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Design of Microstrip Patch Antenna Array for Wireless Communication

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ABSTRACT: The rapid evolution of 5G technology demands efficient compact and high-performance antenna system to meet the growing requirements of high data rates, low latency and seamless connectivity. In this paper a 2x2 Microstrip patch antenna array is designed and analysed for 5G C-band wireless communication. The compact 2x2 array configuration enhances the gain, bandwidth and directivity compared to a single–element patch. The radiation pattern analysis shows the broadside directional beam with minimal side lobes, ensuring reliable communication and reduced interference. The compact size and light weight design makes the antenna array highly suitable for integrating into 5G small cells. The FR4 Epoxy substrate is used to design the antenna. Computer Simulation Technology (CST) software is used to design and simulation the proposed antenna array pattern. In conclusion, the design and analysis of a 2x2 Microstrip patch antenna array for 5G C-band wireless communications is a vital step toward building efficient and reliable communication systems.

KEYWORDS: 5G antenna, Microstrip patch array, C-band, Wireless communication, MIMO (Multiple Input Multiple Output), Beam forming, Gain, Bandwidth, Return loss, Radiation pattern, High-frequency simulation.

I. INTRODUCTION

The usage of a Microstrip antenna is an achievement in wireless communication systems and it is satisfying the necessity of the most recent age of wireless communication technology corresponding to new innovation. Microstrip antennas are being utilized in each of these systems because of their advantages, such as light weight planner structure, and economical efficiency. However the narrow operating bandwidth is the limitation of it, and this imposes restrictions in its use in wireless systems. Broadband application performing various tasks and wireless gadgets have comes out to be a fundamental part of our day by day correspondence life. Therefore the requirement for low profile wideband has been scaled down. Microstrip antenna satisfies the greater part of the requirements for mobile and satellite equipments, and numerous business requirements are satisfied by the utilization of it. The measure of electronic circuits required for wireless applications are contracting definitely, where the Microstrip is very much suitable. The size of the antennas being used for the most of application is also shrinking drastically. Microstrip antenna fixes design fulfilment with the needs of these. Different techniques have been considered and it found that proper impedance bandwidth of the Microstrip antenna can be one reason for improvement. Very basic form of the Microstrip antenna can be constructed using dielectric substrate as a base material and a radiating conducting material itched on a upper side of the substrate. The shape of the radiating conducting material is of any geometrical shape as a basic form or some other common shape for the simplification of the analysis and performance prediction. The rapid evolution of wireless communication technology has led to the widespread adoption of fifth-generation (5G) networks; offering significantly higher data rates; lower latency and improved connectivity compared to previous generations. To effectively support 5G wireless communication the design of efficient and compact antennas is crucial. Microstrip patch antennas (MPAs) have emerged as a preferred solution due to their low profile light weight structure, ease of fabrication and compatibility with Printed Circuit Board (PCB) technology.

5G ANTENNA

Compared to 4G technology, 5G antennas are designed to operate at higher frequencies, including the millimeter wave (mm wave) band, typically between 30 GHz and 300 GHz. These high frequencies allow greatly increased transmission rates, but the signal coverage is smaller and the penetration is weaker. 5G Antennas, use broadband antennas from 700-3800 MHz. The exception is, if the base station is more than 10 Km away, in which case you should select an antenna for a specific band. They have a slightly higher gain than broadband universal antennas. 5G is a unified, more capable air interface. It has been designed with an extended capacity to enable next-generation user experiences, empower new deployment models and deliver new services. With high speeds, superior reliability and negligible latency, 5G will expand the mobile ecosystem into new realms.

MICROSTRIP PATCH ARRAY

A Microstrip Patch Antenna consists of a conducting patch of any planar or non planar geometry on one side of a dielectric substrate with a ground plane on the other side. It is a popular printed resonant antenna for narrow-band microwave wireless links which require semi-hemispherical coverage. A Microstrip antenna consists of a patch of metal foil of various shapes on the surface of a PCB, with a metal foil ground plane on the other side of the board. There are three types in Microstrip antenna. They are, Microstrip patch antenna, Microstrip solt/travelling antenna and Printed Dipole Antenna. Among the above three type Microstrip patch antenna can have any shape. Microstrip slot/travelling antenna is mostly rectangular or circular shape.

