OPEN ACCESS

Middle East Research Journal of Engineering and Technology
ISSN: **2789-7737** (Print) **2958-2059** (Online)
Frequency: Bi-Monthly
DOI: 10.36348/merjet.2023.v03i01.003

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Design and Analysis of MSPA using FR-4 Epoxy Dielectric for Wireless Broadband Application

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Abstract: In modern communication devices, microstrip patch antennas are preferred to conventional antennas due to their size. In this review, a survey of commonly used techniques and designs for microstrip antennas is conducted. These techniques and designs were used by the authors to design an effective, low-profile, small, compatible, and affordable microstrip antenna. They were mostly used to design reconfigurable, multiband, and wideband antennas. After that, a initiator patch design with dimensions is provided on which technique will be used to analyze various antenna parameters. In recent years, research into microstrip patch antennas has made significant progress. Microstrip patch horns outperform conventional microstrip patches in a number of ways, including their low cost, ease of integration with integrated microwave circuits (MICs), low volume, small size, high performance, and low weight.

Keywords: Microstrip patch antenna (MPA), Performance Parameters, Return Loss, Directivity, Gain.

Review Paper

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How to cite this paper:
Sneha Srishti *et al.;* "Design and Analysis of MSPA using FR-4 Epoxy Dielectric for Wireless Broadband Application". Middle East Res J. Eng. Technol, 2023 Jan-Feb 3(1): 12-20.

Article History:
| Submit: 15.12.2022 |
| Accepted: 01.01.2023 |
| Published: 21.01.2023 |

1. INTRODUCTION

An antenna is a transducer used in any wireless communication system to transmit and receive electromagnetic waves from a transceiver. Any wireless communication system's most fundamental and crucial component is this. Antenna gain, aperture, effective length, bandwidth, polarization, and other performance parameters are just a few examples [1-3]. Antennas come in a variety of forms, including wire, reflector, microstrip patch, and others. The group of planar antennas known as microstrip patch antennas (MSPA) has been the subject of extensive research and development over the past four decades [4-6]. They have gained popularity among antenna designers and have been utilized in numerous commercial and military wireless communication system applications. The theory, analysis, and design of this antenna are the focus of this paper. At the beginning of this paper, we briefly overview various MSP feeding strategies [7-9]. The paper then, at that point, talks about, in everyday terms, the essential calculation of the MSPA, material contemplation, and different receiving wire boundaries. The following is a discussion of the knowledge and abilities required to design MSPAs [10-12]. The electromagnetic spectrum and how it is used for various wireless communication applications are included at the end of the paper for easy reference. The Figure1 depicts the structutre of Microstrip Patch Antenna (MSPA).

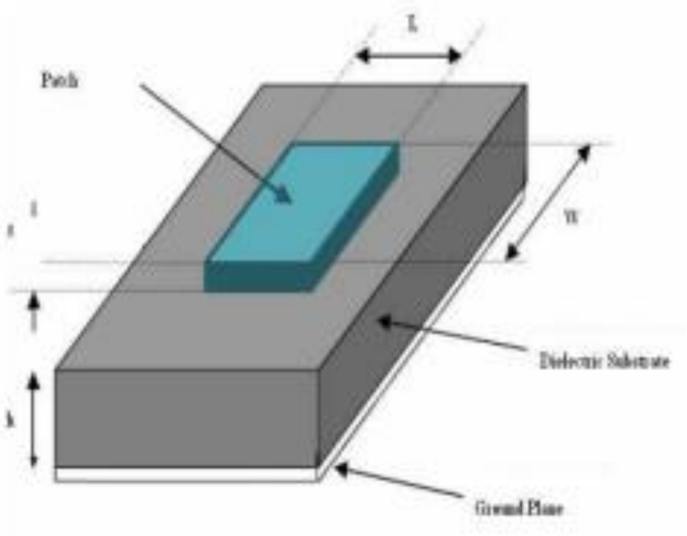

Figure 1: Structure of Microstrip Patch Antenna

Mobile communication requires small, low-cost, low-profile antennas. Microstrip patch antenna meets all requirements and various types of microstrip antennas have been designed for use in mobile communication systems. The IEEE 802.16 standard is known as WiMAX. It can reach up to 30-mile radius theoretically and data rate 70 Mbps. MPA generates several resonant modes and therefore, be used in WiMAX compliant communication equipment. In telemedicine application antenna is operating at 2.45 GHz. Wearable microstrip antenna is suitable for Wireless Body Area Network (WBAN).The fundamental components of a microstrip patch antenna are fairly simple to construct [13-15]. As a result, a lot of research has been done on the analysis of microstrip antennas. Microstrip patch antennas, which are small, low- profile, and broadband, are needed because of the rapid growth of wireless technologies.

