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Design and Analysis of Rectangular and Circular Microstrip Patch Antenna

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Abstract: The advantageous radiation characteristics, low cost, lightweight design, ease of production and analysis, and affordability of microstrip patch antennas have contributed to their recent surge in popularity. Patch antennas provide a lot of advantages, but they also have certain drawbacks, such as a limited bandwidth, weak gain, and the potential to modify and reduce radiation patterns. In this paper, a circular and rectangular microstrip patch antenna design, modelling, and analysis are provided. The performance of the antennas is discussed in relation to the bandwidth, front-to-back ratio, 3D radiation pattern, reflection loss, and reflection factor coefficient at the inlet. Resonant antenna designs are required, and they are constructed on FR-4 substrates with a thickness of 0.71 mm and a permittivity ratio (εr) of 10, fed by a 50 Ω microstrip feed line. With a gain of 6.37dBi, the rectangular patch antenna operated at 0.17GHz in bandwidth. The 6.53dBi and 0.16GHz bandwidths are displayed simultaneously by the circle patch antenna. Based on a comparative analysis of their respective performances, the rectangular antenna performs better in terms of bandwidth than the circular antenna. Circulars are superior to rectangular at achieving good matching, even if circulars have better profits. As such, applications requiring fixed end-to-end communications may find the antennas to be a perfect solution. microstrip feedline arrangement. Sugandha's et al.
Keywords: Rectangle, circle, microstrip antenna, reflection loss, amplification, emission direction

I. INTRODUCTION

In today's world of wireless and mobile communication, optimising connectivity requires the use of antennas with high bandwidth and low loss (Alam et al., 2015). Although the concept of microstrip patch antenna radiators was first proposed in 1953, it gained significant attention in the 1970s when suitable substrates became available (Kumar & Srivastava, 2010; Free & Aitcheson, 2022). Microstrip patch antennas are becoming more and more popular because to their advantages, which include being lightweight, inexpensive, and easy to build using current circuit technology (Nasidi & Bello, 2022). Microstrip patch antenna drawbacks include non-directional emission pattern, low gain, and narrow bandwidth (Schantz, 2004). Microstrip patch antenna gain can be increased in a number of techniques that have been reported in literary works. For instance, a circular patch antenna with three bands that operates at 2019 saw the design of 5.8 GHz, 2.4 GHz, and 1.8 GHz by Parveen T. et al. Because of the patch antenna's slot formation, our target frequency, 1.8GHz, had a gain of 5.5dBi. Sharma et al. (2022) designed a circular microstrip patch antenna with a finite ground plane and three rings positioned on the patch. The antenna managed to achieve its pitiful 1.3dBi gain. Using a surrounding cylindrical patch antenna, Umayah and Srivastava (2020) built a planar antenna. With this design, a gain of 3.74dBi was obtained. A sector patch antenna with a fractal faulty ground structure and a circular polarisation is compared by the author of (Ramya & Gupta, 2022). At 1.8 GHz, the system operates. A gain of 3.39 to 3.75 dBi is provided. Moreover, (AL-Amoudi, 2021) designed antennas with elliptical, circular, and rectangular patch forms, among others. The antenna has a 5dBi gain/directivity and is shaped like a patch of rectangles. Optimising the antenna's size is another method of improving performance. (2014) used this technique to exhibit improved antenna performance, specifically a gain of 6.37dBi and a return loss of -29.2133. The 0.16GHz and 6.53dBi bandwidths are displayed simultaneously via the circular patch antenna. Based on a comparative analysis of their respective performances, the rectangular antenna performs better in terms of bandwidth than the circular antenna. Circulars are superior to rectangulars at achieving good matching, even if circulars have better profits. A square spiral antenna was created by Supratha and Robinson to boost a microstrip antenna's bandwidth. Conventional shape—albeit at high frequencies—were also employed to characterise the performance of microstrip patch antennas, but at 2.4GHz, the complex architecture could only muster a measly 593MHz bandwidth. The efficacy of these methods is impaired due to the Low Because low gain sometimes equates to high loss and vice versa when bandwidth is raised, the effectiveness of these approaches is hampered. This paper describes the design and analysis of a Microstrip patch antenna that uses both rectangular and circular patches. The front-to-back ratio, gain, bandwidth, radiation pattern, and voltage standing wave ratio (VSWR) are the components of complete antenna characteristics. In every domain under investigation, the antenna operates flawlessly. It could be useful in applications involving point-to-point connectivity.

