Circular microstrip patch antenna for wlan applications

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Abstract - *The design of a small circular micro strip patch antenna covering the 5.7 to 6.15 GHz frequency is presented in this work for WLAN applications. The antenna is constructed using a micro strip line feed and a 1.4 mm thick FR-4 (lossy) substrate with a relative permittivity of 4.4. The circular patch is chosen radius is 8 mm. In order to optimize the size and performance of the suggested antenna, a slot measuring 19 mm x 19 mm is etched onto the ground plane. By Using CST Microsoft Studio Simulation Software, the antenna is designed.*

Many antenna properties are studied, including radiation efficiency, directivity, antenna gain, percentage bandwidth, return loss, and radiation pattern. We have designed a circular micro strip patch antenna that operates at a frequency of 5.8GHz in this paper. The patch antenna is designed on a FR4 (Flame Retardant 4) substrate, which has a height of 1.6mm and a dielectric constant of εr= 4.4 & Copper material is used in patch and ground design.

***Key Words*: Antenna, Rectangular shape, Hfss, Micro strip antenna, CST.**

1.INTRODUCTION

Electric power is converted into electromagnetic waves, often called radio waves, using an electrical device called an antenna, sometimes called an aerial. An antenna receives a signal from a coaxial cable or other transmission line or guiding device, which produces a guided wave. The signal is converted by the antenna into electromagnetic energy, which allows it to travel across open space. Microstrip antennas with radiating patches might be square, rectangular, circular, triangular, elliptical, and more in form. Because of their simplicity in design and performance analysis, patch antennas with rectangular, circular, and square forms are used more commonly among them. With only one changeable degree of freedom (radius), circular patch antennas are simpler to build and offer readily tunable radiation. Furthermore, the circular patch antenna is 16% smaller than the rectangular patch antennas at the same design frequency.

Microstrip antennas have a variety of applications, especially in the areas of military, satellite, mobile, and medical communications. Their applications have grown as a result of their small size and low weight. Fast and low-cost fabrication is essential for antenna prototype for performance evaluation.

1.1 Types of Antennas

1.1.1 Dipole Antenna

The end of a transmission line that radiates energy through a bent wire like this is called a dipole, or dipole antenna. The reactance of the input impedance is determined by the dipole's length and radius. The amplitude of the reactance rises as the radius decreases. It corresponds to the wavelength. Thus, the length and radius of the dipole also need to be considered. Usually, it has an impedance of 72Ω.

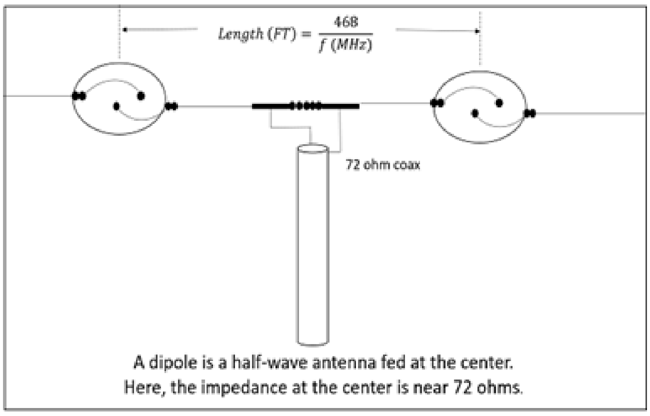

Fig-1: Dipole Antenna

1.1.2 Horn Antennas

The Horn Antenna, which affects the transition between transmission line and wave traveling in free space, is one of the most often used antennas. It functions as a waveguide's organic extension.