2. Basic Feeding Techniques - MSPA

The signal can be fed into microstrip patch antennas in a variety of ways. On one side of the dielectric substrate, let the conducting patch be rectangular. Let "L" denote the length and "W" denote the width of a rectangular conducting patch, respectively. The thickness of the microstrip substrate is h, and its dielectric constant is r. Antenna feeds can be contacting, in which the RF signal is directly fed through the contacting element, like coaxial cable, or non-contacting, in which the RF signal is transferred through electromagnetic coupling.

2.1 Line Feed

As depicted in the figure, a conducting strip is connected directly to the microstrip patch's edge in this type of feed technique. The patch has a wider width than the conducting strip. A feeding technique in which the microstrip patch is directly connected to the conducting microstrip feed line has the advantage of allowing the feed to be etched on the same substrate to produce a planar structure. The feeding of MSPA is depicted in Figure 2.

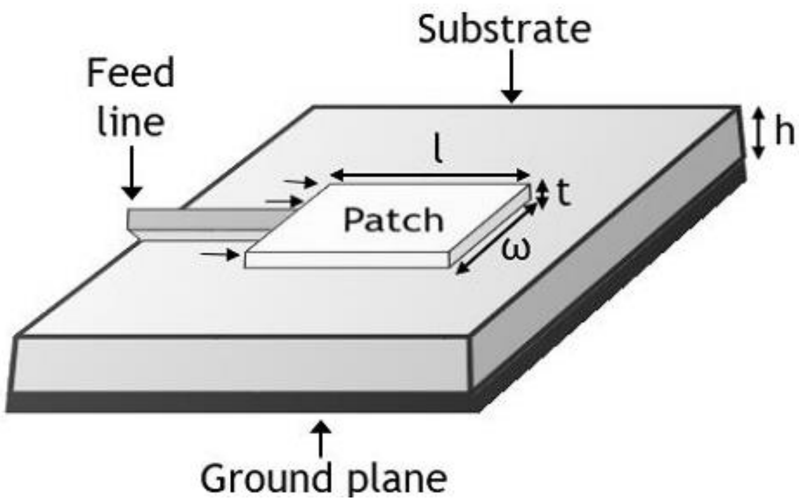

Figure 2: Line Feeding Technique

Source: https://electronicsdesk.com/patch-antenna.html)

2.2 Aperture Couple Feed

This feed has two distinct substrates separated by a ground plane. The microstrip patch and feed line are coupled through a slot in the ground plane in this approach. The aperture coupled feeding method has the advantages of minimizing interference and pure polarization. Figure 3 depicts the MSPA aperture couple feed.

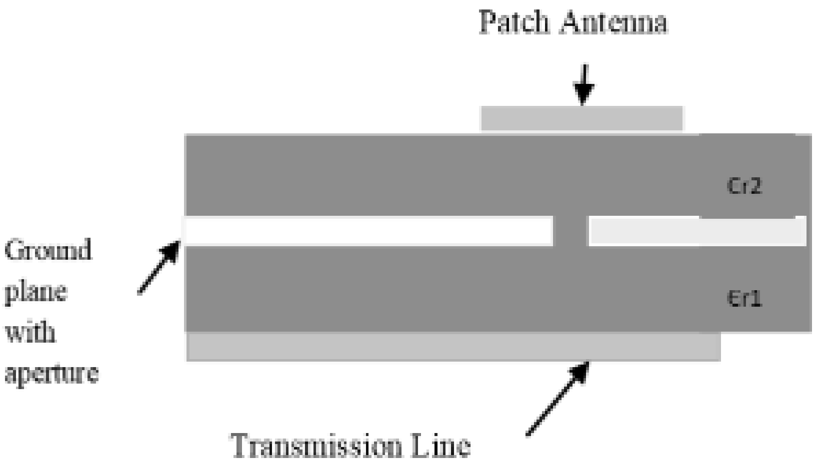

Figure 3: Aperture Coupled Feed for MSPA
(Source: https://electronicsdesk.com/patch-antenna.html)

2.3 Proximity Coupled Feed

Comparatively, this feeding method's fabrication is somewhat complicated. In this method, two dielectric substrates are used. The feed line runs between two substrates, and the microstrip patch is located on the upper surface of the upper dielectric substrate. It avoids false radiation and offers the highest bandwidth. The MSPA proximity couple feed is depicted in Figure 4.

