50 Ω. A layout of the radiator has been given in figure.The planar antenna consists of an rectangle -shaped patch (element 1) which is fed directly by the microstrip feed line and is placed on the top section of the dielectric substrate and a parasitic resonator (element 2) placed on the bottom and is directly connected to the ground. Element 1 is responsible for generation

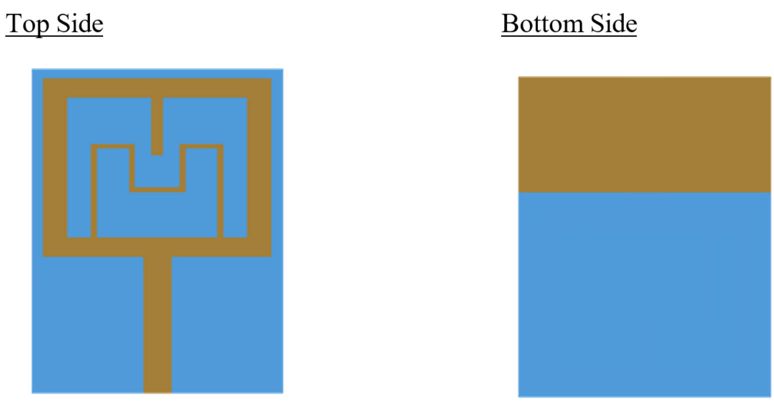

Figure 4.1: Antenna Top and Bottom side

of the wide5GHz frequency band for the higher WLAN bands at 5.2 and5.8 GHz as well as the WiMAX band at 5.5 GHz. The presence of element 2 leads to the generation of the bands at 2.3 GHz and 3.5 GHz for the lower bands of WLAN, WiMAX and Bluetooth. If seen from the top, element 2 seems to surround element 1 with a gap ‘g’ between them. Together they occupy an area of around 15.9 mm x 7.4 mm. The ground plane is around 40 mm x 20 mm in size and the overall dimensions of the antenna are 40 x 30 x 0.8 mm3. The antenna has been designed on a dielectric substrate with a relative permittivity of 3.5 and a loss tangent of 0.02. The antenna dimensions have been optimized using computer simulations.

Top:

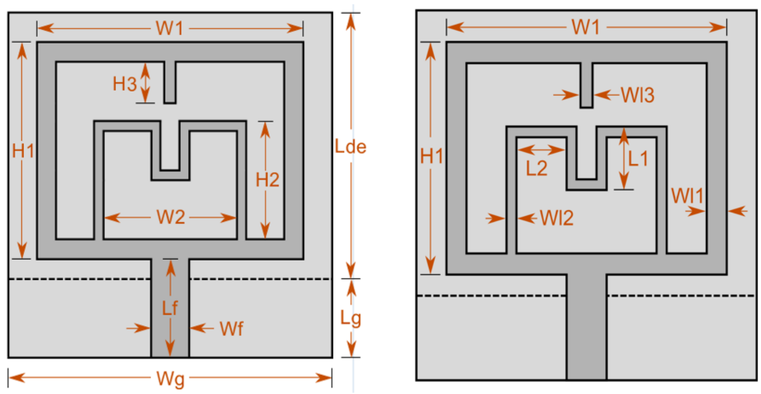

Figure 4.2: Antenne Top Geometry

The proposed antenna’s geometry is shown in Fig. 5(b), and the design specifications are given in Table I.To achieve a characteristic impedance of 50, a 1.04 mm wide microstrip feed line was used.The radiator’s layout is depicted in Figure 1. The planar antenna consists of a rectangle-shaped patch (element 1) placed on the top section of the dielectric substrate and fed directly by the microstrip feed line

Bottom:

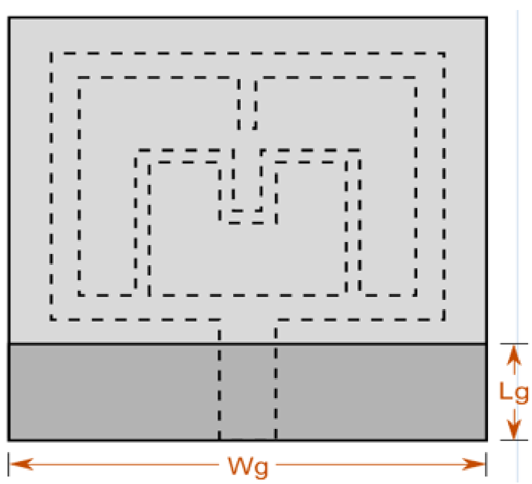

Figure 4.3: Antenne Bottom Geometry

4.4 ANTENNA DESIGN PARAMETER

Antenna Parameters

Name	Description	Value (mm)
Wg	Ground plane width	21.43
Lg	Ground plane length	12.50
Wf	Feed line width	2.392
Lf	Feed line length	14.58
W1	Width of the large loop	19.48
W2	Width of the inner loop	10.24
H1	Height of the large loop	19.10
H2	Height of the inner loop	9.995
H3	Height of the monopole element	6.158
L1	Length of the meander section of the inner loop	5.156
L2	Distance between meander section and lines of the inner loop	2.710
W11	Line width of the large loop	2.083
W12	Line width of the inner loop	520.8
W13	Line width of the monopole	1.042
Lde	Dielectric extension above ground plane length	22.19
H	Substrate height	1.5mm

Table 4.2: Antenna Parameters

4.5 COMPUTER SIMULATION TECHNOLOGY

CST is a high-performance 3D EM analysis software package for designing, analysing and optimizing electromagnetic (EM) components and systems. Electromagnetic field solvers for applications across the EM spectrum are contained within a single user interface in CST. The solvers can be coupled to perform hybrid simulations, giving engineers the flexibility to analyse whole systems made up of multiple components in an efficient and straightforward way. EM simulation to be integrated into the design flow and drives the development process from the earliest stages. Common subjects of EM analysis include the performance and efficiency of antennas and filters, electromagnetic compatibility and interference (EMC/EMI), exposure of the human body to EM fields, electro- mechanical effects in motors and generators, and thermal effects in high-power devices. CST Studio Suite is used in leading technology and engineering companies around the world. It offers considerable product to market advantages, facilitating shorter development cycles and reduced costs. Simulation enables the use of virtual prototyping. Device performance can be optimized, potential compliance issues identified and mitigated early in the design process, the number of physical prototypes required can be reduced, and the risk of test failures and recalls minimized.

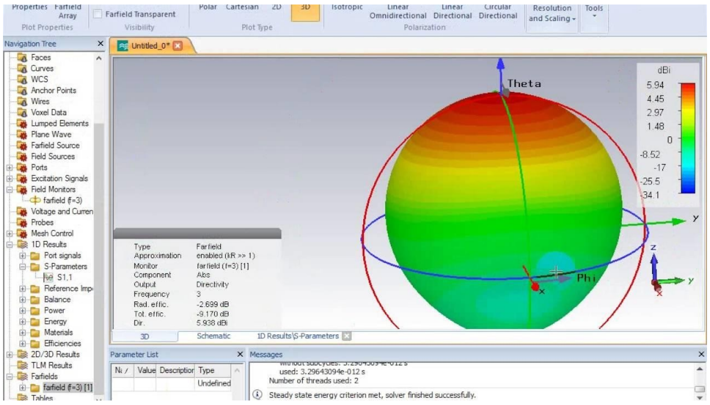

Figure 4.4: Antenne Bottom Geometry

FEATURES OF CST

- CST provides a wide range of applications across the electromagnetic spectrum as well as multi physics and particle applications.
- All CST tools are available and can be linked together for direct hybridization of simulations. CST offers unparalleled performance, making it first choice in technology leading R&D departments.
- CST enables the fast and accurate analysis of high frequency devices such as antennas, filters, couplers, planar and multilayer structures and EMC effects.
- The tool filter designer 3D (FD 3D) can automatically synthesize cross coupled and diplexer filter designs to meet the specifications including the Q factor and transmission zeros.

CHAPTER 5

SIMULATED RESULT

5.1 RESULTS

The design of the triple band antenna is introduced in the previous section. In this section, we use CST simulation software to simulate and optimize the antenna. CST Microwave simulation software is widely used in antenna simulation because of its convenient designs and reliable results. The simulated result of the proposed triple band antenna is shown

5.2 S PARAMETER (S11) OR RETURN LOSS

The measurement of the amount of light that is reflected back toward the source is called Return loss, and its unit of expression is also in decibels (dBs). Furthermore, this measurement parameter is always a positive number, and a high return loss is a favorable measurement parameter, and it typically correlates to a low insertion loss. Similarly, reflectance, which is also a measurement parameter that expresses reflection in decibels, is a negative number, and if it is excessive, it is not a favorable measurement parameter.