II. METHODOLOGIES

Computer-simulated software, or CST, is used in this work to design and assess the antennas. It is advised to use thick substrates with low dielectric constants for greater bandwidth and improved antenna performance. Therefore, a FR4 substrate with a permittivity ratio (εr) of 10 and a width of 0.71 mm that is easily found in the market is used. While the patches are patterned on the substrate's front side, its rear serves as a grounded surface. The ground plane is meant to have an infinite length. The antenna patch is fed by a microstrip feedline with a matching impedance and minimal insertion. That is, an impedance of characteristic 50Ω is used. The microstrip feedline's length Lf and thickness Wf were calculated using the the equations found in the referenced literature (Balanis, 2005).

The goal of the design is to get higher add-on and good radiation properties with resonance at 1.8GHz. The antenna dimensions consequently take on significant importance since they affect both the resonant frequency and performance. The transmission line model equation (Balanis, 2005) can be used to compute the dimensions of both circular and rectangular antennas, as will be discussed in the following sections.

III. DIAGRAM

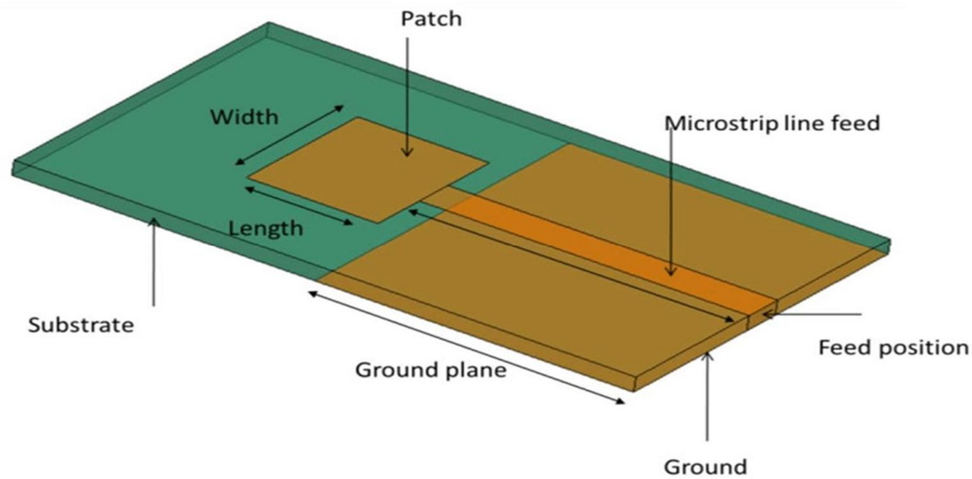

Fig 1- Rectangular Microstrip Patch Antenna

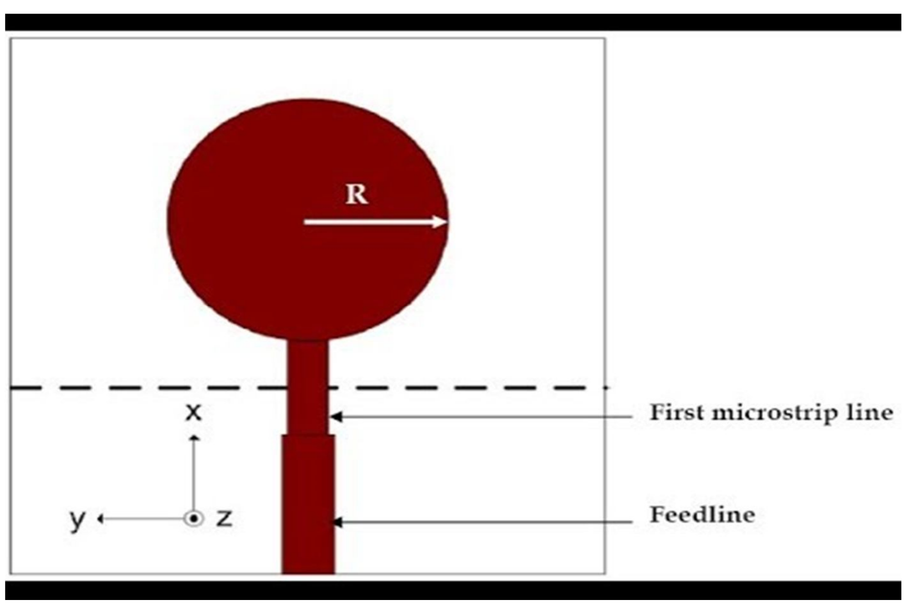

Fig 2- Circular Microstrip Patch Antenna

IV. LITERATURE REVIEW

The patch, ground plane, substrate, and feeding part are the four components that make up the single-layer design of the Microstrip Patch Antenna. These antennas are integrated with active devices and printed stripline feed networks. Antenna engineering is quite new in this field. Patch antennas are within the category of single-element resonant antennas. Everything (such as input impedance, radiation pattern, etc.) stays constant once the frequency is determined. The patch consists of an extremely thin ($t \ll \lambda_0$, where λ_0 is the wavelength of free space) radiating metal strip (or array of strips) that is positioned on one side of a thin, non-conductive substrate. The metal that forms the ground plane is on the other side of the substrate.

