



SCARE CROW SHAPED ANTENNA FOR C BAND APPLICATIONS

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Abstract

This paper presents the design, simulation, and experimental validation of a patch antenna for C-band applications. The antenna features a unique configuration consists of a partial ground plane and a radiating patch shaped in the likeness of a scarecrow. To improve impedance bandwidth, the ground plane incorporates etched slots, including circles with tiny etches, two half-circle slots, and square-shaped slots. The antenna is designed using Rogers RT6002 substrate with a permittivity of 2.94 and dimensions of 15mm x16mm x1mm. Simulation and experimental analysis, conducted using CST Microwave Studio, demonstrate excellent performance with an S_{11} below -10 dB across the 4-8 GHz frequency range. Further investigation focuses on the far-field pattern and current distribution at resonant frequencies of 4.9, 6.9, 8.86, 10.5, and 13.9 GHz.

Keywords: Patch antenna, Scarecrow, C-band applications, Impedance bandwidth, CST Microwave Studio, Far-field pattern, Current distribution.

1. Introduction

Microstrip antenna is a planar RF which is commonly used for communication purposes which is designed on a flat surface. Microstrip patch antennas consists of substrate, patch, ground plane and feedline. Scarecrow-shaped antennas represent an innovative approach to antenna design. This unique configuration has gained attention in recent years for its potential in various applications, particularly in the C-band frequency range (4 to 8 GHz). As demands for high-performance antennas continue to rise, exploring novel designs like C band antennas holds promise for meeting the evolving needs of satellite communication, radar systems, and beyond.

The advancement in wireless communication technologies demands antennas that can operate efficiently across a wide range of frequencies. In pursuit of this goal, researchers have proposed various innovative antenna designs tailored for specific applications. In this context, a comprehensive literature survey reveals several notable contributions in the field of antenna design, each offering unique characteristics and advantages.

In this paper, the design and analysis of a scarecrow-shaped antenna tailored for C-band applications is analysed. Antennas with unconventional geometries have garnered grab in now a day due to their potential for achieving broadband performance and addressing specific application requirements. Tiwari et al. (2020) proposed a tiny, compact monopole antenna for UWB communications that has a tapered slotted ground plane and radiators in the shape of a kite to reach a 14.2 GHz impedance bandwidth.

Drawing inspiration from existing literature, such as Bhupendra et al. (2017) and Djengomemgoto et al. (2020), which explore the design of broadband and C-band antennas respectively, we propose a unique scarecrow-shaped configuration to meet the demands of modern wireless communication systems) [1] [2][7].

Multilayered microstrip patch antennas have also garnered attention for their performance improvements. Hannan et al. (2023) explored a design featuring a semicircle patch with a PEC sheet, achieving a gain of 9.6 dB in the C-band. Fractal antennas, as explored by Edwin (2016), have demonstrated enhanced bandwidth through geometric alterations and impedance matching techniques, making them suitable for various wireless communication applications [5][6].

In the pursuit of dual-band capabilities, Djengomemgoto et al. (2020) introduced a single-layer Gemini-shaped patch antenna with resonance frequencies in the C-band and X-band. Their design exhibited high gain performance, rendering it suitable for satellite and radar

communications. Kumar and Patel (2023) further enhanced the broadband capabilities of the scarecrow antenna by introducing a modified version with a boat-shaped ground, achieving a fractional bandwidth of 128.76% from 1.3 GHz to 6 GHz [7][8].

Mukherjee and Roy (2020) presented a novel approach to notch filtering in UWB antennas, incorporating a modified inverted H-shaped slot into an octagonal microstrip patch design. This innovation enabled a notched band within the UWB spectrum, enhancing the antenna's utility in various applications. Ullah et al. (2019) addressed the demand for high-efficiency antennas with their Z-shaped microstrip monopole, offering a bandwidth ratio of 8.33:1 and realizing gains ranging from 1.6 to 6.4 dBi across the UWB spectrum [3][4].

Ayalew and Asmare (2022) explored optimization techniques for dual-band rectangular microstrip patch antennas, achieving impressive impedance bandwidths and radiation efficiencies suitable for 5G mobile communication applications. Finally, Mubarak and Zaiping (2015) addressed ground plane effects in ultra-wideband antennas through innovative radiator designs, achieving broadband performance from 3.6 to over 11 GHz [9][10].

The significance of this research lies in its contribution to the advancement of antenna design methodologies, particularly in the context of C-band applications where robust and efficient communication is essential. Through rigorous simulation and analysis, we evaluate the performance metrics of the designed scarecrow-shaped antenna, including impedance bandwidth, radiation characteristics, and gain, to validate its suitability for C-band communication systems. Various shapes of antenna models are designed by researchers [11]-[23].

From this study, we proposed a scarecrow-shaped antenna specific to applications in the C-band. The antenna configuration includes a scarecrow-shaped microstrip line, partial ground plane, and radiating patch. By incorporating adjustments in the patch and ground plane dimensions, we aim to achieve desired characteristics such as wide impedance bandwidth and low reflection coefficient. The antenna's performance will be evaluated through numerical simulations and experimental validation, building upon the insights provided by the existing literature. Through this endeavour, we strive to contribute to the ongoing discourse in antenna engineering and pave the way for innovative solutions to address the challenges of next-generation communication systems.

2. Design Methodology

A Scare Crow Shaped antenna with slotted feed has been implemented with partial slotted ground structures to achieve the desired results. The patch and ground are designed using copper material. On the ground plane, there are two half-circle, square-shaped slots and a circle with tiny scratches.

The suggested antenna measures 15mm x 16 mm and uses a Rogers RT6002(Lossy) substrate with a permittivity of 2.94 and a thickness of 1 mm. Both ground and patches with a 0.035 mm thickness are made of copper. CST tool is used for antenna design and simulation with different substrates.