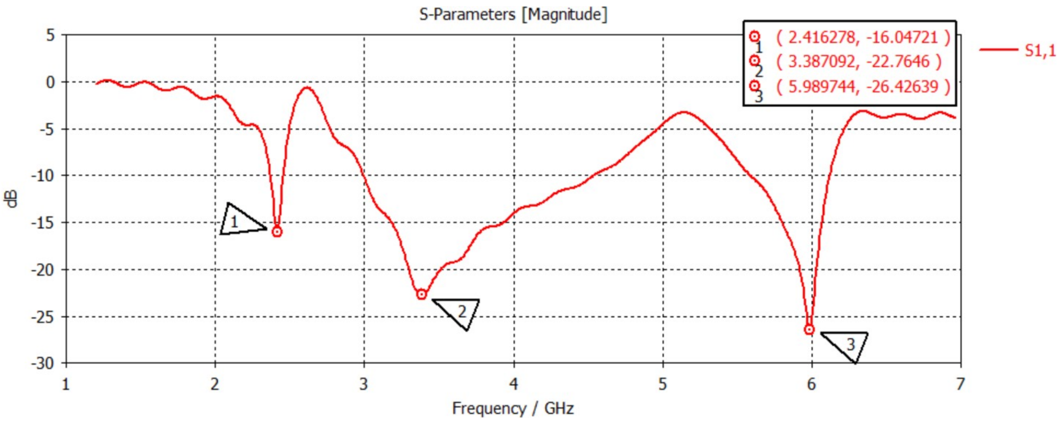

Figure 5.1: Bandwidth from S11

5.3 BANDWIDTH FROM S11

At 2.4 GHz

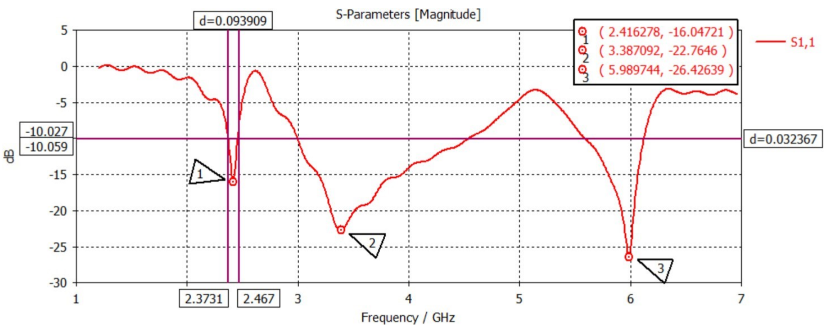

Figure 5.2: Bandwidth from S11 – 2.4 Ghz

At 3.3 GHz

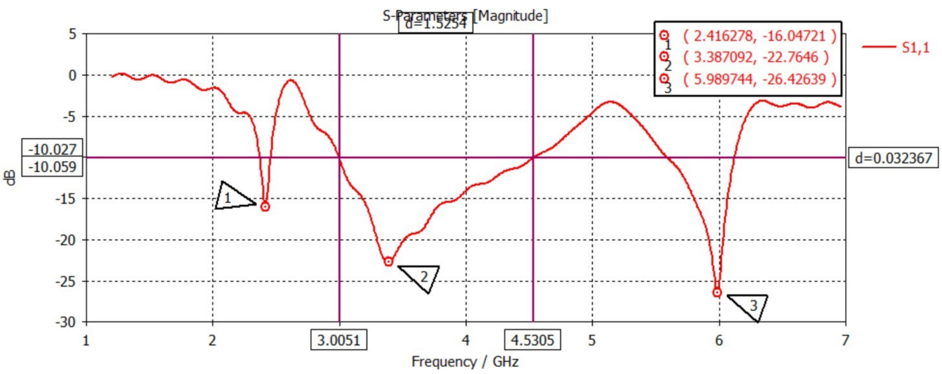

Figure 5.3: Bandwidth from S11 – 3.3 Ghz

At 5.9 GHz

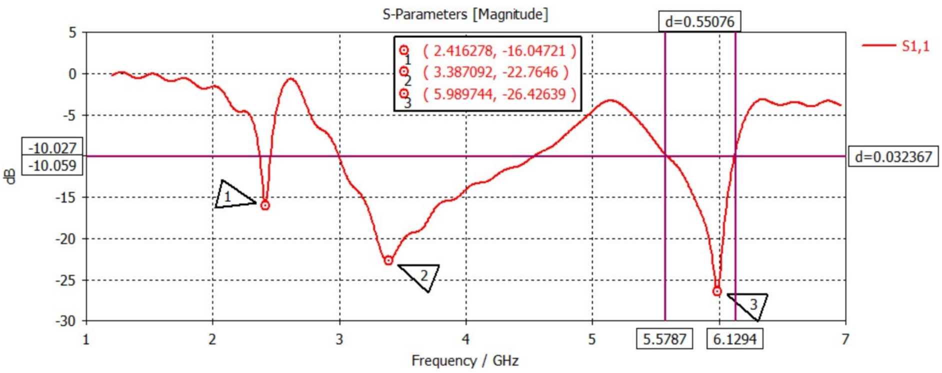

Figure 5.4: Bandwidth from S11 – 5.9 Ghz

5.4 VSWR

The Voltage Standing Wave Ratio (VSWR) is an indication of the amount of mismatch between an antenna and the feed line connecting to it. This is also known as the Standing Wave Ratio (SWR). The range of values for VSWR is from 1 to . A VSWR value under 2 is considered suitable for most antenna applications So when someone says that the antenna is poorly matched, very often it means that the VSWR value exceeds 2 for a frequency of interest. Return loss is another specification of interest and is covered in more detail in the Antenna Theory section. **At 5.9 GHz**