The patch can be whatever shape you like and is typically composed of conductive materials like gold or copper. Typically, photoetching is used to create the radiating patch and feed lines on the dielectric substrate. The thickness of the substrate layer is 0.01–0.05 of the wavelength in free space . The main purpose of this is to give the patch and its ground plane the appropriate mechanical support and spacing. To load the patch and make it smaller, it is also frequently employed with materials that have a high dielectric constant.

V. RELATED WORK

The study and efforts of Li et al. (2008) are among the most recent advancements in the field of rectangular patch antenna design. In this paper, a planar metamaterial patterned substrate is used to design a Microstrip patch antenna. It was created with a standard patch. antenna, as well as on the metal patch and ground plane, were etched isolated triangle gaps and crossed strip-line gaps. Literature demonstrates that this patterned substrate has left-handed properties. This results in a greatly expanded operating band from megahertz to gigahertz and considerably increased wave propagation along the patch. Full wave FEM simulator simulations were used, and the results indicate that the patch has the required and desired qualities (low loss, low VSWR, and high efficiency).

The Koch curve-defined fractal boundary microstrip patch antenna was first presented by Hazdra and Maz'anek (2004). The third iteration of the Koch3 fractal-boundary microstrip patch antenna was examined in terms of its attributes. The objective was to locate and identify the localised modes that improve antenna directivity (the behaviour of an antenna can be thought of as an array). They were able to solve the antenna as a planar resonator by effectively using the cavity model based on FEM (Hazdra, 2003; Garg and Bharita, 2000). The set of Eigen modes and Eigen numbers are the outcome of this. Since the feeding point had to be situated in the centre of the electric field, this was the first quick approximation method of the fields inside the resonator.

Since millimetre wave technology has many uses, it is an emergent field that is still mostly unexplored, according to Kumar and Srivastava (2010). As such, significant research efforts are needed. They designed a rectangular patch on a thick substrate in their work. They also announced the invention of a unique analytic technique for millimetre wave frequency circular patch antennas, which they simulated using SONNET software.