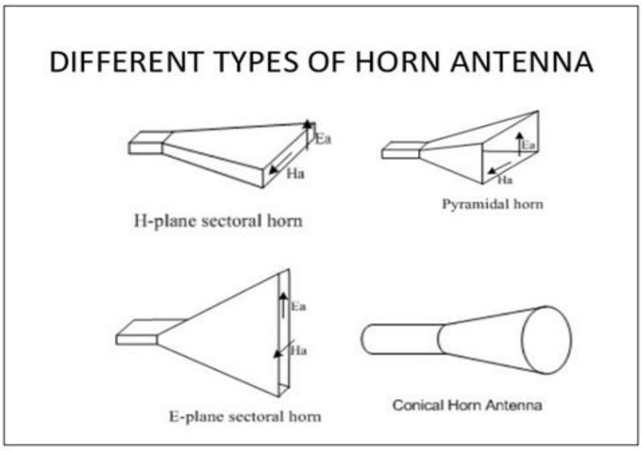

Fig-2: Horn Antenna

2. REVIEW OF LITERATURE

In order to enable wideband operation, the authors in suggested using a circular microstrip antenna with a circular slot etched on the circular patch. The FR-4 substrate design parameters were (εr =4.3) with a 25 mm×25 mm ground plane, a 8 mm radius circular patch, and a 1 mm substrate thickness using Computer Simulation Technology (CST) tool, they design and model the antenna to function at 5.8GHz. They discovered that 660MHz was a broader bandwidth with a low return loss of -29dB. This review focuses on microstrip patch antennas incorporating slots. Researchers explore the effects of slots on various antenna parameters, including bandwidth, gain, radiation pattern, and return loss. The bandwidth of microstrip patch antenna increases with the help of slots. Antenna structure can be made more compact and the gain of microstrip patch antennas increased by using varied shaped slots. A brief overview of the design of circular microstrip antennas, where it is concluded that these antennas can be designed for a variety of frequency bands and that different substrate materials can be excited by the antenna using a variety of feeding techniques, including coaxial, strip line, aperture coupling, and proximity coupling. Over the past 20 years, communications have concentrated on microstrip patch antennas because of their advantages. The microstrip patch antennas are having limiting gain, narrow bandwidth, depleted radiation pattern, and surface wave excitation are further disadvantages.

3. MICROSTRIP PATCH ANTENNA

3.1 Fundamental Parameters of Antennas

The features of the antenna that is employed in a typical wireless communication system determine its properties. Sometimes, these variables are also referred to as antenna attributes or characteristics. A summary of several essential antenna properties is provided below.

- Directivity and Gain
- Radiation Efficiency and Power Gain
- Input Impedance
- Effective Length
- Bandwidth
- Effective Aperture
- Antenna Polarization

3.2 Construction and Geometry

A microstrip patch antenna is a type of antenna that operates in the microwave frequency range. Let's delve into its details:

- A microstrip patch antenna consists of a thin metallic patch (usually made of conductive material) on a dielectric substrate. The other side of the substrate is grounded.
- The thickness of the dielectric slab typically ranges from 0.03λ to 0.05λ.
- The dimensions of the patch fall within the range of λ/3 to λ/2, with the dielectric constant of the slab varying from 2.2 to 12.
- These antennas are often etched onto circuit boards using photo-etching technology, making them low-profile and suitable for integration.

3.3 Types of Microstrip Patch Antennas

There are several varieties of microstrip patch antennas, including:

- Rectangular Patch Antenna: A straightforward rectangle design.
- Antenna in the circular patch design.
- The antenna is shaped like a triangle.
- Dual-Frequency Patch Antenna: Made to function on two frequencies.
- Several patches piled vertically is known as a stacked patch antenna.
- Aperture-Coupled Patch Antenna: Connected via a ground plane aperture.

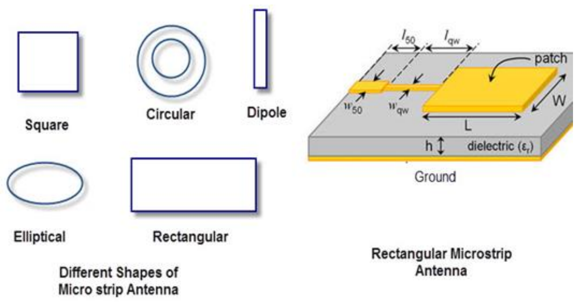

Fig -3: Different Shapes of Antennas

Microstrip antennas find application in a variety of sectors, including radars, satellites, spacecraft, missiles, airplanes, wireless communication systems, and mobile phones. The wireless communications industry uses these antennas.

3.4 Applications of Microstrip patch Antennas

Microstrip patch antennas find widespread applications in various fields due to their unique characteristics.