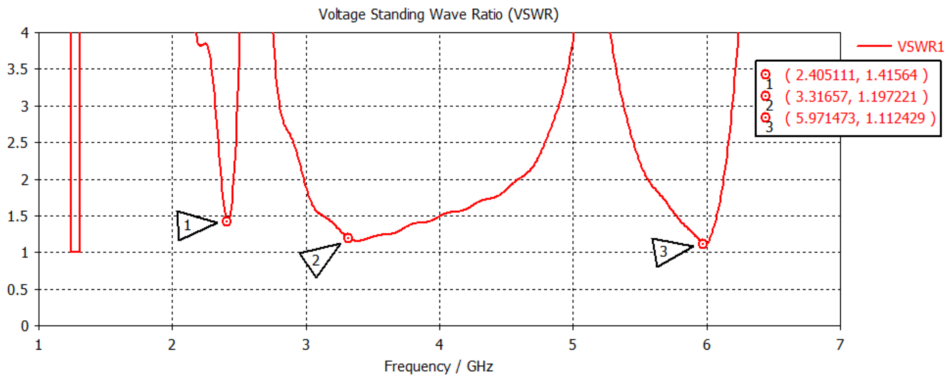

Figure 5.5: Bandwidth from S11 – 5.9Ghz

5.5 EFFICIENCIES

The radiation efficiency of a small loop is proportional to the square of the frequency (+40 dB/decade). The results demonstrate that the proposed antenna exhibits an average radiation ef-

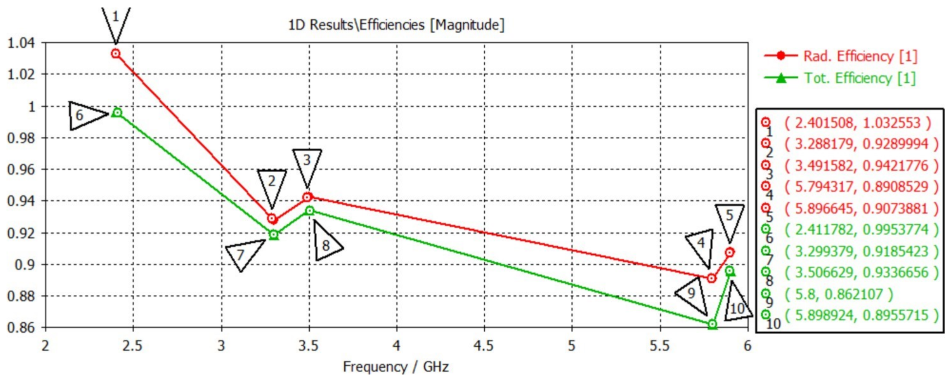

Figure 5.6: Effiecncy

ficiency of 72% over the frequency range of the WLAN band, which makes it suitable for WLAN application

5.6 FAR FIELD

Far-field refers to the field that is located far away from the antenna. It is also known as a radiation field because the radiation effect is strong in this area. Many antenna parameters, such as antenna directivity and radiation pattern, are only taken into account in this region. The simulated far-field (3D) radiation pattern of the antenna shows dual beam radiation pattern. The simple physical geometry of the antenna is attractive for use in intelligent transportation systems