2.1: Antenna geometry

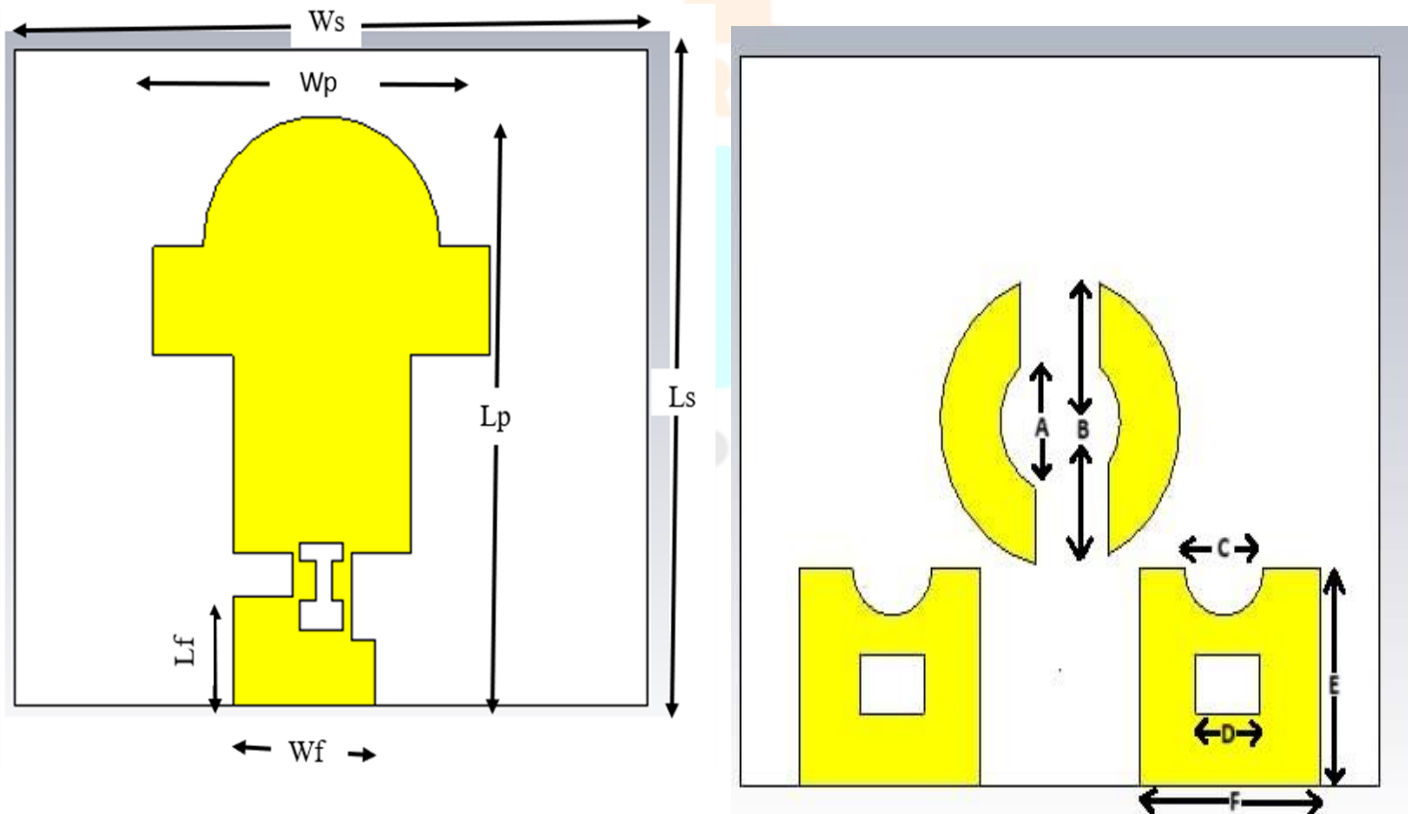


fig2.1: the geometric layout of the antenna; (a) frontside, (b) back side (ground)

table 1: Dimensions of the designed antenna

Parameters	Description	Rogers RT6002 value (mm)
Lp	Length of the patch	13.5
Wp	Width of the patch	7.5
Lf	Length of the feedline	2.5
Wf	Width of the feedline	2.21
Ls	Length of the substrate	15
Ws	Width of the substrate	16
A	Radius of inner circle on the ground	2.52
B	Radius of outer circle on the ground	5.78
C	Radius of semicircle cut on ground	2.00
D	Small cut in ground	1.2

2.2: Antenna Simulation and Results

High frequency devices, including antennas, filters, couplers, multi-layer structures, and EMI/EMC effects, can be quickly and accurately analysed with the help of CST Microwave Studio. CST develops simulation models of the antennas that are being studied. The optimum simulation technique for wideband/planar antennas in CST may be the transient solver. Drawn using the integrated Graphical User Interface is the antenna structure.

To excite the antennas, waveguide ports are assigned after the antenna structure has been simulated. Prior to the transient solver commencing, the intended frequency range is chosen. For the simulation to begin, the transient solver is run. Input impedance, return loss, VSWR, radiation patterns, gain, and other electrical characteristics and frequency domain parameters of the antenna can be easily shown, saved, and printed using the simulated results.

Parameters like a component's size or location, the material's characteristics, and the values of the circuit elements that are connected to it can all be optimised using CST's parameterization and optimisation abilities. In order to get the necessary impedance response, the antenna shape can then be suitably optimised. By positioning virtual probes on a spherical surface surrounding the antenna at the appropriate locations, transient response may be analysed.

The Scarecrow shaped antenna is designed for C-Band applications in this chapter. Computer Simulated Technology (CST) programme version 2020 is used to simulate and configure the designed antenna. This programme is used to simulate Electro Magnetic Fields (EMFs).

The efficiency of the planned antenna architecture is evaluated in this chapter using the following parameters.

- S-Parameters
- Voltage Standing Wave Ratio (VSWR)
- Gain
- Directivity
- Radiation Efficiency
- Surface Currents
- Co & Cross Polarizations

a. S -Parameters:

The reflection coefficient of a device, or the amount of an incident signal reflected at specific frequencies, is described by S_{11} parameters. For evaluating the effectiveness of parts such as amplifiers, filters, and antennas in C-band applications, S_{11} characteristics are vital. As low reflection and maximum power transfer are indicated, the S_{11} parameters for the specified frequency range (4 to 8 GHz) should preferably be as close to zero as feasible. Because components and gearbox lines can have flaws, there will always be some reflection in real-world situations.