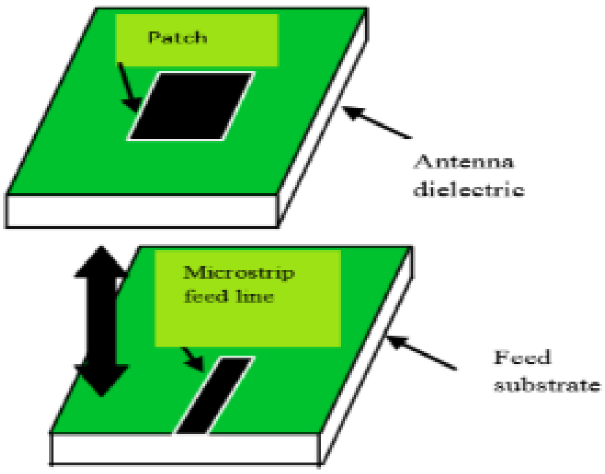

Figure 4: Proximity Couple Feeding for MSPA
(Source: https://electronicsdesk.com/patch-antenna.html))

2.4 Coaxial Feed

This method is widely used. After passing through the dielectric substrate on the opposite end of the substrate, the inner conductor of the coaxial cable is welded to the antenna's radiating element. In contrast, the ground plane is directly connected to the outer conductor of a coaxial cable [10]. The advantage of this method is that it can be used to match the coaxial cable's impedance to that of the antenna input port by placing the feed in a convenient location anywhere on the patch.

3. Parameter

The IEEE defines an antenna as "that part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves," as stated by Stutzman and Thiele. An antenna is an electrical conductor or system of conductors. Transmitter: Sends electromagnetic energy into space. Receiver: Collects electromagnetic energy from space. The following sections provide definitions of the main antenna parameters.

3.1 Antenna Gain
At the highest intensity of radiation, gain is a measure of the antenna's capacity to convert input power into radiation in a particular direction. By directing the radiation away from other parts of the radiation sphere, gain is achieved. The antenna's gain-biased pattern is typically used to define gain.

$$G = \frac{4\pi U}{P_{in}} \ldots\ldots\ldots \quad (1)$$

Gain generally outperforms directivity. Ohmic and other losses are introduced. It is defined as the product of the total input power accepted by the antenna and the radiation intensity in a particular direction from the antenna divided by 4π.

3.2 Antenna Efficiency
A measure of the relative power radiated by the antenna, or antenna efficiency, is the surface integral of the radiation intensity over the radiation sphere divided by the input power PO. Where Prad is the power that is radiated. The reflected power or material losses in the antenna caused by a poor impedance match reduce the radiated power.

$$Antenna\ Efficiency = Prad/Pt \ldots\ldots\ldots \quad (2)$$

3.3 Effective Area
A portion of the power generated by passing waves is transmitted to the terminals by antennas. The power that is delivered to the terminals is the product because of the incident wave's power density and the antenna's effective area.

$$Ae = \frac{\lambda^2}{4\pi} G \ldots\ldots\ldots\ldots \quad (3)$$

3.4 Directivity
The concentration of radiation in the direction of maximum is measured by directivity. Gain and directivity only differ in efficiency, but directivity can be easily estimated from patterns. Gain must be measured—directivity multiplied by efficiency.

$$D = \frac{1}{\frac{1}{4\pi} \iint_0^{2\pi} |F(\theta, y)|^2 \sin\theta \, d\theta \, dy} \ldots\ldots\ldots (4)$$

3.5 VSWR
According to the definition of VSWR, the VSWR is the ratio of the line's maximum voltage to its minimum voltage. The sum of the voltage components from the forward power and the reflected power causes the voltage fluctuations.

$$VSWR = \frac{1+|\tau|}{1-|\tau|} \ldots\ldots\ldots\ldots \quad (5)$$

3.6 Admittance/ Y- Parameters matrix
Any linear electrical network that can be thought of as a black box with a number of ports is described by a Y- parameter matrix. In this context, a port is a pair of electrical terminals with a specific voltage between them that carry equal and opposite currents into and out of the network.