- Wireless Communication Systems
- Satellite Communication
- Mobile Radios and Handheld Devices
- Medical Imaging and Material Characterization
- Unmanned Aerial Vehicles (UAVs)

4. SOFTWARE REQUIREMENTS

A powerful 3D EM analysis toolkit for creating, evaluating, and improving electromagnetic (EM) systems and components is called CST Studio Suite. Electromagnetic field simulation finds widespread application in CST Studio Suite. The program CSTStudioSuite2023 is used to design and model the antenna.
The CST Studio Suite includes a number of modules, such as:

- Solvers for Electromagnetic Simulation: applicable to EM devices and systems.
- Electromagnetic Design Environment: An EM system's graphical user interface.
- Automatic Optimization: EM system optimization procedures.
- Project management for simulation is made easier by systems modeling.
- Workflow Integration: Simplifies import and sharing of data.

4.1 Design Process

These are the procedures for utilizing CST Studio Suite to design and simulate a microstrip patch antenna.

a. Create Geometry: Specify the patch's length, breadth, and form as well as the characteristics of the substrate material.Install the ground plane and microstrip feed line in the feeding mechanism. Indicate the thickness of the substrate and the dielectric constant.
b. Excitation and Boundary Conditions: Give the feed line the proper excitation, which is often a voltage source. Define the behavior of the antenna by setting up boundary conditions (such as a radiation barrier or a perfect electric conductor).
c. Meshing: For a precise simulation, break the geometry up into smaller components. To balance accuracy and computational efficiency, adjust the mesh settings.
d. Configuring the Solver: Select the proper solver (time domain or frequency domain, for example). Indicate the frequency range of the simulation (for radiation patterns, S-parameter analysis, etc.).
e. Simulation and Analysis: Run the simulation to get information on radiation patterns, impedance matching, and S-parameters (return loss, VSWR). Examine the bandwidth, directivity, and resonance frequency.
f. Simulation Outcomes: CST Studio Suite yields a range of output outcomes. Utilize modeling programs (such as CST Microwave Studio and HFSS) to confirm the antenna's functionality.

5. EXISTING ANTENNA SYSTEM

In the Existing Antenna System the design of a compact circular microstrip patch antenna for WLAN applications which covers the band 5.15 to 5.825 GHz. The antenna is designed using 1.4mm thick FR-4 (lossy)substrate with relative permittivity 4.4 and a microstrip line feed is used. The radius of the circular patch is chosen as 7.62mm. To reduce the size and enhance the performance of the antenna, a circular slot is loaded on circular patch and a square slot is etched on the ground plane of dimension 30mm×30mm. Design of the antenna is carried out using CST Microsoft Studio Simulation Software. The antenna resonates at 5.5 GHz with a wider bandwidth of 702 MHz and it provides low return loss of -31.58 dB, good gain of 3.23 dB and directivity of 4.28 dBi and efficiency of around 79% against the resonance frequency. The 5.15 to 5.825 GHz frequency is covered by the microstrip line feed used in WLAN applications. The CST Studio Suite 2015 software is used to design and simulate the antenna.

Parameter	Length(mm)	Width(mm)	Height(mm)	Material
Ground	30	30	0.035	Copper(annealed)
Substrate	30	30	1.4	FR-4(lossy)
Microstriplinefeed	6	2	0.035	Copper(annealed)
Patch	Radius = 7.62 mm			Copper(annealed)