3D Pattern Gain At 2.4 GHz

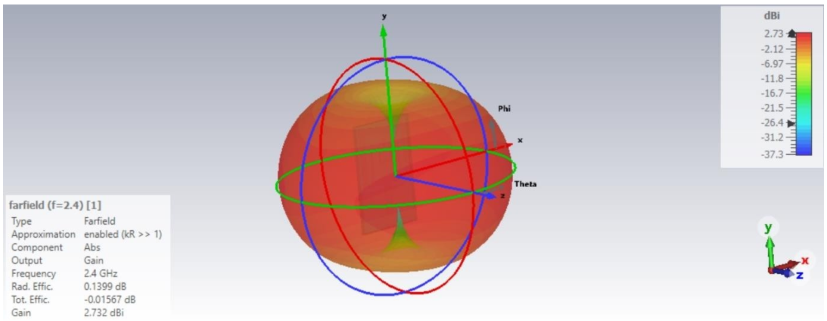

Figure 5.7: 3D pattern and gain – 2.4GHz

3D Pattern Gain At 3.3 GHz

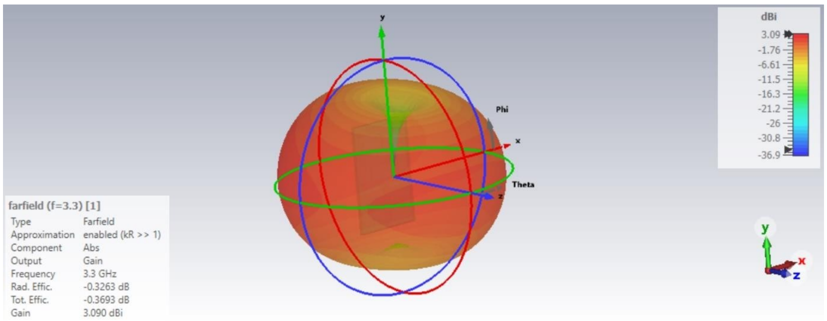

Figure 5.8: 3D pattern and gain – 3.3GHz

3D Pattern Gain At 5.9 GHz

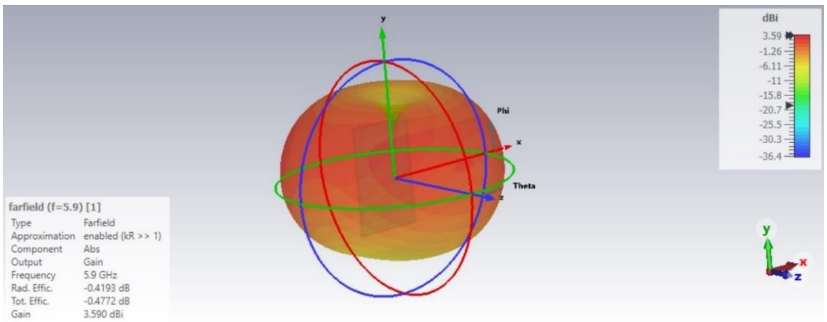

Figure 5.9: 3D pattern and gain – 5.9GHz

3D Pattern Directivity At 2.4 GHz

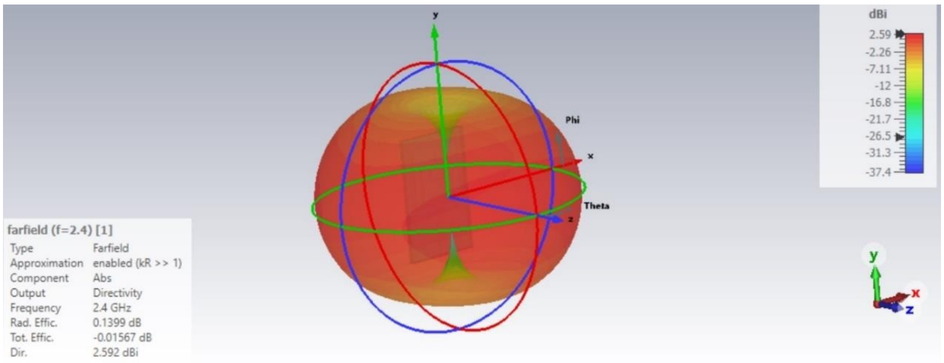

Figure 5.10: 3D pattern and Directivity – 2.4GHz

3D Pattern Directivity At 3.3 GHz

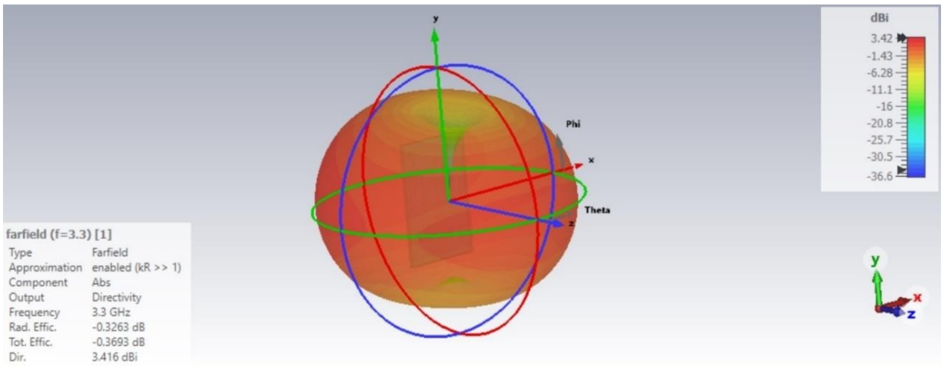

Figure 5.11: 3D pattern and Directivity – 3.3GHz

3D Pattern Directivity At 5.9 GHz

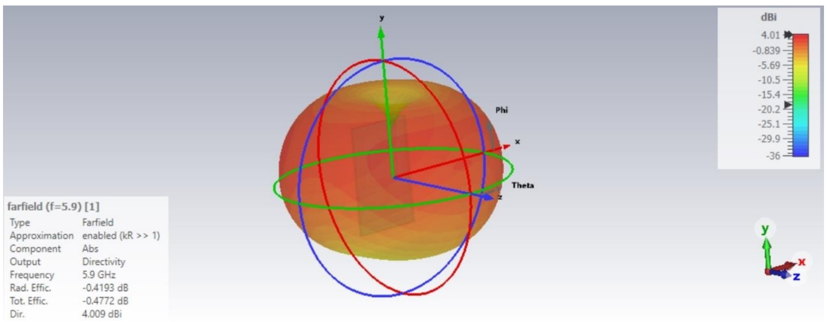

Figure 5.12: 3D pattern and Directivity – 5.9GHz

5.7 POLAR PATTERN AND GAIN

An isotropic antenna radiates equally in all directions (that's the definition of an isotropic antenna), so the average power per unit solid angle (steradian) is the same as the "instantaneous" power per unit solid angle. The gain of an antenna is just the amount of power in the direction of maximum radiation divided by the average power (so it is unitless). If the radiation pattern has cylindrical symmetry about the axis of maximum radiation, you can integrate it to get the total power (in picture Decibels). You could then compute the average power (total power divided by 4 pi). In this case you would get -9 dB for the average power per steradian. To the sides of the main lobe we may find areas where the radiation is higher than the adjacent areas. These are side lobes. The side lobes are usually separated by areas of little radiation called nulls. There is usually a side lobe in the direction opposite the main lobe. This special side lobe is known as the back lobe.