3.7 Radiation Pattern
A mathematical function or a graphical representation of the antenna's radiation properties as a function of space coordinates is used to describe the radiation pattern.

3.8 Return Loss
The reflection of a device's signal power in a transmission line is known as return loss. As a result, the RL is a parameter that, like the VSWR, tells how well the transmitter and antenna are matching. The RL is as follows:

$$RL = -20 \log 10 (\Gamma) \text{ dB} \ldots\ldots \quad (6)$$

4. Antenna Geometry

In this antenna, the substrate has a thickness h=1.4 mm and a relative permittivity ϵr = 4.4. The length and width of patch are L=28.12 mm and W=38.39 mm respectively. The length and width of ground are Lg=56.24 mm and Wg=76.78 mm respectively. Edges along the width are called radiating edges and that along the length are called non- radiating edges. For the designing of rectangular microstrip antenna, the following relationships are used to calculate the dimensions of rectangular microstrip patch antenna for resonating frequency 2.4 GHz.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{W}{h}\right]\hat{}(1/2) \ldots\ldots\ldots \quad (7)$$

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}} \ldots\ldots\ldots \quad (8)$$

$$\frac{\Delta h}{L} = 0{,}412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \ldots\ldots \quad (9)$$

$$L = L_{eff} - 2\Delta L \ldots\ldots.. \quad (10)$$

$$f_r = \frac{v_0}{2L\sqrt{\varepsilon_r}} \ldots\ldots\ldots \quad (11)$$

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \ldots\ldots\ldots \quad (12)$$

$$L_g = 6h + L \ldots\ldots\ldots. \quad (13)$$

$$W_g = 6h + W \ldots\ldots. \quad (14)$$

5. Proposed Design

Figure 5 depicts the proposed microstrip line fed patch antenna's front view geometry and structure, which were developed using the CST Microwave Studio software and operate in a single band for WLAN applications. The proposed antenna's dimensions and feed point location have been optimized to achieve the best possible impedance match. The proposed antenna is designed with the following parameters in mind:

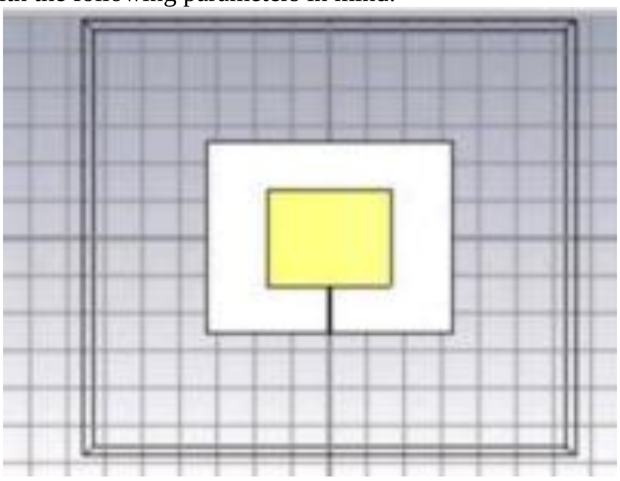

Figure 5(a): Front View of Designed Antenna on CST 2022

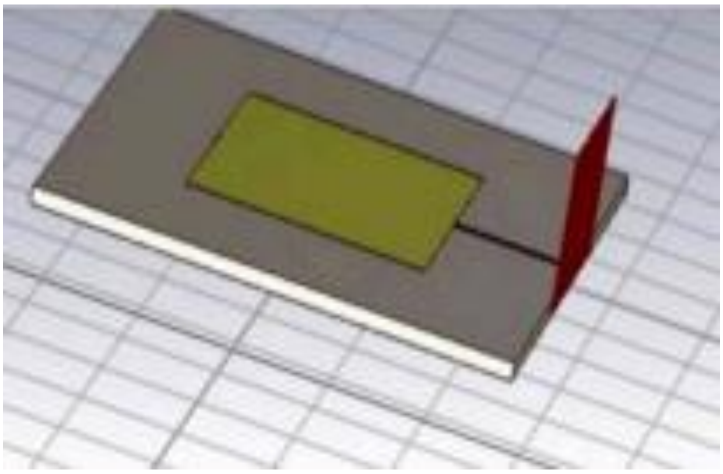

Figure 5(b): Plot View of Designed Antenna on CST 2022

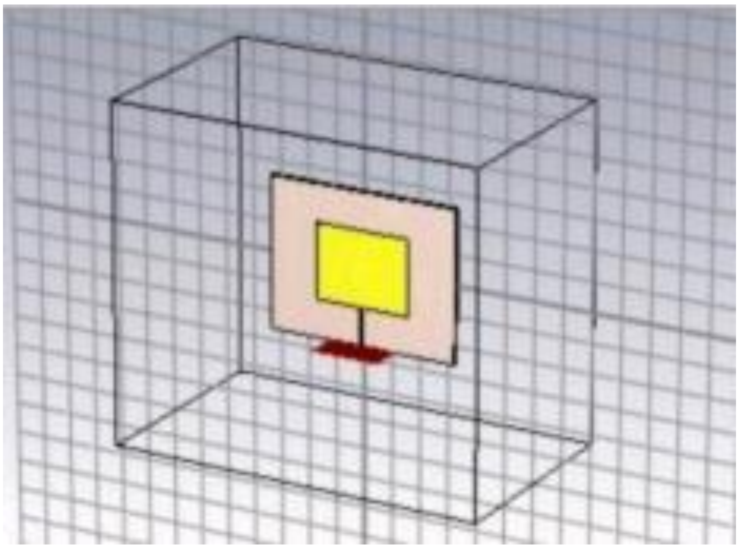

Figure 5(c): Perspective View of Designed Antenna on CST 2022

Design frequency = 2.4 GHz Substrate permittivity = 4.4 Thickness of substrate = 1.4 mm Length of patch (L) = 28.12 mm Width of patch (W) = 38.39 mm Length of Ground (Lg) = 56.24 mm Width of Ground (Wg) = 76.78 mm.

6. SIMULATION RESULTS

The parameters for the designed antenna were calculated and the simulated return loss results are shown in Figure 6. The bandwidth at the2.4 GHz band is around 80 MHz with the corresponding value of return loss as 6.6 dBi.

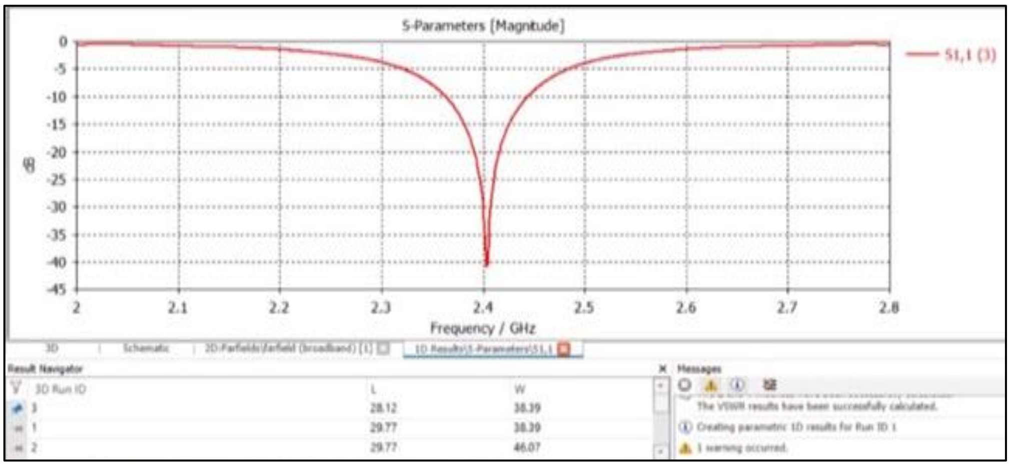

Figure 6(a): RL for 2.4 GHz resonating frequency is 6.6 dBi

The following Far Field Directivity of 2.4GHz is obtained using Main Lobe Magnitude of 6.32 dbi and 60 degrees of Main Lobe Direction. The Angular width is 101.6deg and side lobe is -11.7deg. Thus it describes the various parameters taken into prediction.