C-BAND

C-band has the potential to be a key element of 5G because the frequency can cover wide distances and has expected peak data rates between 600 Mbps and 900 Mbps. C-band refers to the portion of the electromagnetic spectrum allotted for satellite transmission in the 4GHz to 8GHz frequency range. C-band sits on the mid-band spectrum of cellular broadband network frequencies especially between 3.7 GHz and 3.98 GHz. C-band which sits within the mid band spectrum, is the perfect middle ground. It performs significantly better than low band, providing speeds between 100 Mbps to 500 Mbps. The C-band is used by 5 GHz Wi-Fi networks, for example to connect laptops (left) to the internet through a wireless router.

MIMO

MIMO (Multiple Input Multiple Output) is a wireless communication technology that uses multiple antennas at both the transmitter and receiver to improve communication performances. It enhances data rates, reliability and spectral efficiency by exploiting multipath propagation. MIMO is widely used in modern wireless standards like Wi-Fi (802.11n/ac/ax). 4G LTE and 5G NR enable faster and more reliable wireless communication. Multiple antennas improve signal robustness by reducing the effects of fading. It directs signal toward a specific receiver, improving signal strength and reducing interference. It increases data rates by transmitting independent data streams over different antennas. A large number of antennas are used to further enhance capacity and efficiency.

RADIATIONPATTERN

In wireless communication, a radiation pattern describes how an antenna distributes radio frequency (RF) energy in space. It represents the relative strength of the transmitted or received signal in different directions. There are three types, Omnidirectional pattern, Directional pattern and Isotropic pattern. Radiation patterns are typically displayed as: 2D polar plots-Showing the radiation in a plane (E-plane and H-plane). 3D plots-Providing a complete spatial view of radiation distribution. Optimizing Coverage ensures efficient signal transmission and reception. Directional antennas help minimize interference in network deployments. Improves signal strength and reliability in communication systems.

II. LITERATURE OVERVIEW

S-band [1] is defined as the frequency range from 2 GHz to 4 GHz consisting of a wavelength (λ) range of 75-150 mm [2]. The means of communication in any wireless domain is a well-organized antenna with small size, very high gain, low Return Loss, and high Bandwidth. In such cases, MPA is common because of its excellent features, such as low profile, lightweight, low cost, dependability, and ease of manufacture [3], [4]. The essential construction of an MPA includes a metallic radiating patch component, which is combined into a grounded dielectric substrate. There are various techniques of MPA feeding. The Microstrip feed line is one of them [9]. It's known that the 2.4 GHz frequency can cover applications such as wireless local area network (WLAN), Multiple-Input and Multiple-Output (MIMO), Wi-Fi, Bluetooth, and ZigBee [10], [12]. Numerous programming languages had used for solving antenna equations and designing MPA structure.

A U shaped Microstrip based antenna was developed, which can work in resonant frequency of 25GHz for Wi-Fi and WLAN applications [2]. In a multiple tuned antenna, the ground loss is reduced. The return loss is good observed followed by the using HFSS software. The return loss is good observed followed by the radiation pattern

Design and simulate a patch antenna operating a 1.7 GHz with an ideal coaxial feed [3]. The selected substrate for the design is a plastic material known as polypropylene. Dielectric permittivity: εr = 2.2 Thickness: H = 5 mm.5.1 Model the structure 1. Open CST Design Environment and create a new CST Microwave Studio project. 2. Select the template Antenna (Planar), that makes a reasonably selection of the parameters described in section. Define the dielectric substrate of the patch antenna. You can define a new material from de-context menu of the folder Materials in the navigation tree or from the menu bar (Solve→Material→New material. Select New Material... and, in the new dialogue window, specify the dial. A circular polarization is made by the superposition of two orthogonal linear polarization with a phase delay of 90◦ If we use the patch antenna designed above, and set W=L, then overlay two orthogonal patch antennas is equivalent to put a second coaxial excitation at coordinates X=0, Y=Feed

There have been issues coming up with the patch of the antenna and its large size and its large size and heavy weight of the antenna due to the material thickness applied to different patch shapes being circular, rectangular, square, triangular, elliptical etc [4]. Different methodologies are being used to create an antenna according to the requirement of the applications. Several works are available in the literature on designing Microstrip patch antenna. The radiation of triangular antennas has better properties than other antenna shapes. A single patch of triangular antennas was designed using Ansys software R2. It was experimented with few changes in dimensions and observed the best possible outcome that has least input impedance along with its simulation for single patch with feeding line input.

