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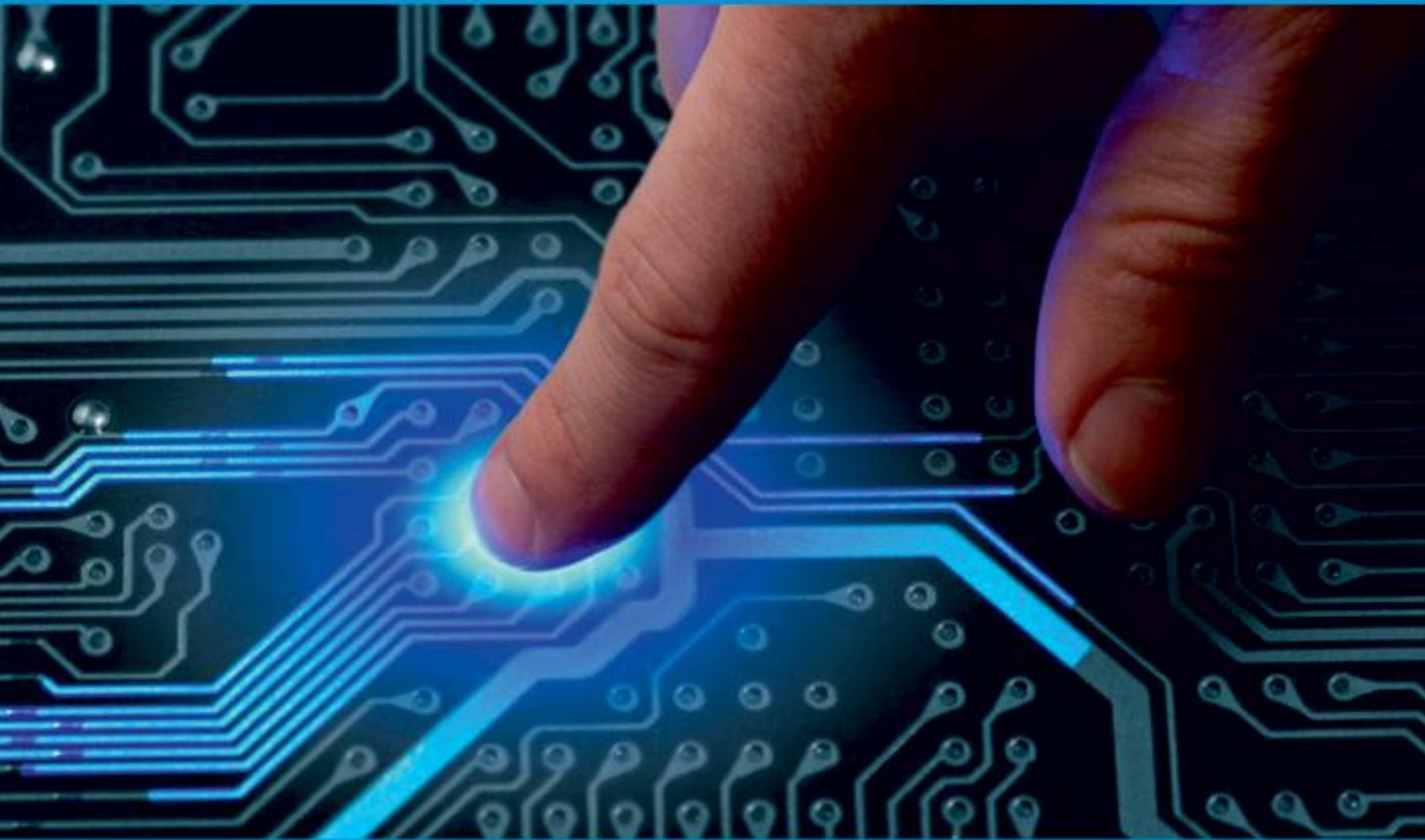

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Designing and Testing of a Microstrip Patch Antenna