The antenna was analysed, simulated, and designed for 39GHz on a thick substrate. The outcomes of the theoretical study that was conducted showed a strong correlation with the outcomes of the simulation.

VI. PERFORMANCE COMPARISON

Table 1 displays a performance comparison between the recommended circular-shaped patch antenna and rectangular-shaped patch antenna. The results show that in terms of bandwidth, VSWR, and return loss, the rectangular patch antenna performs better than the circular patch antenna. However, the circular antenna provides better gain/directivity and front-to-back ratio. In light of this, the rectangular patch antenna is inferior. A rectangular patch antenna is suggested for applications that need essential bandwidth, however a circular patch antenna shows better unidirectional strength.

Applications requiring a high gain/directivity and low front-to-back ratio to avoid interference can benefit from the use of circular patch antennas. One may note that our proposed design offers a higher gain by using a circular patch antenna.

Performance Parameter	Return Loss (dB)	Bandwidth (GHz)	VSWR	Gain /directivity (dBi)	Reflection Coefficient
Rectangular	14	0.17	1.5195	6.37	0.2055
Circular	13.712	0.15	1.4406	6.53	0.1806

Table 1- shows the performance comparison

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VII. RESULT

The results of the design and analysis of rectangular and circular microstrip patch antennas depend on several factors including the desired operating frequency, bandwidth, gain, radiation pattern, and impedance matching requirements. Here are some typical results that one might obtain:

Resonant Frequency: One crucial factor is the patch antenna's resonant frequency. The dimensions (length and width) of a rectangular patch antenna, the characteristics of the substrate material, and the substrate's dielectric constant all have an impact. The diameter and substrate characteristics of a circular microstrip patch antenna can influence the resonant frequency. The range of frequencies that an antenna can effectively operate over is determined by its bandwidth. Patch geometry, dielectric constant, and substrate thickness are some of the variables that affect it. Broader bandwidths are typically found in rectangular patch antennas as compared to circular ones.

The radiation pattern explains the way in which electromagnetic energy is radiated into space by the antenna. The feeding method (microstrip feed line or coaxial feed), shape, and existence of any extra structures (parasitic elements or slots) all affect the radiation pattern of microstrip patch antennas, whether they are circular or rectangular.

Gain: The antenna's ability to focus energy in a specific direction is determined by measuring the directionality of its radiation pattern. When properly built and optimised, rectangular patch antennas frequently provide higher gains than circular ones. Impedance matching: To reduce reflection losses, impedance matching makes sure the antenna's input impedance matches the impedance of the transmission line or circuit it is attached to. Microstrip patch antennas in the form of rectangles and circles can be adjusted for impedance matching by modifying their sizes and feeding strategies.

VIII. CONCLUSION

This paper describes the construction, modelling, and analysis of microstrip patch antennas with circular and rectangular shapes that are fed by microstrip transmission lines. The antennas were designed to resonate at 1.8 GHz. This band was chosen since it is meant to be used with low to medium capacity requirements. With a bandwidth of 0.17GHz, the rectangular patch antenna shows a gain or diversity of 6.37dbi. With a bandwidth of 0.16GHz, the circular patch antenna has a gain or directivity of 6.52dbi. The VSWR of both antennas is nearly perfect, indicating good impedance matching. Other measures show that the rectangular patch antenna performs better. Conversely, the circular patch antenna performs better in terms of gain or diversity and ratio to

Using Matlab/Simulink software, a rectangular patch (probe feed) antenna was designed and completed. The simulations produced good results that meet the specifications needed to build the ideal antenna for the Bluetooth exchange of ideas. The Simulink programme and the Gwinstek Spectrum Analyzer were used to optimise the antenna. This resulted in the identification and study of key parameters (such as the radiation pattern, return loss curve, gain, and antenna efficiency) that have an impact on design and applications and whose implications are known.