Table -1: Design parameters and their associated values

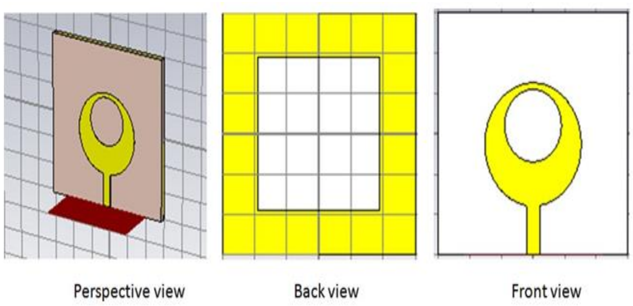

Fig-4: Different views

Here, the antenna is printed on a FR4 (lossy) substrate with a substrate thickness of 1.4 mm and a relative permittivity of 4.4. The radius of the circular patch is chosen to be 7.62 mm. The ground plane, which is printed on the substrate's bottom side, has a size of 30 mm by 30 mm. To improve the performance of the suggested antenna, a square slot is cut from the ground plane and a circular slot is cut from the circular patch. The square hole is 19 mm by 19 mm, while the circular slot has a radius of 4.5 mm. For the circular patch to accomplish the impedance matching 50Ω between the patch antenna and the transmission line, a microstrip feed line measuring 6mm by 2mm is employed. Table displays the specific dimensions of the proposed antenna.

5.1 Simulation Results and Discussion

The suggested circular microstrip patch antenna is designed and simulated using CST simulation software. Until the intended results are obtained, this strategy keeps performance improvement and size reduction in the ideal proportion. The research looks at the recommended antenna's performance in terms of radiation pattern, gain, directivity, bandwidth, VSWR, return loss, and overall efficiency.

5.2 Return loss

The amount of electromagnetic power that the microstrip patch antenna reflects back is measured by return loss, also known as the S parameter. This quantity is also known as the reflection coefficient. It determines how well the measured load at the receiving end and the transmitting end match in terms of impedance (source).An efficient radiation mode has a return loss of less than -10 dB. Figure 2 shows the S parameter vs frequency curve for the proposed antenna. It is clear that the resonance frequency of the proposed antenna is 5.5 GHz. The graph shows that at 5.5 GHz, the antenna's return loss is -31.58 dB, which indicates a smaller energy loss and better impedance match.

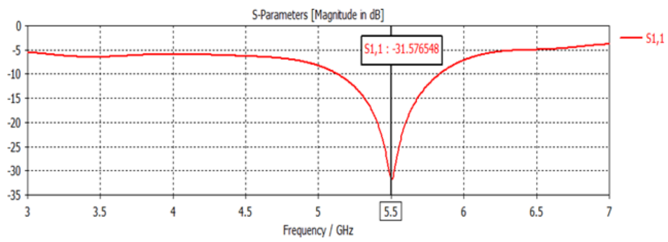

Chart-1: The proposed antenna's parameter versus frequency curve

5.3 Voltage StandingWaveRatio (VSWR)

VSWR is used to measure the impedance mismatch between the transmission line and antenna. When an antenna is well-designed, its VSWR value should be less than 2. The suggested antenna's VSWR Vs. frequency plot is shown in Fig, where it can be observed that the value of VSWR is 1.054, much less than 2, at the resonance frequency of 5.5 GHz. The suggested antenna's improved impedance match to the transmission line is shown by a lower VSWR, which also indicates a higher power supply to the antenna.

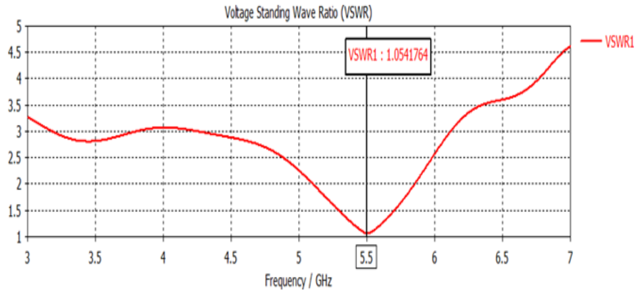

Chart-2: VSWRVs. the suggested antenna's frequency curve

5.4 H-field pattern

Figure shows the polar plot of the Far-field H-field pattern at 5.5 GHz for the proposed antenna. 10 degrees is the primary lobe direction, and -33.5 dBA/m is the measured magnitude. The recommended antenna's Far-field H-field pattern is plotted in three dimensions in Figure 10, which shows that its maximum radiation intensity, or Hmax, is 33.53dBV/m.