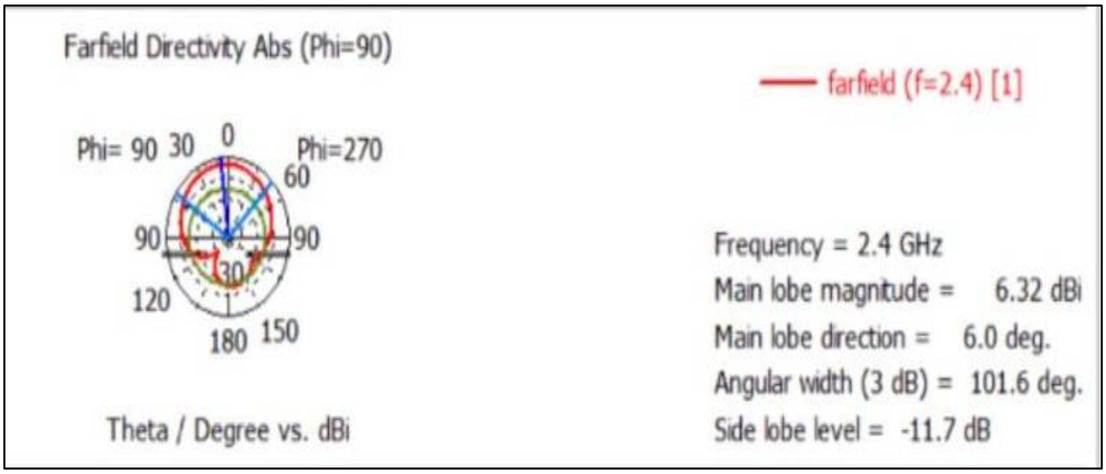

Figure 6(b): Far Field Directivity at 2.4 GHz

The depicted is the 3-D result of designed 2.4GHz microstrip patch antenna.

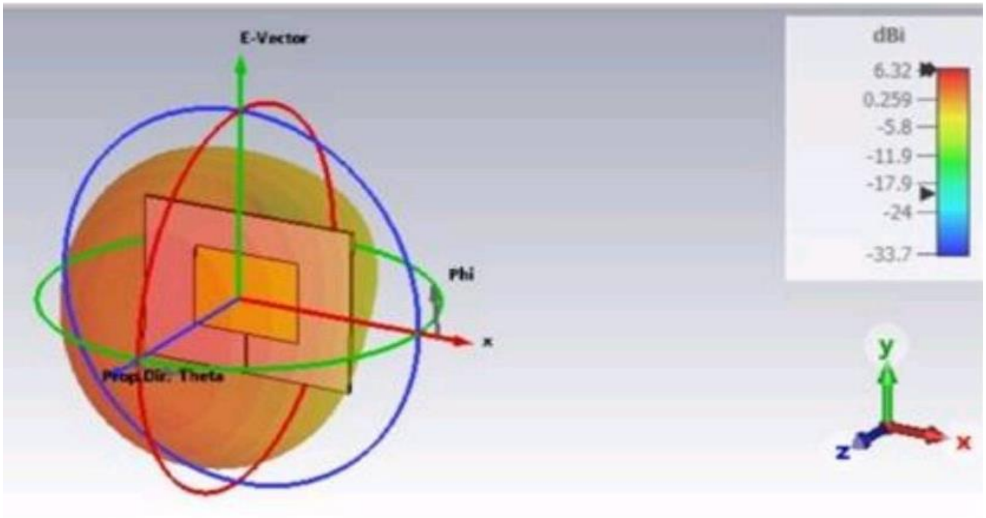

Figure 6(c): 3-D Radiation Pattern for 2.4Ghz Designed Antenna

The VSWR is plotted against the frequency in Figure 6(d). The VSWR of a coaxial signal must be exactly one for the antenna to work correctly. The desired VSWR for this design is 0.03, indicating that the antenna matches the resonant frequency well. Additionally, this demonstrates that 2.4GHz is its lowest frequency. In accordance with the antenna's resonant frequency. Figure 6(d) shows that the VSWR in the band is 2.8, and the thick line indicates that the antenna is better matched to the coaxial probe the closer the VSWR is to 1.