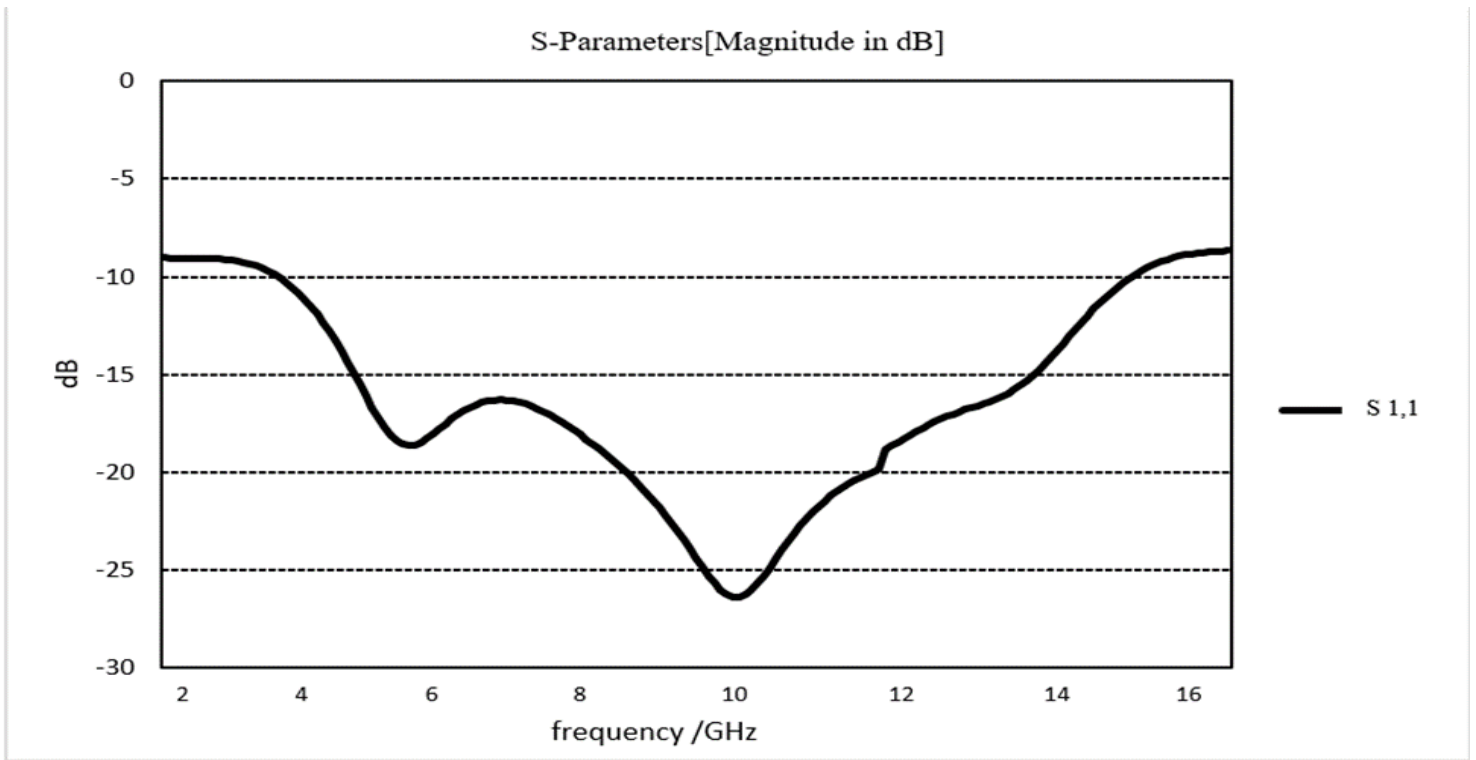


fig2.1:S-Parameters

Less than -10 dB is often an acceptable S₁₁ parameter in this range, indicating that more than 90% of the signal is transmitted as opposed to reflected. Decreased performance, impedance mismatch, and signal loss might result from more severe reflection, which is indicated by a higher value.

b. VSWR:

For the better performance of transmission and reception, VSWR should be less than 2. As shown in figure, the suggested antenna design has a VSWR < 2 in the necessary operating band.

Voltage Standing Wave Ratio (VSWR)

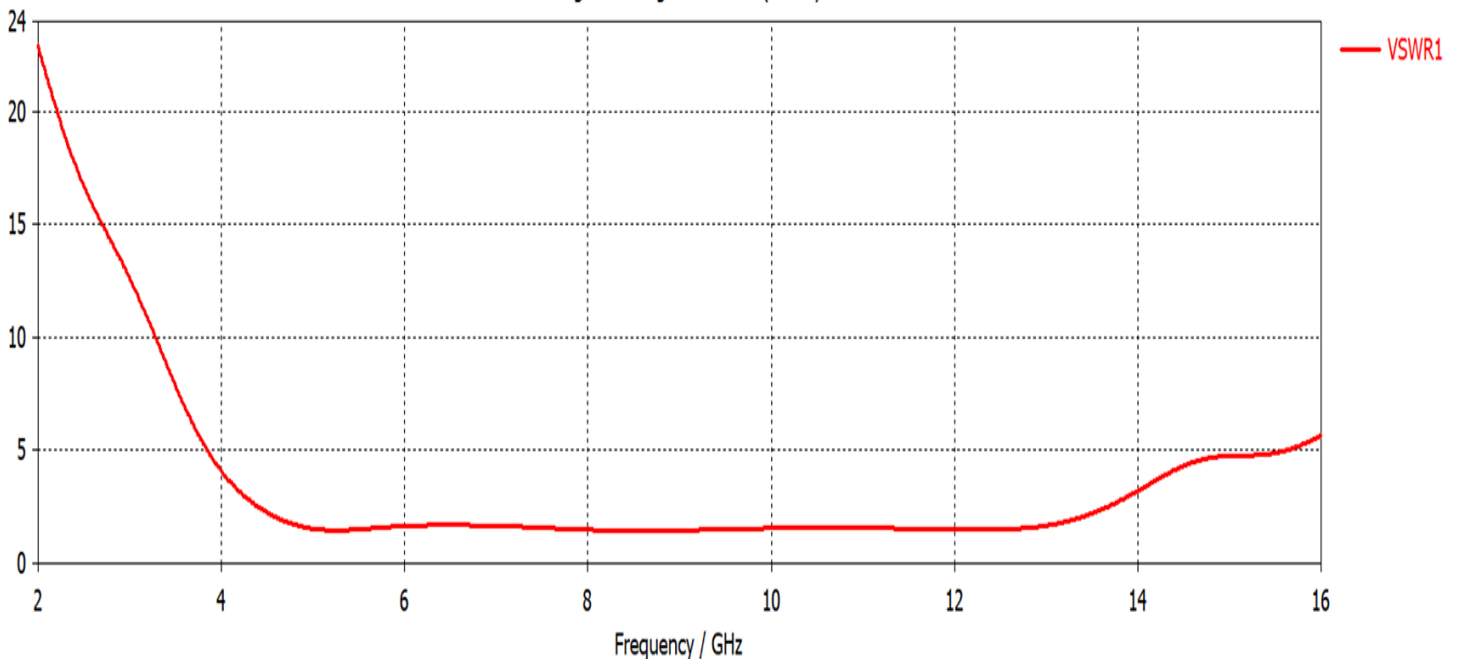


fig2.2: VSWR

c. Gain:

By calculating the simulated radiation pattern, the scarecrow-shaped antenna's gain may be found. Comparing the antenna to an isotropic radiator (an ideal radiator that radiates evenly in all directions), gain indicates the antenna's capacity to focus electromagnetic energy in a specific direction. Antenna gain can be precisely measured at different angles and frequencies with the capabilities provided by CST software.