III. PROPOSED REVIEW

The proposed method for designing and analyzing a Microstrip patch antenna for wireless communication involves a systematic approach to optimize its performance in terms of gain, bandwidth, and efficiency. The design begins with defining key parameters such as the operating frequency, substrate material, and dielectric constant. Using analytical models like the transmission line and cavity model, the initial dimensions of the patch, ground plane, and feed structure are determined. The design is then simulated using electromagnetic simulation tools like CST Microwave Studio such as S-parameters, radiation patterns, and efficiency. Following simulation, the optimized design is fabricated using PCB etching or photolithography techniques and tested with a Vector Network Analyzer (VNA) to validate its real-world performance. This method ensures the development of a compact, high-performance Microstrip patch antenna suitable for modern wireless communication applications, including Wi-Fi and 5G. Simulation of Single patch antenna is shown in Figure 1. Figure 2 shows the Microstrip Patch Antenna Array and Figure 3 shows the Simulation and fields of Single patch antenna.

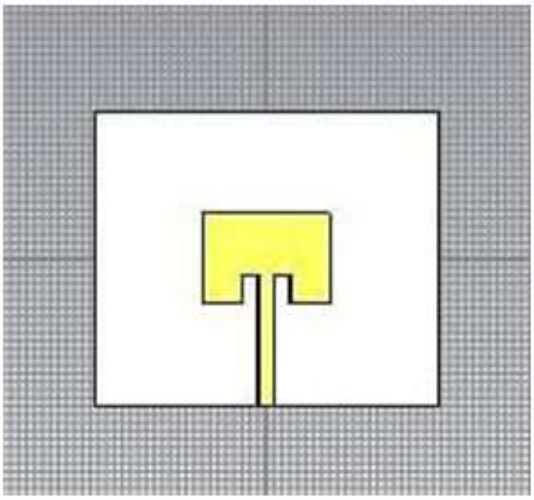

Figure 1: Single patch antenna

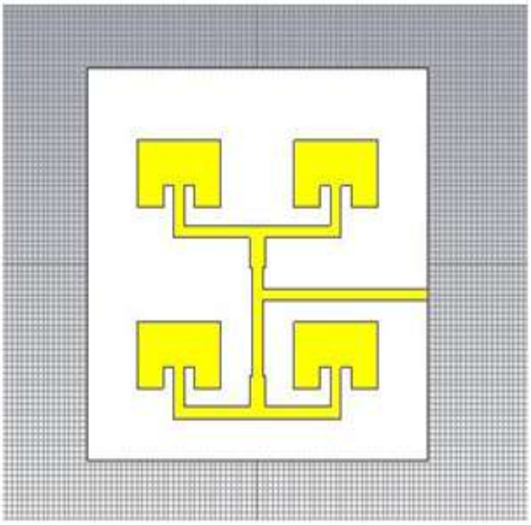

Figure 2:2x2 Microstrip Patch Antenna Array

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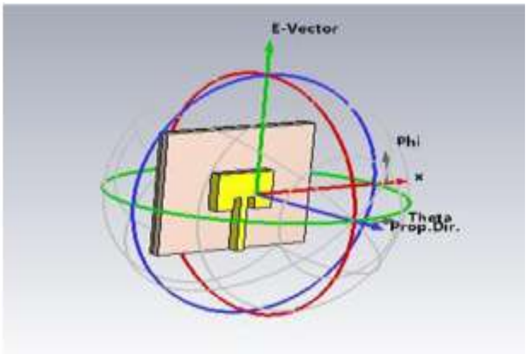

Figure 3: Simulation and fields of Single patch antenna

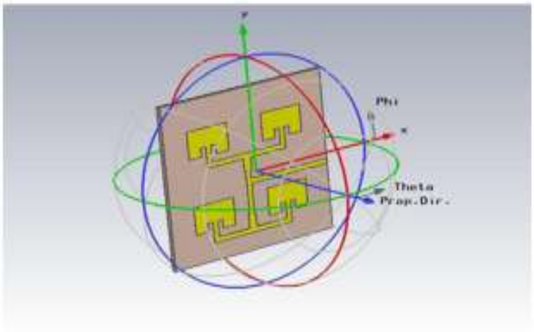

Figure 4: Simulation and fields of 2x2 Microstrip patch antenna

IV. SIMULATION AND RESULT

The overall size of the single patch antenna is 43mm × 36 mm × 6mm (L×W×H), while 2x2 microstrip patch antenna array is 65mm × 65 mm × 1.64 mm (L×W×H) and printed on Flame Retardant 4 (FR4) with arelative permittivity of 4.4 FR4 and a loss tangent of 0.06. Table 1 list the dimension of the antenna array. The antenna is fed by 50 Ohm and 0.5W. Table 1 shows the design parameters of Single Microstrip Patch Antenna and Table 2 shows the Design parameters of 2x2 Microstrip patch Antenna Array