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ABSTRACT: The antenna is the backbone of a communication system with the advent of technology, a lot of innovation is happening to develop the antenna. The antenna is a smart device that transmits, receives, and works as a transducer. In this project work, the compact antennas are designed using an FR4 substrate with a dielectric constant of 4.4. The antenna is fabricated to prototype and verified using Vector Network Analyzer (VNA). In this work, a compact antenna with a slotted ground plane making a DGS and a slot on the patch is designed to obtain multiple frequencies. A rectangular slot on the patch and an L slot on the ground plane helped the structure enhance the gain of the antenna. The obtained frequencies are 4.9 GHz and 5.9 GHz with the return loss of -28.98 dB and -12.83 dB respectively, which are useful for sub 6GHz applications. In comparison, an acceptable correlation is observed between simulated and measured results. In this work, a compact antenna with a slotted ground plane making a DGS and inset feed is designed to obtain multiple frequencies.

KEYWORDS: Microstrip antenna, Slots, DGS, Sub 6 GHz applications.

I. INTRODUCTION

Communication has evolved from human voice to wireless systems, which have become increasingly important in various applications. Wireless communication has become more practical and efficient, as wired systems are impractical or nearly impossible to implement. Microstrip patch antennas, small antennas fabricated over a printed circuit board, can be used for both transmission and reception of electromagnetic radiation. These antennas can collect electrical signals from a transmission line and convert them into radio waves while receiving antennas accept radio waves from space and convert them into electrical signals.

The use of dielectric materials and high-conductive nature-based materials has drastically reduced antenna size for practical applications. This Project aims to provide a solution for various demanding parameters in microstrip patch antennas, including size reduction, large bandwidth, and higher data rates.

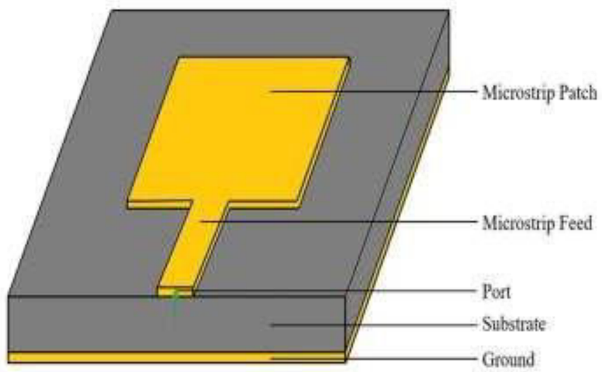

Figure 1: - Microstrip Patch Antenna

A microstrip patch antenna is a widely used type of antenna in communication systems like cellular phones, satellite communication, and radar systems. It consists of a dielectric substrate, a radiating patch, and a ground plane. The patch acts as a resonator, generating standing waves that radiate into space. The ground plane enhances the antenna's

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radiation efficiency. The resonant frequency depends on the patch's size, shape, dielectric constant, and substrate thickness.

Designing the effective length of patch (L_{eff}):

$$L_{eff} = \frac{C}{2fr\sqrt{\varepsilon_{eff}}}$$

Designing the actual length of patch (L_p):

$$L_p = L_{eff} - 2\Delta L$$

Designing the patch width (W_g):

$$W_g = (6 \times h) + W_p$$

Designing the patch length (L_g):

$$L_g = (6 \times h) + W_p$$

Designing the length extension (ΔL):

$$\Delta L = (0.412)h\left[\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W_p}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W_p}{h} + 0.8\right)}\right]$$

Designing the width of patch (W_p):

$$W_p = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

II.LITERATURE SURVEY

1) Enhanced Bandwidth Microstrip Patch Antenna Using Metamaterial Substrate by Jane Smith et al. (2022):
This study introduces an enhanced bandwidth microstrip patch antenna utilizing a metamaterial substrate. The metamaterial substrate is designed to manipulate the propagation characteristics of electromagnetic waves, leading to improved antenna performance, particularly in terms of bandwidth expansion. The paper discusses the design methodology, simulation results, and experimental validation of the proposed antenna structure.

2)Dual-Band Microstrip Patch Antenna Design for 5G Applications by Emily Johnson et al. (2024):
The antenna is optimized to operate at two distinct frequency bands allocated for 5G applications, enabling multi-band communication capabilities. The authors discuss the antenna design process, simulation results, and practical implementation considerations for 5G deployment.