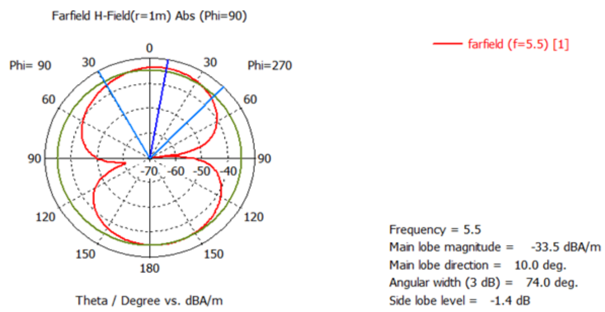

Fig -5: H-field pattern

5.5 Total Efficiency

The percentage relationship between the radiated power and the incident power at the antenna is known as antenna efficiency. The suggested antenna's overall efficiency vs frequency curve is displayed in Figure 6. Antenna efficiency is found to be above 67% across the whole operational band (5.13GHz - 5.83GHz), with a maximum value of about 79% at the resonance frequency of 5.5GHz.

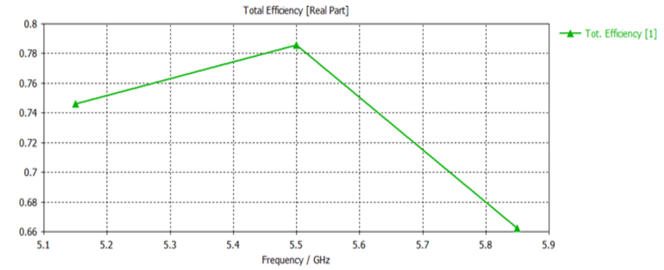

Chart-3: Efficiency

6. RESULTS

With CST Studio Suite 2023, an antenna for a circular microstrip patch is created.This study presents the design of a tiny circular microstrip patch antenna covering the frequency range of 5.7 to 6.15 GHz for WLAN applications. A microstrip line feed and a 1.4 mm thick FR-4 (lossy) substrate with a relative permittivity of 4.4 are used in the construction of the antenna. The selected circular patch has a radius of 8 mm. A 19 mm × 19 mm slot is etched onto the ground plane to maximize the size and performance of the proposed antenna.

After the design is finished, the antenna's real-world performance may be estimated by simulating it in the program. The height of the substrate, h (in mm), the resonant frequency, and the dielectric constant of the substrate (εr) are assumed to be known for the purpose of antenna design. The design parameters of a circular microstrip patch antenna are then determined using a set of simplified cavity model equations, as follows.

6.1 Calculate Antenna Parameters

- Radius of the circular patch is given by :

$$a = F.$$

$$[1 + 2h/\pi F\varepsilon r\ (\ln\{\pi F/2h\} + 1.7726)]\ 0.5$$

$$\text{where, } F = 8.791 \times 109/fr\sqrt{\varepsilon r}$$

εr= Dielectric constant of substrate Length and width of the substrate can be calculated by

$$\text{Substrate length, } Lsub = 2 \times 2a$$

$$\text{Substrate width, } Wsub = 2 \times 2a$$

- The antenna design parameters for WLAN band & WiFi (5.7–6.15) GHz are computed as follows. Here, a FR4 (lossy) substrate with a dielectric constant of 4.4 is employed, and 1.4 mm is selected as the substrate height.

1. Resonance frequency fr= 5.7+6.15/2 = 5.4875 $GHz \approx 5.925\ G\quad z$
2. $F = 8.791{\times}10^9/ fr\sqrt{\varepsilon r}$ = 7.073 mm
3. Radius of the circular patch = a
 a =$F/$ [1+ $2h/\pi F\varepsilon r$ (ln{$\pi F/2h$ }+1.7726)] $^{0.5}$= 7.9 mm =~ 8.0(approximately)
4. Substrate length, $Lsub = 2 \times 2a$ = 30mm
 Substrate width, $Wsub = 2 \times 2a$ = 30 mm