S.no	Parameter	Value
1	Lower Frequency	4GHz
2	Higher Frequency	7GHz
3	Dielectric Constant	4.4GHz
4	Ground(LxW)	43mmX36mm
5	Ground height	0.035
6	Substrate (LxW)	43mmX36mm
7	Substrate height(h)	1.57mm
8	Single Patch (LxW)	16mmX11mm
9	Line Impedance	50
10	Tangent Loss	0.06
11	Input watt	0.5W

Table 1: Design parameters of Single Patch Antenna

S.no	Parameter	Value
1	Lower Frequency	4GHz
2	Higher Frequency	7GHz
3	Dielectric Constant	4.4GHz
4	Ground (L x W)	65mmX65mm
5	Ground height	0.035
6	Substrate (L x W)	65mmX65mm
7	Substrate height(h)	1.57mm
8	Single Patch (L x W)	16mmX11mm
9	Top Full design patch (L x W)	46mmX41mm
10	Line Impedance	50
11	Tangent Loss	0.06
12	Input watt	0.5W

Table 2: Design parameters of 2x2 Microtrip Patch Antenna Array

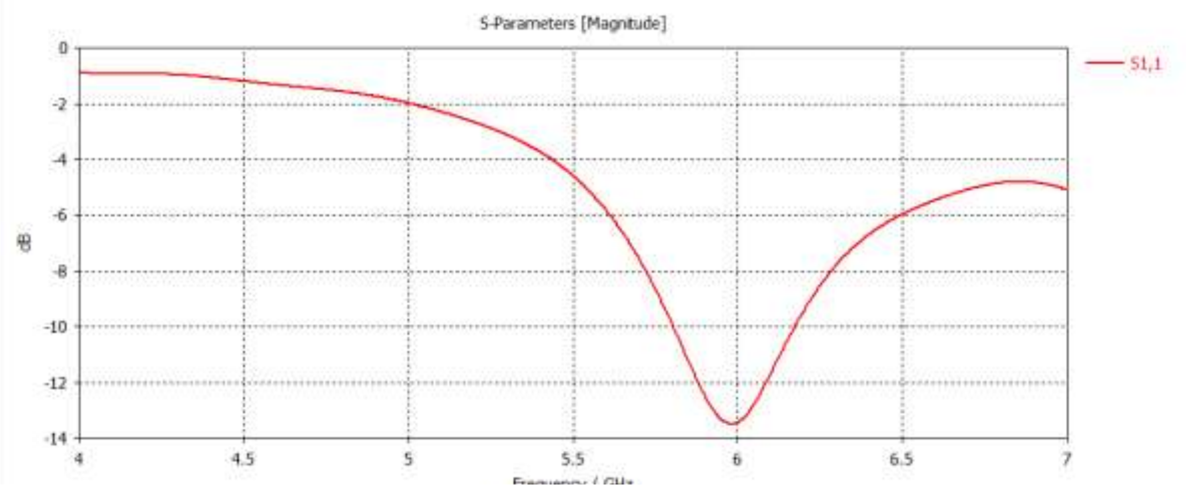

Figure 5: S Parameter curve for Single Patch Antenna

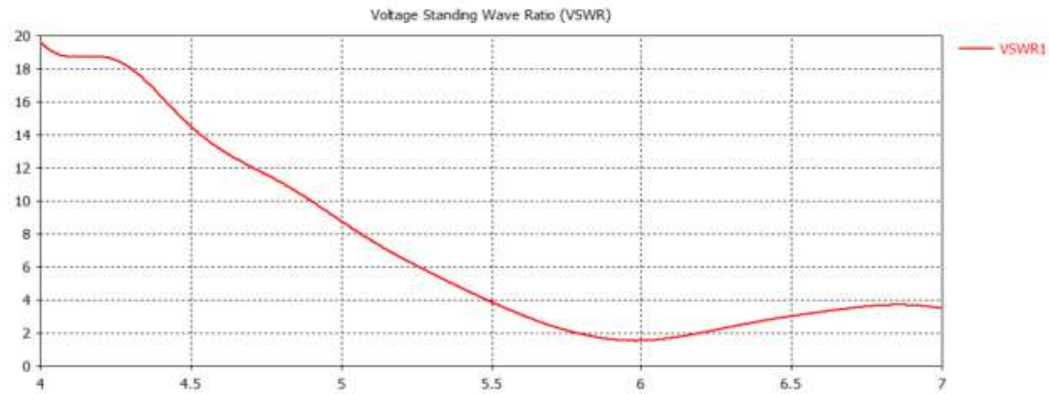

Figure 6: VSWR curve for Single Patch Antenna

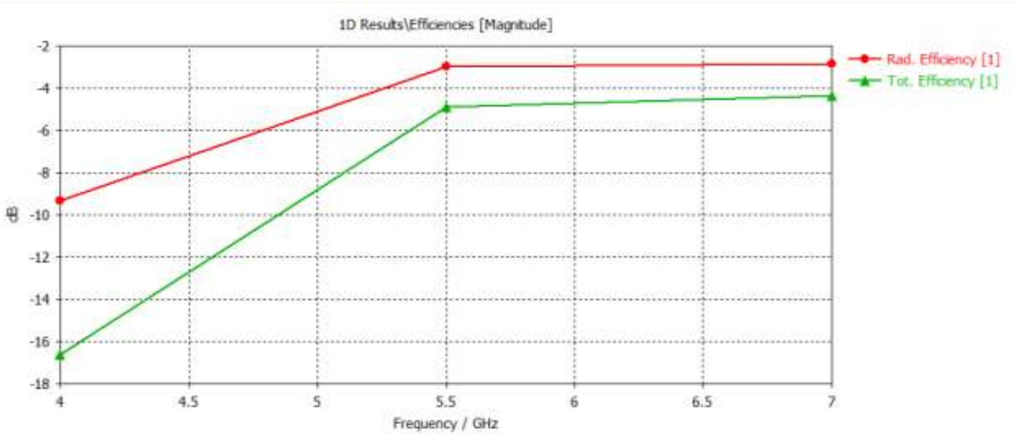

Figure 7: Efficiency curve for Single Patch Antenna

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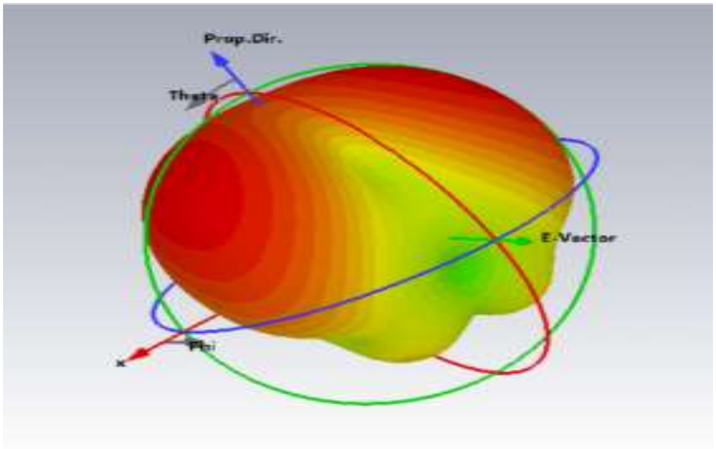