3)Circularly Polarized Microstrip Patch Antenna Array for Satellite Communication Systems by David Brown et al. (2023):
This paper presents the design and analysis of a circularly polarized microstrip patch antenna array for satellite communication systems. The antenna array configuration is optimized to achieve circular polarization and high gain

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characteristics, essential for satellite communication links. The authors provide detailed simulation studies and experimental validations to demonstrate the performance of the proposed antenna array in satellite communication applications.

4)Reconfigurable Microstrip Patch Antenna Design Using RF MEMS Switches by Sarah Adams et al. (2022):
This research introduces a reconfigurable microstrip patch antenna design employing RF MEMS switches for frequency agility and beam steering capabilities. The antenna's radiating elements can be dynamically adjusted using RF MEMS switches, allowing for flexible frequency tuning and beam steering functionalities. The paper discusses the design principles, simulation results, and experimental evaluations of the reconfigurable antenna system for wireless communication applications.

III.METHODOLOGY AND DISCUSSION

Methodology

- Design a microstrip antenna using HFSS. Incorporate feeder inputs using the HFSS simulator.
- Parametric analysis of the designed antenna for different parameters like Return loss, VSWR, Gain, and Bandwidth.
- Fine-tuning of the results using different approaches like slots, DGS, etc.
- Fabricate the antenna and validate the antenna parameters using a Vector Network Analyzer (VNA)
- The proposed antenna was designed using an FR4 substrate.

OBJECTIVES

▪ To design a compact patch antenna for IoT and sub-6GHz applications.
▪ Parametric analysis of designed antenna such as S11, Gain, VSWR, etc.
▪ To fabricate the antenna and validate the same using VNA.

IV. TOOLS DESCRIPTION

Software used: [High-Frequency Structural Simulator]
HFSS is widely used in various industries, including telecommunications, aerospace, automotive, and electronics, for antenna design, RF and microwave circuit design, signal integrity analysis, electromagnetic compatibility (EMC) and electromagnetic interference (EMI) analysis, waveguide analysis, metamaterial design, and biomedical applications.

By providing engineers with comprehensive insights into electromagnetic behavior, HFSS enables them to innovate and optimize designs, accelerating the development of advanced electronic systems and devices. Overall, HFSS is a cornerstone in electromagnetic simulation, empowering engineers to push the boundaries of high-frequency electronics and usher in a new era of innovation and efficiency.

SOFTWARE SIMULATION
We compare the performance of our antenna with existing slot and patch antennas in the literature. Overall, the compact slot antenna presented in this chapter shows promising results for future IoT and sub-6GHz applications.

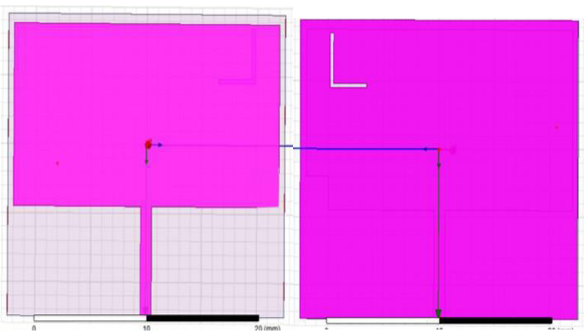

Figure 2:- Front view and Back view

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Antenna Measurements

Table 1

Measurements ofPatch	
L (Length of patch)	13.3mm
W (Width of patch)	24mm
L1 (Length of feed)	8mm
W1 (Width of feed)	1mm

Measurements ofGround	
L3(Length ofsubstrate)	22mm
W2 (Width ofSubstrate)	25mm

The design of a slot antenna with an L-shaped ground slot is proposed in this design. The antenna has a size of length 22mm, a width of 25mm, and a substrate height of 1.6mm. The detailed measurements are given in table 3.2.1. The antenna has produced double frequency bands of 4.9 GHz & 5.9 GHz with a gain of 4.63 dB, and 1.55 dB respectively. The resonated frequencies are suitable for Sub 6GHz applications. Ansoft HFSS tool is used to design the antenna. The vector network analyzer is used to test the antenna prototype. The measured and simulated results have been compared.