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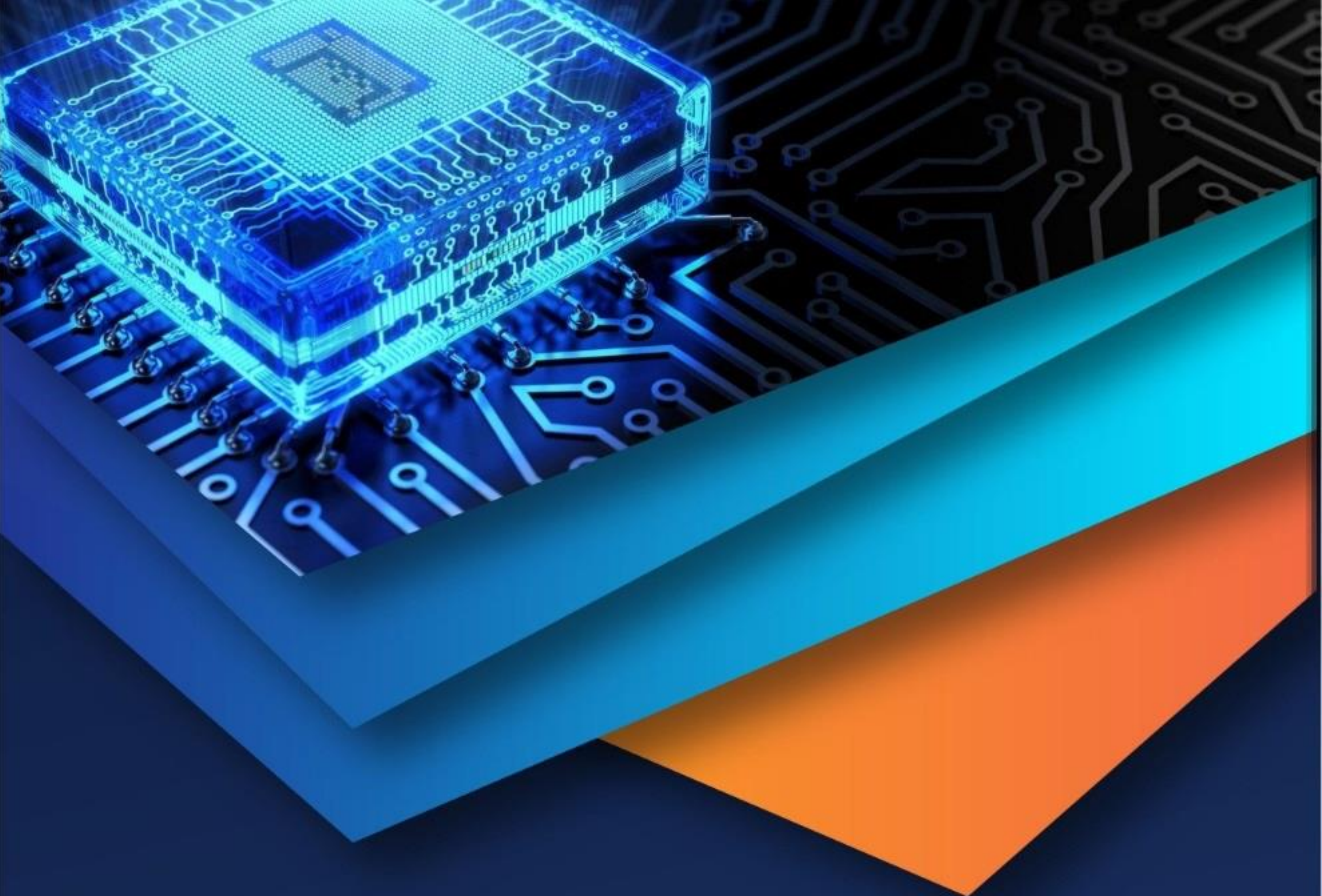

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