Figure 8: Radiation Pattern for Single Patch Antenna

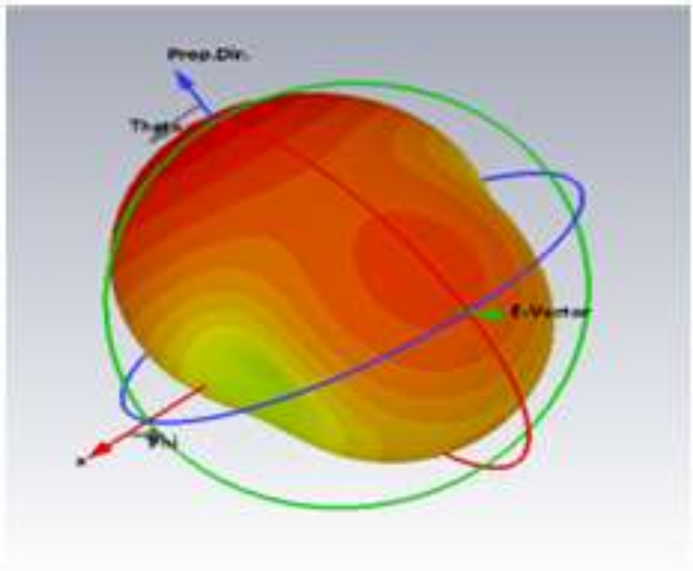

Figure 9: Radiation Pattern for 2x2 Single Patch Antenna

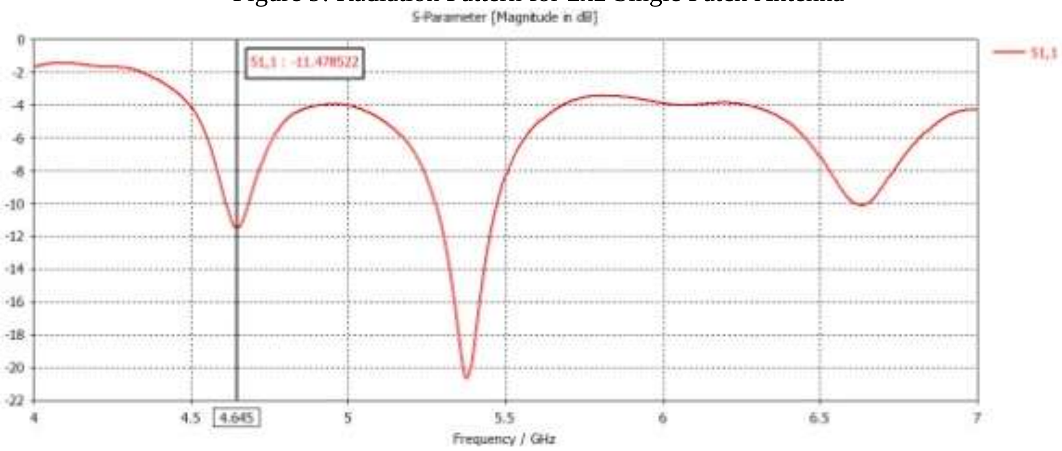

Figure 10: S Parameter curve for 2x2 Patch Antenna

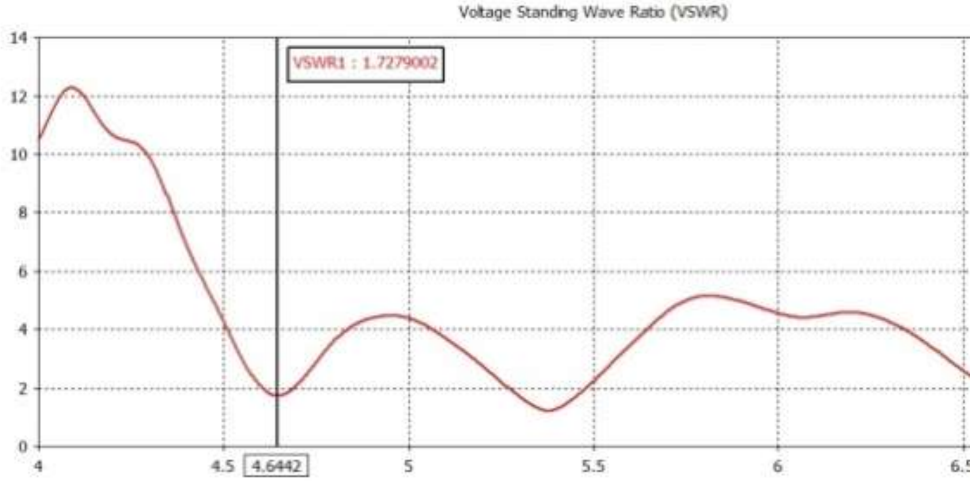

Figure 11: VSWR curve for 2x2 Patch Antenna

Figure12: Fabricated Single Patch Antenna

Figure 13: Fabricated 2x2 Microstrip patch Antenna Array

V. CONCLUSION

The design of the 2x2 microstrip antenna array shows the significant improvement in performance when compared to the single patch microstrip antenna. While the single patch antenna, with a substrate size of 43mm x 36 mm x 2 mm and a simple rectangular patch structure offers a compact solution, it is limited in terms of gain and overall radiation efficiency. In contrast, the 2x2 antenna array designed on a 65 mm x 65 mm x 1.64 mm FR4 substrate with a relative permittivity of 4.4 and a loss tangent of 0.024 demonstrates enhanced performance characteristics. The array structure fed with a 50 ohm input, achieves better impedance matching, improved gain, and higher radiation efficiency. This enhancement is particularly suitable for 5G C-band applications, where reliable high performance antennas were needed. The increased surface area and array configuration of the 2x2 design enable constructive interference of radiated signals, leading to higher directivity and better coverage. Thus the 2x2 microstrip antenna array proves to be a more effective and efficient solution for modern wireless systems compared to the single patch antenna.

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