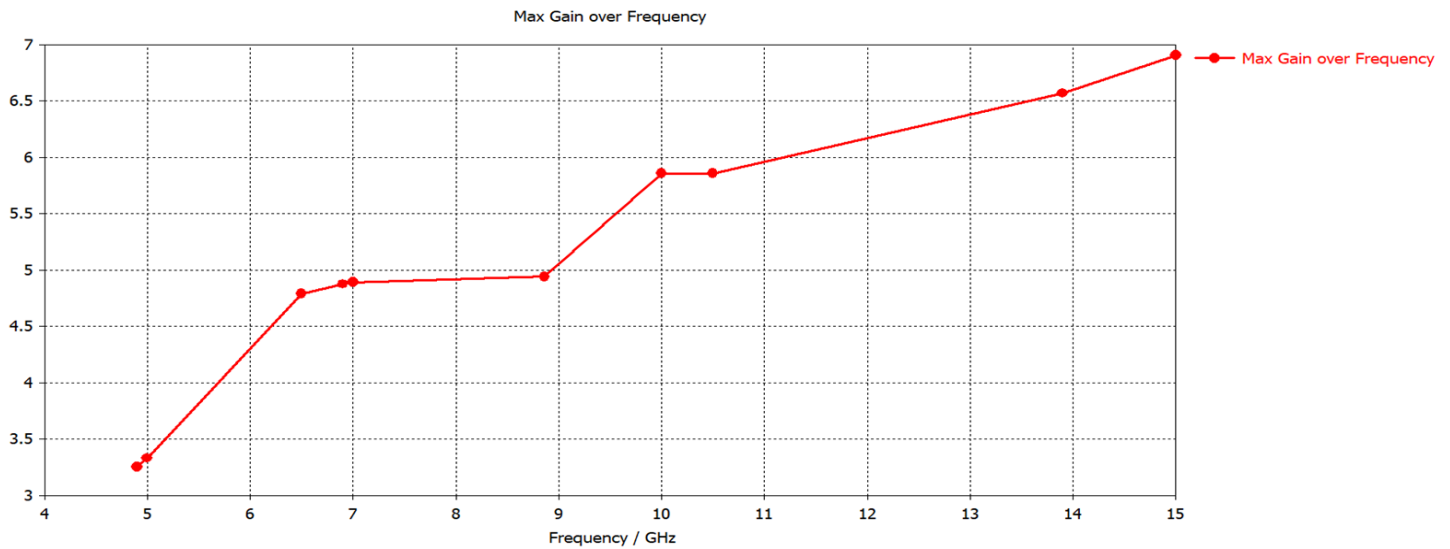


fig2.3: Gain

The highest gain that may be obtained in the C-band for a scarecrow-shaped antenna will rely on the particular design and optimisation efforts, it is vital to realise. Furthermore, the performance of the antenna might be impacted by external factors including installation concerns and ambient circumstances. Thus, to find the maximum gain of the antenna in real applications, precise simulation and testing are necessary.

d. Directivity:

The design, size, materials, and operating frequency within the C-band range (usually 4 to 8 GHz) are some of the elements that affect the directivity of a "scarecrow-shaped" antenna for C-band applications. It is difficult to determine an exact directivity value in the absence of a specific design or other information.

But generally speaking, an antenna's directivity is defined as its capacity to concentrate radiation in a specific direction. Decibels (dB) are frequently used to measure it. More directed radiation in a certain direction is implied by higher directivity.

Directivity,3D,Max. Value (Solid Angle)