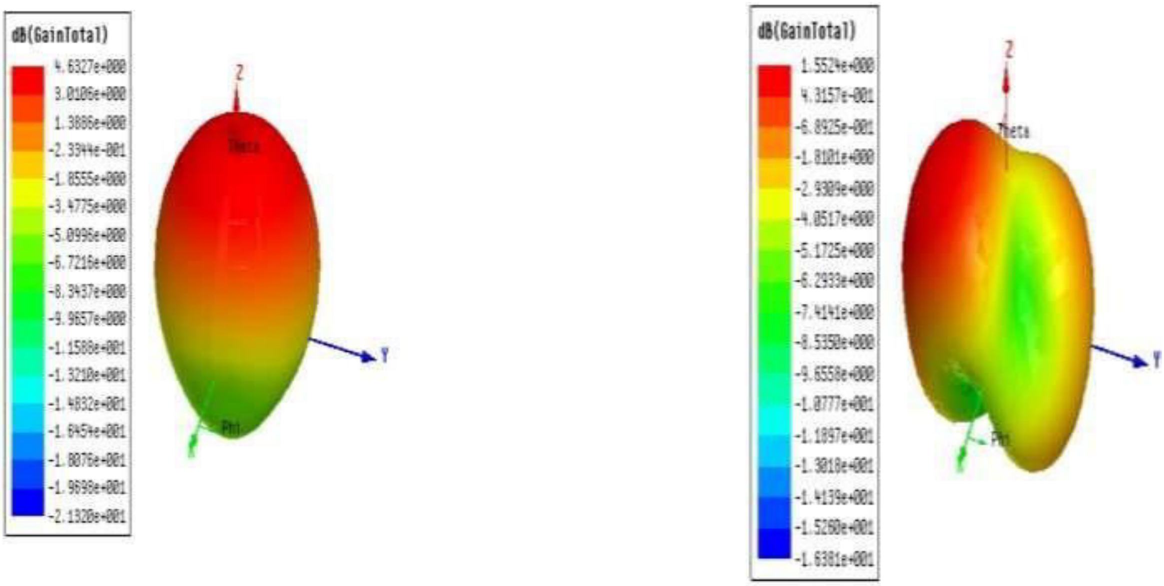

Figure 3:- XY Gain plot for 4.9 and 5.9 GHz Frequency

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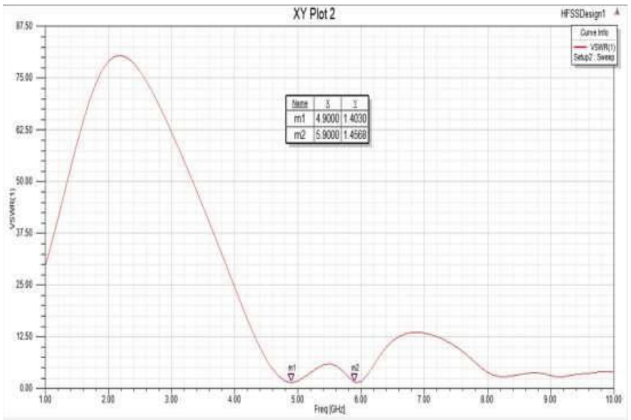