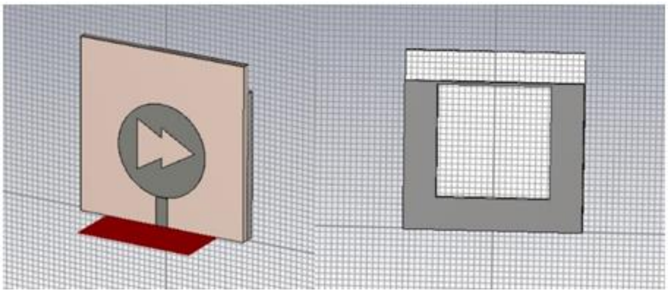

Fig -6: Proposed Antenna Front view and Back view

The trial and error approach is used to reduce the size of the proposed antenna while simultaneously improving its performance once the antenna parameters have been computed. The antenna is printed on a FR-4 (lossy) substrate with a substrate thickness of 1.4 mm and a relative permittivity of 4.4. The circular patch's radius is set at 8 mm. The ground plane, which is printed on the substrate's bottom side, has a size of 30 x 25 mm. To improve the performance of the suggested antenna, two triangle slots are cut from the circular patch and one square slot is cut from the ground plane. After the antenna characteristics are calculated, a trial-and-error method is utilized to minimize the proposed antenna's size while concurrently enhancing its performance. The antenna is printed on a 1.4 mm thick, FR-4 (lossy) substrate with a relative permittivity of 4.4. The radius of the circular patch is 8 mm. The size of the ground plane, which is printed on the bottom side of the substrate, is 30 x 25 mm. Two triangular slots are cut from the circular patch and one square slot is cut from the ground plane in order to enhance the performance of the proposed antenna.

6.2 Return loss (or) S-Parameters

- The degree to which an antenna reflects power back to the source is measured by return loss. The mismatch between the antenna and its feeding network is quantified.S-parameters define the input-output relationships that characterize the behavior of a network, like an antenna.
- A radiation mode that is successful requires a return loss of less than -10 dB. The suggested antenna's S-parameter versus frequency plot is displayed in Figure.

- It can be observed that the suggested antenna's resonance frequency is 5.87 GHz. The graph demonstrates that the antenna's return loss is -30.58 dB at 5.87 GHz, indicating a better impedance match and less energy loss.
- In Fig shows the frequency range bordered by a return loss of less than -10dB, which may be used to calculate the bandwidth of the constructed antenna.

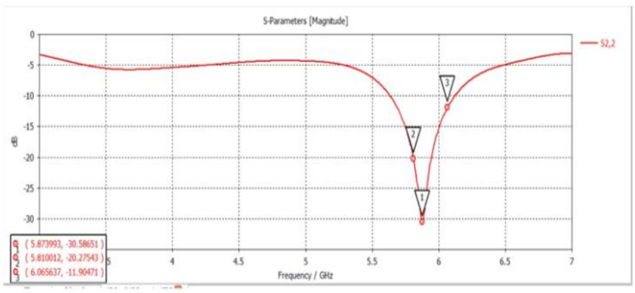

Chart-4: The suggested antenna's S-Parameter vs. frequency curve

6.3 Voltage StandingWaveRatio (VSWR)

VSWR is used to measure the impedance mismatch between the transmission line and antenna. When an antenna is well-designed, its VSWR value should be less than 2. The suggested antenna's VSWR Vs. frequency plot is displayed in Figure 3, where it can be observed that the value of VSWR is 1.06, significantly less than 2, at the resonance frequency of 5.8 GHz.The suggested antenna's improved impedance match to the transmission line is shown by a lower VSWR, which also indicates a higher power supply to the antenna.

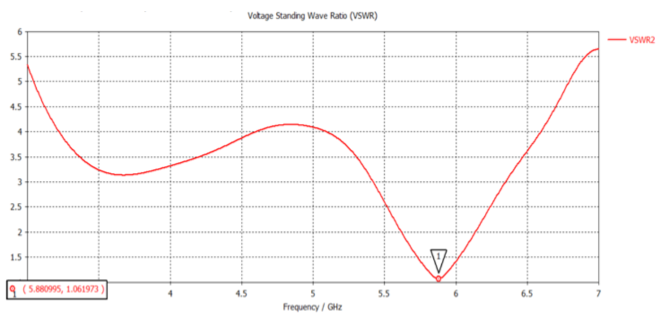

Chart-5: VSWRVs. the suggested antenna's frequency curve

6.4 Radiation Efficiency

"The ratio of the total power radiated by an antenna to the net power accepted by the antenna from the connected transmitter" is the definition of radiation efficiency. It is frequency-dependent and has a percentage expression.