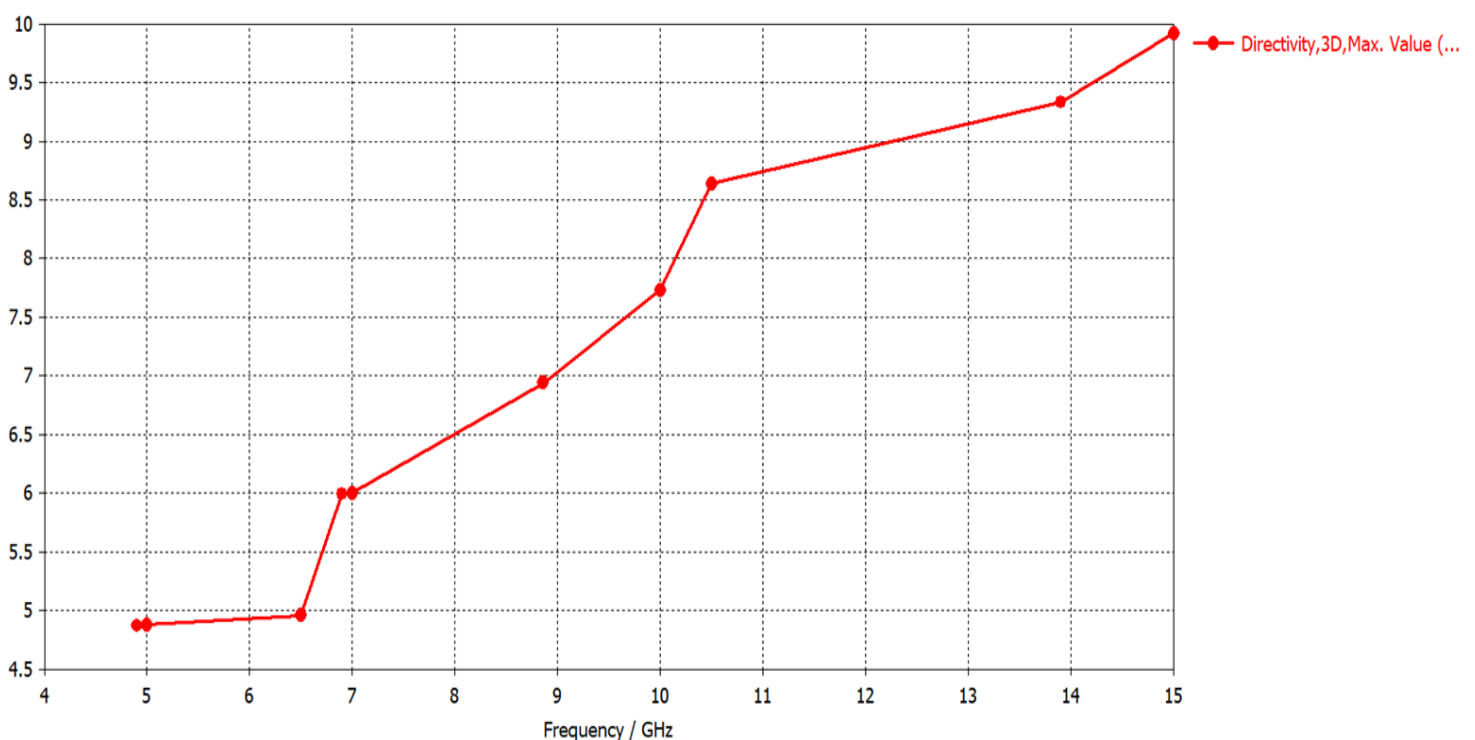


fig2.4: directivity

The capacity of a scarecrow-shaped antenna to focus radiation in a particular direction may have an impact on its directivity. In comparison to a more straightforward antenna design, the form may have higher directivity if it is optimised for focussing radiation.

e. Radiation efficiency:

The design of the antenna, the materials used, the manufacturing quality, and the climatic circumstances all affect how effective an antenna is at distributing radiation, even a scarecrow-shaped antenna intended for C-band uses.

Calculation of Radiation Efficiency: The radiated power and the total input power to the antenna must be compared in order to get the radiation efficiency. You can use the following formula to get the radiation efficiency (η_r):

$$\eta_r = \text{Prad}/\text{Pin} \times 100\%$$

Where:

Prad is the radiated power by the antenna.

Pin is the total input power to the antenna.

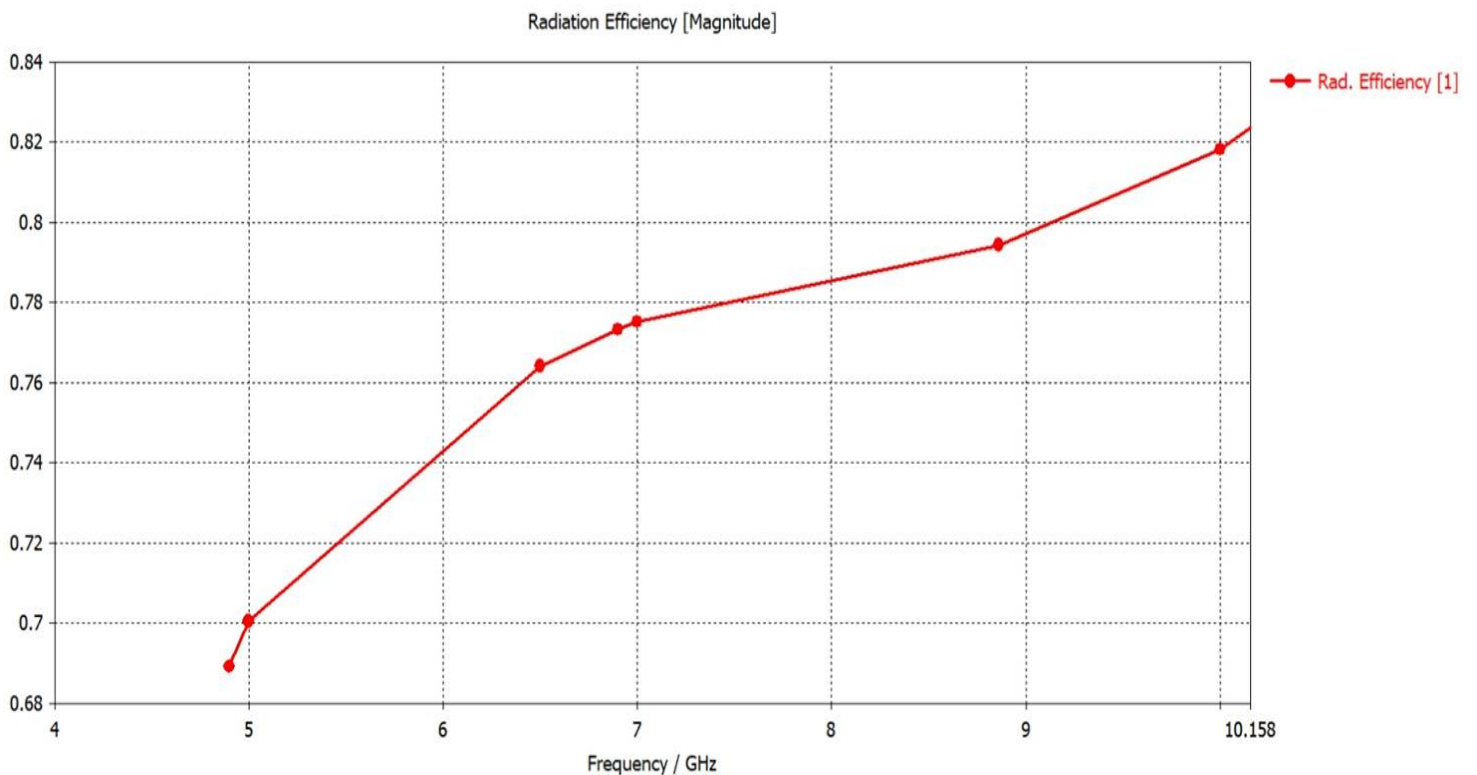


fig2.5: Radiation Efficiency

f. Surface Currents:

A simulation of the scarecrow antenna's cross- and co-polarization patterns is included. The E-plane and H-plane patterns are shown for four sample frequencies: 4.9, 8.86, 10.5 and 13.9 GHz. Good agreement is seen in the simulated findings. Patterns for the E- and H-planes are almost omnidirectional at all frequencies. For the E-plane, the cross-polarization level is substantially lower than the co-polarization level.