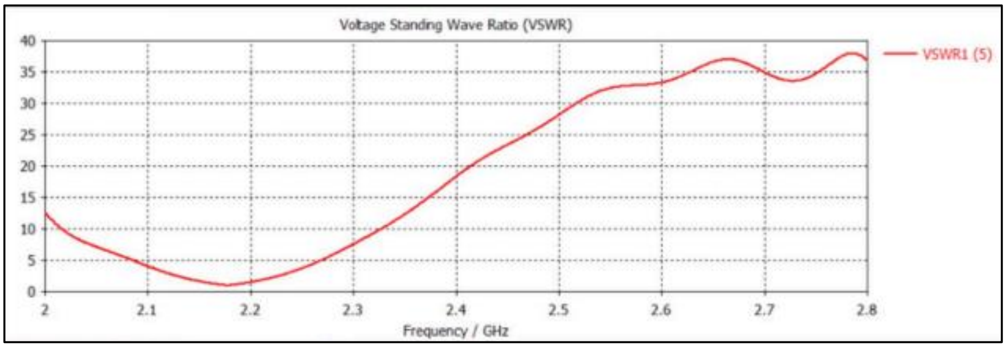

Figure 6(d): VSWR for 2.4 GHz Designed Antenna

The arrows that generate radiation in the normal direction of the single patch antenna are depicted in the animated contour of field E on the surface of Figure 6 (e).

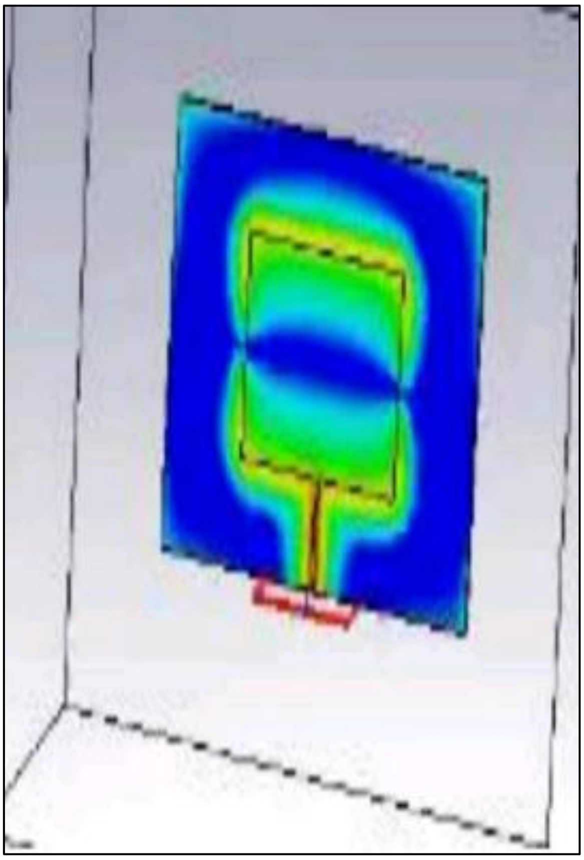

Figure 6(e): E-Field Pattern for Designed Antenna

The difference between a lower frequency and a higher frequency is called the channel width. Here, lower frequency refers to the channel's initial frequency and higher frequency to its final frequency. Wi-Fi at 2.4 GHz: The ideal channel width for 2.4 GHz is 20 MHz. We only have 100 MHz of bandwidth in this band; if we switch to 40 MHz or 80 MHz, the number of channels will be 2 and 1, respectively. We can create four channels without overlapping if we use a channel width of 20 MHz. Wi-Fi at 5 GHz: when to employ 80 MHz: When there isn't much interference or the wireless client is close to the router but we need more throughput, we use 80 MHz.

7. CONCLUSION

We evaluated our work as follows at the conclusion of our project: It was clear how antennas worked in general. The major parameters that have an impact on both design and applications—such as Return Loss curves, Radiation Patterns, Directivity, and Beamwidth—were investigated in order to comprehend their ramifications. The constructed biquad and slotted waveguide antennas were able to operate at the frequency and power levels that were intended. Using CST, a number of patch antennas were simulated to achieve the desired level of optimization. It was decided that the hardware and software results we got were the same as what was predicted theoretically.

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