Figure 4:- VSWR

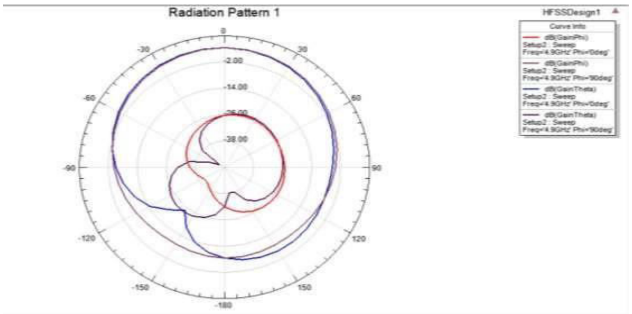

Figure 5:- Radiation Pattern for 4.9GHz

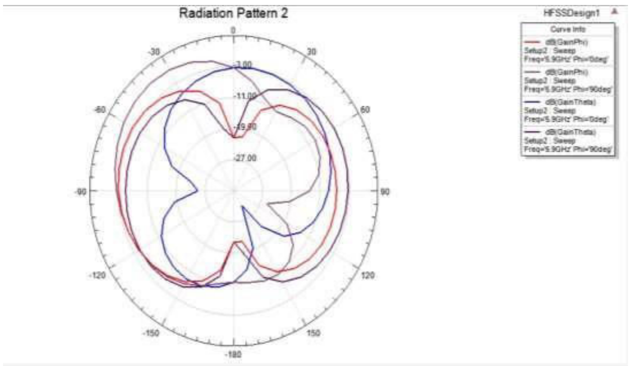

Figure 6:- Radiation Pattern for 5.9GHz

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Polarization of the Antenna

Table 2

	E Plane Co polarization
	H Plane Co polarization
	E Plane Cross polarization
	H Plane Cross polarization

PATCH ANTENNA

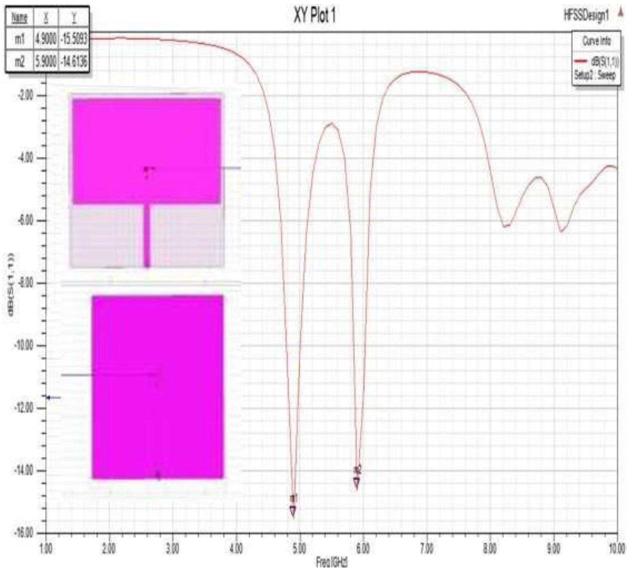

Figure 7:- Front View, Back View, and XY Plot of Patch Antenna

We designed a normal patch antenna. We obtained two frequencies they are 4.8 GHz and 5.9 GHz with -15.59 and -14.60 return loss respectively.

HARDWARE.

1. SMA Connector:- SMA is a type of coaxial RF connector, commonly used in high-frequency applications like RF and microwave communications. It features a threaded interface for secure connections and is available in various sizes, including SMA, SMA-RP, and SMA Edge. SMA connectors are widely used in antennas, RF cables, test equipment, and other RF/microwave devices. They offer excellent electrical performance and mechanical durability, making them suitable for demanding applications in both commercial and military sectors.

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Figure 8:- SMA CONNECTOR

2. Spectrum Analyzer:- A spectrum analyzer is a test instrument used to analyze the frequency spectrum of signals. It displays signal amplitude (power) versus frequency, providing insights into the frequency content of a signal. Spectrum analyzers are widely used in telecommunications, RF engineering, audio engineering, and other fields. They can identify and characterize RF interference, signal harmonics, spurious emissions, and other frequency-related phenomena. Modern spectrum analyzers come with advanced features such as real-time analysis, frequency mask triggering, and signal demodulation capabilities.

Network Analyzer:- The electrical behavior of networks or devices under test (DUT) in terms of their scattering parameters (S-parameters). It characterizes the performance of components such as filters, amplifiers, antennas, and transmission lines across a range of frequencies. Network analyzers can measure parameters like insertion loss, return loss, impedance, and phase shift.

They are widely used in RF and microwave engineering, telecommunications, and high-speed digital design.
Network analyzers come in various types, including scalar network analyzers.