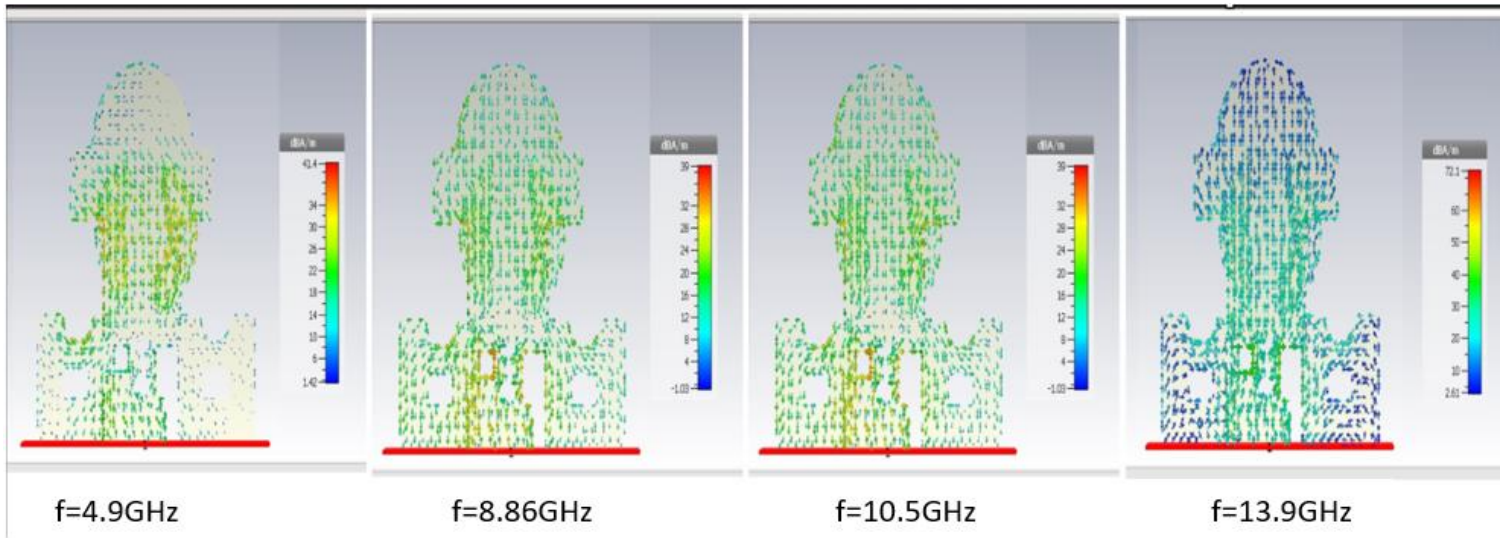


fig2.6: Surface Currents

g. Co-Cross Polarization:

First, when we talk about polarization we are concerned with the electric field vector, thus, Polarization is the property of the EM waves describing direction and magnitude of the E-field vector.

Linear Polarisation: The E field vector can exhibit either vertical or horizontal linear polarisation, with just a difference in amplitude.

Circular Polarisation: The E field vector rotates towards the direction in which the waves are propagating, maintaining a constant magnitude. Examples of this include left- and right-hand circular polarisation.

Elliptical Polarisation: Both the direction and the magnitude of the E field vary. Moreover, either left- or right-handed elliptical polarisation is possible.

Cross- and co-polarization: Cross polarisation, sometimes referred to as X-polarization, is the orthogonal radiation of desired linear, circular, and elliptical polarisation. For instance, if horizontal polarisation is desired, the orthogonal radiation will be vertical; likewise, if right hand polarisation is desired, the orthogonal radiation will be left hand polarised. On the other side, co-polarization is the desired polarisation of the wave that is emitted.