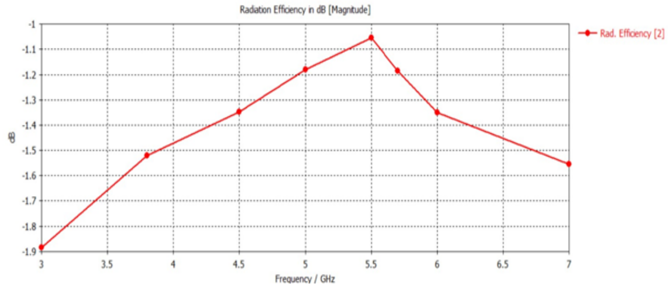

Chart-6: Radiation Efficiency

6.5Total Efficiency

The percentage relationship between the radiated power and the incident power at the antenna is known as antenna efficiency. The suggested antenna's overall efficiency vs frequency curve is displayed in Figure.

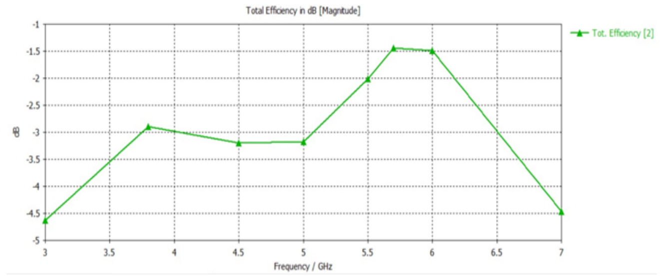

Chart-7: displays the suggested antenna's overall efficiency vs. frequency curve.

6.6 Radiation Pattern

The distribution of the power that an antenna radiates (if it is a transmitting antenna) or receives (if it is a receiving antenna) as a function of the direction angles from the antenna is known as the radiation pattern. It computes in the far-field area most of the time and explains the H-field and E-field patterns.

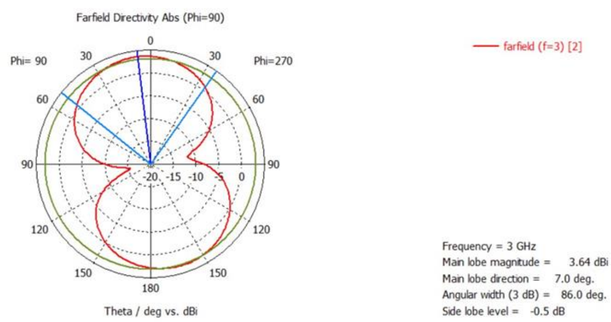

Fig-7 : Radiation Pattern

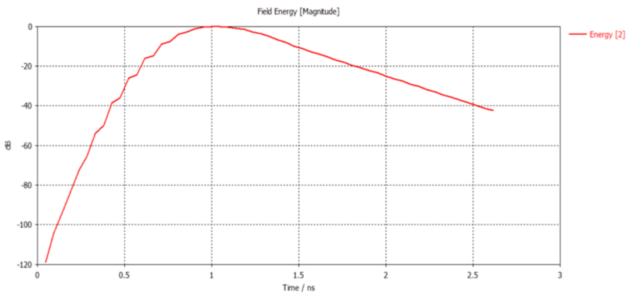

Chart-8: Radiation Pattren

7. CONCLUSIONS

The design and modeling of a circular microstrip patch antenna operating in the WLAN band frequency range are discussed in this study. The circular microstrip patch antenna's simulated results exhibit good directivity and gain values. The circular patch antenna has a directivity and gain of 3.712dBi, and its high return loss value ensures ideal impedance matching between the patch and feed. According to the suggested antenna's VSWR Vs. frequency plot, it will be beneficial for WLAN and Wi-Fi applications at the 5.8 GHz resonance frequency. The VSWR value is 1.06, much less than 2.The suggested antenna's improved impedance match to the transmission line is shown by a lower VSWR, which also indicates a higher power supply to the antenna. Antennas' general operation was recognized.

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