4. Anechoic Chamber:- It is typically lined with special materials called absorbers that absorb incident waves, preventing them from reflecting the source. Anechoic chambers are used for electromagnetic compatibility (EMC) testing, antenna pattern measurements, radar cross-section (RCS) measurements, and acoustic testing. They provide a controlled environment free from external interference, allowing accurate measurement and characterization of devices and systems. Anechoic chambers come in various sizes and configurations, ranging from small chambers for antenna testing to large chambers for aerospace and defense applications.

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Figure 9:- Anechoic Chamber

FABRICATION OF AN ANTENNA

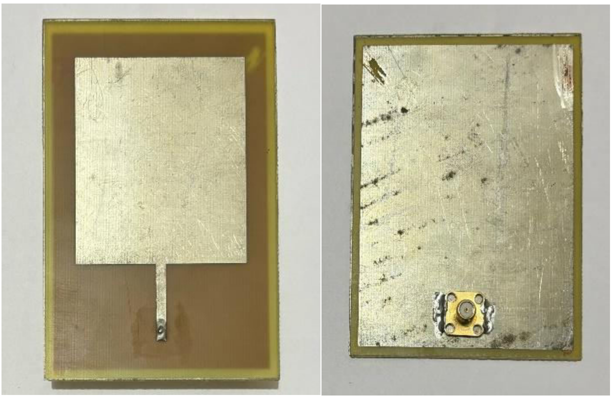

Figure 10:- Front and Back View of Microstrip Patch Antenna

V. RESULTS

TESTED REPORTS OF AN ANTENNA.

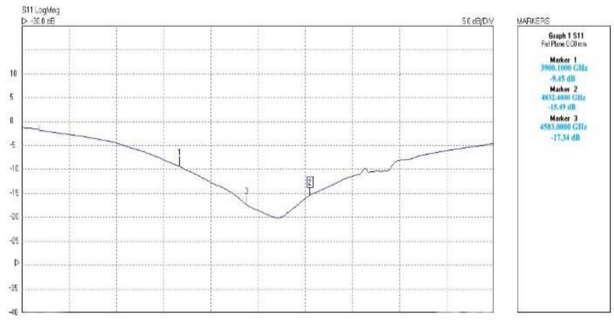

Figure 11:- Gain in dB

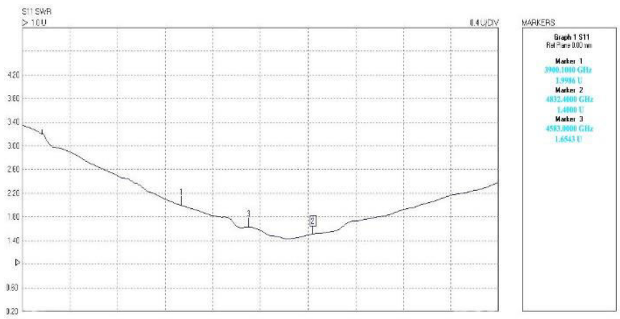

Figure 12:- VSWR

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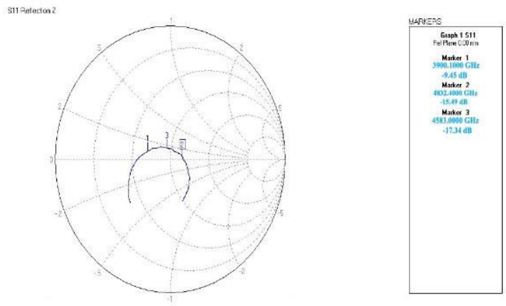

Figure 13:- Radiation Pattern

VI. CONCLUSION

The designed compact antenna for Sub 6GHz applications offers a range of significant benefits. In the first design, a compact patch antenna is designed with a substrate size of 22×25 and the ground plane makes a defective ground structure. This produced dual band frequencies of 4.9 GHz & 5.9 GHz with gain values of 4.63 dB and 1.55dB respectively. These frequencies are acceptable for sub-6GHz applications. In the second design, a miniaturized antenna for 5.9 GHz and 9.2 GHz was designed with a substrate size of 16×18 with an inset feed on the patch and ground plane making a defective ground structure. We obtained a gain of 4.71 and 2.84 for 5.9 respectively. These obtained frequencies are useful for IoT and X-Band applications.

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