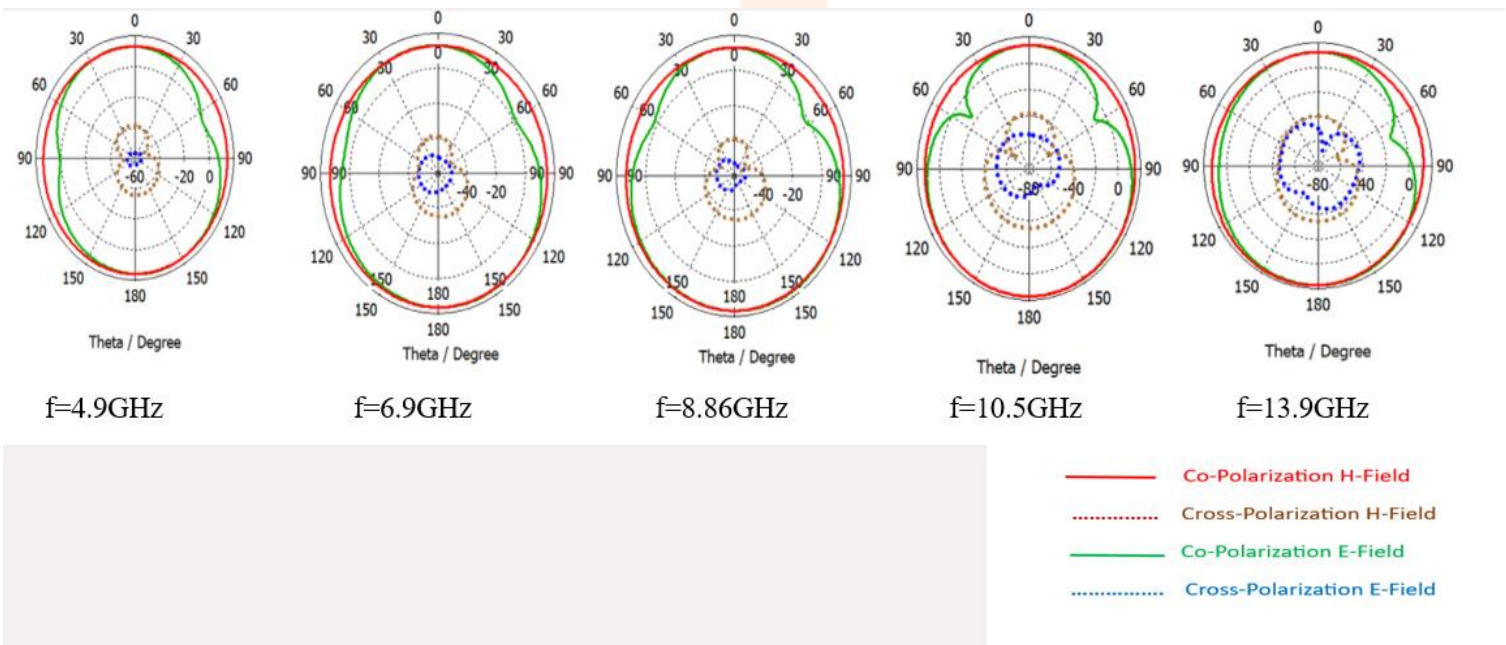


fig2.7: co & cross polarization

2.3: Antenna Fabrication

Photolithography is used to create the antenna prototypes on microwave substrates. When high dimensional accuracy is required, this approach is used. A laser printer prints the antenna geometry's first negative mask onto butter paper. Acetone is used to clean copper clad sheets of the appropriate size in order to eliminate any oxide layer from their surface. A thin layer of photoresist material is placed and cured on copper clad using a high-speed spinner. After that, copper clad is exposed to UV light on a substrate with a prepared negative mask on it. Whereas the unexposed area is unaffected and can be etched by dipping in developer solution, the exposed section of the photo resist material layer hardens. Next, water is used to rinse it. Now, the undesirable copper is etched utilising



fig2.8: Hardware implementation of the proposed antenna

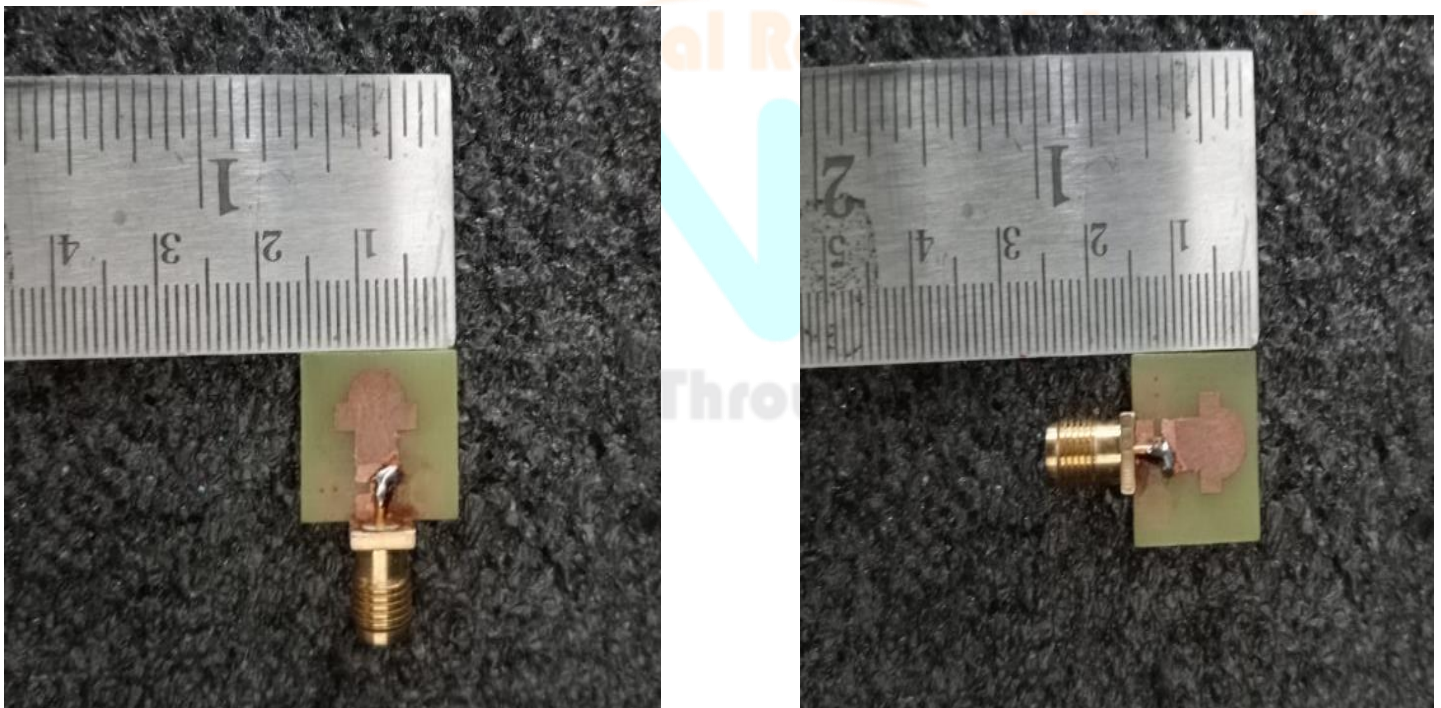


fig2.9: Length and width of the proposed antenna design

2.4: Fabrication Results

a. S-parameters (S_{11})