Polar Pattern Gain At 2.4 GHz

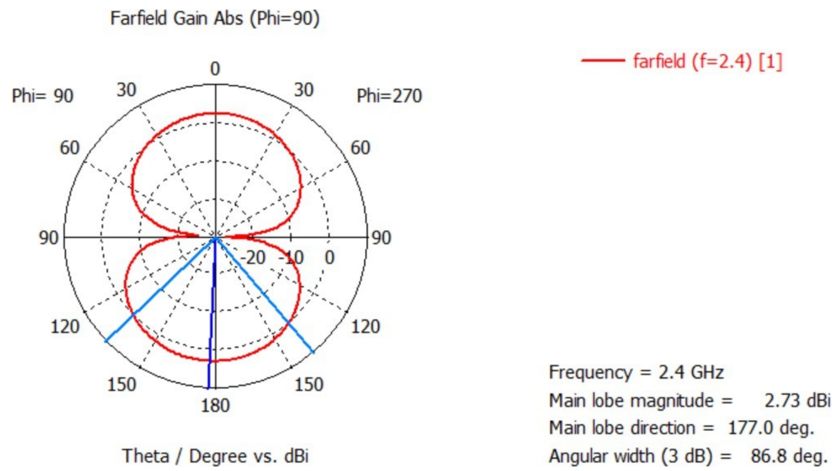

Figure 5.13: Polar pattern and gain – 2.4 GHz

Polar Pattern Gain At 3.3 GHz

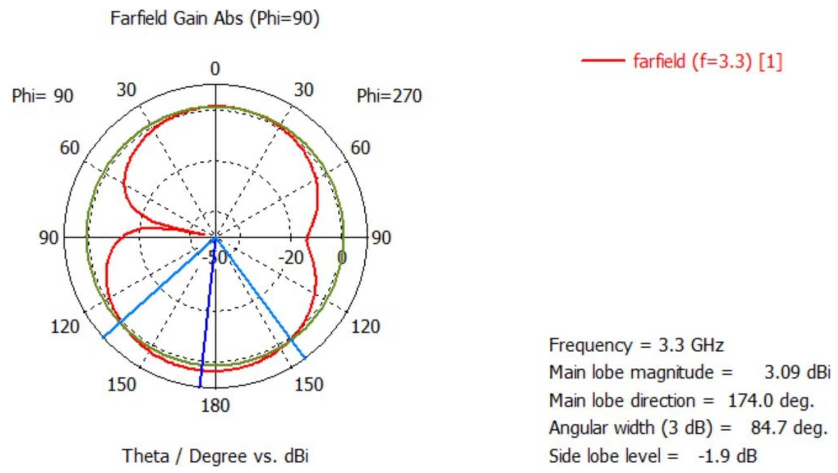

Figure 5.14: Polar pattern and gain – 3.3 GHz

Polar Pattern Gain At 5.9 GHz

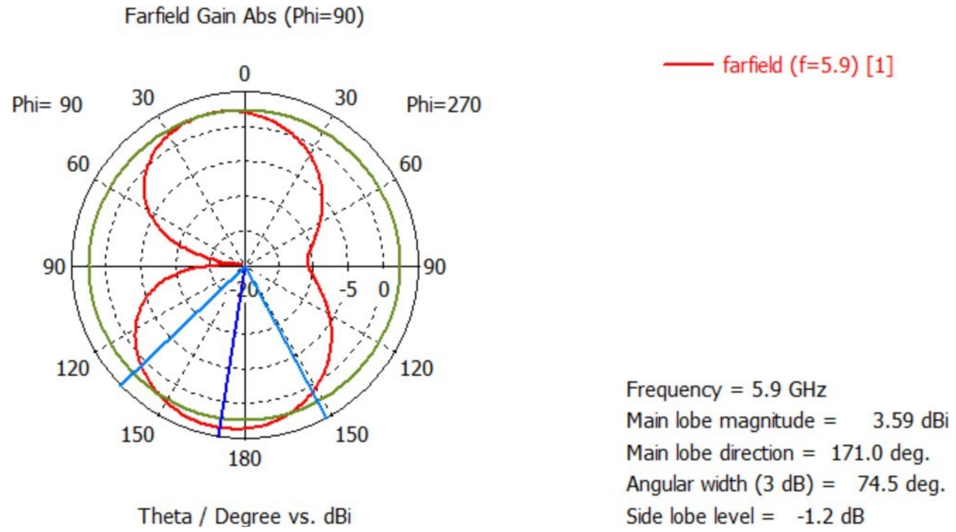

Figure 5.15: Polar pattern and gain – 5.9 GHz

5.8 SURFACE CURRENT DISTRIBUTION/CURRENT DENSITY AT 2.4 GHZ

A radio-frequency current on a wire of radius aa made from a metal with sufficiently high conductivity can be modeled as a uniform surface current existing on the wire surface. In this case, the current is best described as a surface current density JsJs, which is the total current II on the wire divided by the circumference 2a2a of the wire:

$$\mathbf{J}_s = \hat{\mathbf{u}}\frac{I}{2\pi a} \quad \text{(units of A/m)}$$

Surface Current Distribution/Current Density At 2.4 GHz

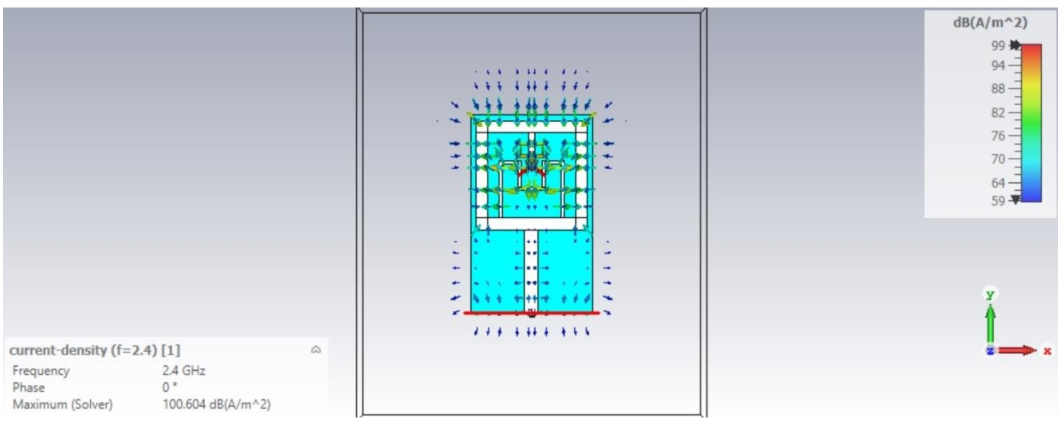

Figure 5.16: Surface Current Density 2.4 GHz

Surface Current Distribution/Current Density At 3.3 GHz

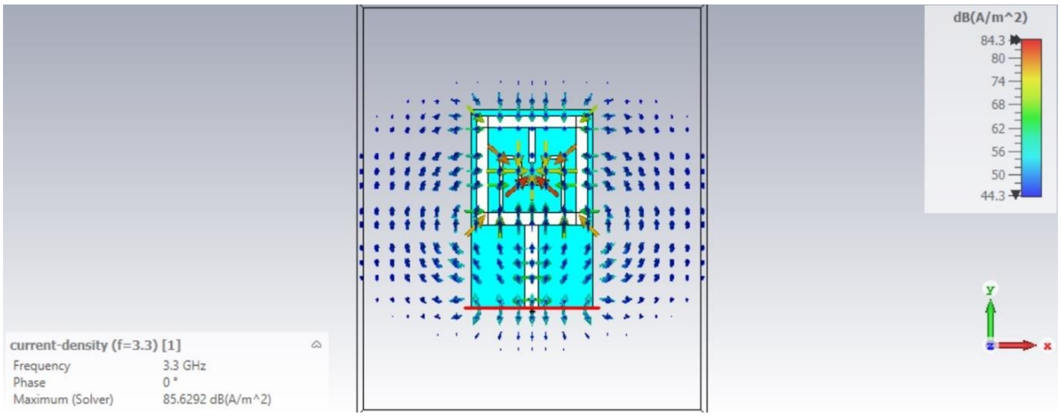

Figure 5.17: Surface Current Density 3.3 GHz

Surface Current Distribution/Current Density At 5.9 GHz

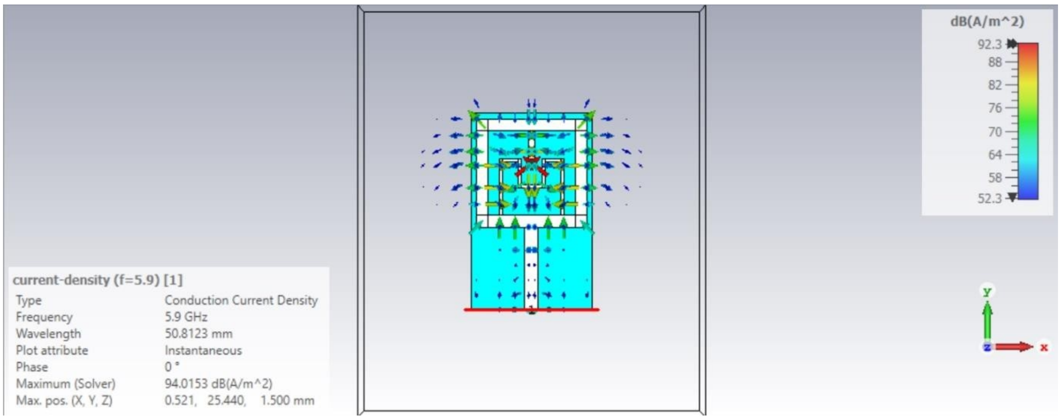

Figure 5.18: Surface Current Density 5.9 GHz

CHAPTER 6

CONCLUSION

The proposed planar antenna with a rectangular concave structure designed for triple band applications has achieved a compact size, high radiation efficiency, and robust performance. Through parametric studies and optimization, the antenna's dimensions and parameters have been tailored to achieve triple-band operation, large bandwidth, and high gain. The rectangular concave structure has enhanced the antenna's bandwidth and gain, while the optimized patch and substrate dimensions have enabled miniaturization without compromising performance. With a reduced size of 30% compared to traditional designs, this antenna offers a promising solution for modern communication systems, including WLAN, satellite communication, and IoT devices, and demonstrates a significant advancement in miniaturized planar antenna technology.

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