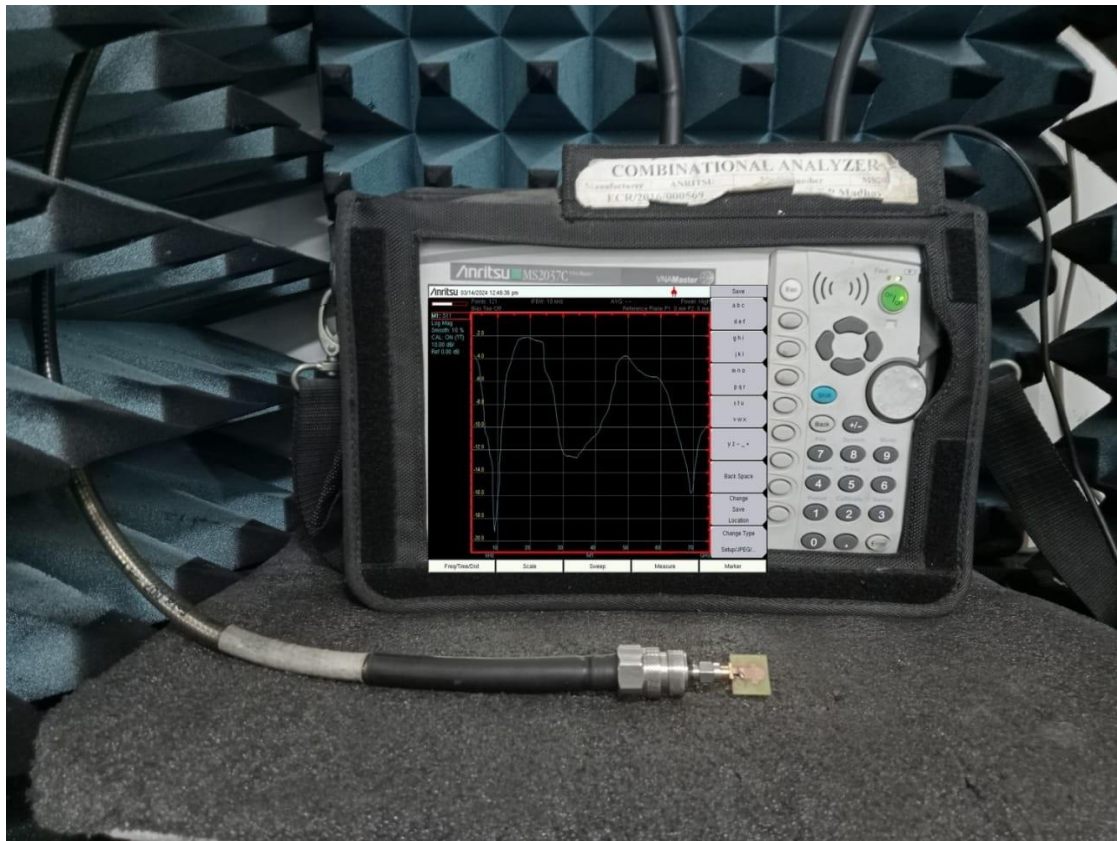


fig2.10: S-Parameters

b. VSWR

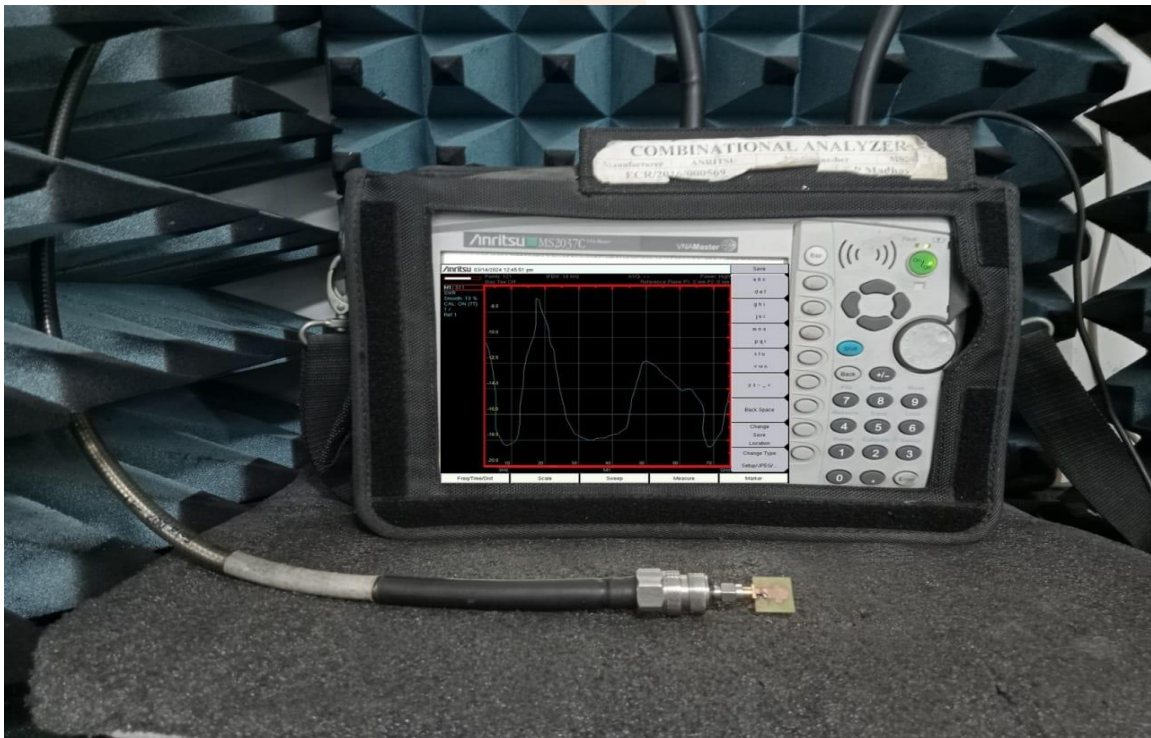


fig2.11: VSWR

table 2: comparison table

Authors	Size (mm ³)	Substrate	Gain (dBi)	Operating Frequency (GHz)
Mubarak et al	25x25x1.6	FR-4	4	5
Amit Kumar Singh et al	85x70x1.6	FR-4	NA	1.3-6
Gerand Djenyomemgolo et al	25x25x0.76	RT Duriod 6002	5.479 9.556	6.53(c-band) 8.62(x-band)
Edwin Barreto et al	85x85x1.57	FR-4	4.8	3.625-4.2
Lijaddis Getret Ayalew	7.9x7.85x1	RT Duriod 6002	6.0 4.15	28 38
Shahidulan et al	38x35x1.57	Roger 5880	6.4	2.8-22.7
RakeshNath Tiwasi et al	25x18x1.6	FR-4	2.28-5	2.8-17
Md Hannan et al	34x34x2	RT Duriod 6002	6.3	5-6
Surajit Mukherjee et al	34x26x1.524	Arlon AD 300A	6.2	3.1-35.2
Bhupendra Shukla et al	100x70x1.6	FR-4	NA	1.23-4.65
Proposed antenna	15×16×1	Rogers RT6002	4.5	4-8

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3.Conclusion

The presented Scarecrow-shaped patch antenna for C-band applications offers a novel approach to achieving wide impedance bandwidth and desired performance characteristics. Utilizing a unique design comprising a Scarecrow-shaped radiating patch, partial ground plane, and strategically placed slots, the antenna demonstrates impressive impedance matching, with $S_{11} < -10$ dB across a frequency varying from 4 to 8 GHz. The use of Rogers RT6002 substrate with specific dimensions of 15mm x16mm x1mm and coaxial feed ensures efficient energy transfer and impedance matching. Numerical simulations using CST Microwave Studio confirm the antenna's performance. Analysis of radiating patterns and distribution of current at specified frequencies provides insight into the antenna's behaviour. Furthermore, the study of parameter effects on frequency response enhances understanding of antenna performance optimization. The design and optimisation of patch antennas for C-band applications are greatly aided by this research, opening the door for future developments in wireless communication technology.

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