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Design and Fabrication of Microstrip Patch Antenna for X Band Applications

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Abstract— In this paper, a patch antenna was designed and fabricated for X-band application. The objective of the project was to develop an antenna with high gain, low profile, and wide bandwidth for use in X-band communication systems. The design process involved selecting the appropriate specifications for the antenna, choosing a patch antenna design, and optimizing the antenna performance using electromagnetic simulation software. The antenna was then fabricated using printed circuit board (PCB) technology, and its performance was tested using a network analyzer. The testing results showedthat the antenna had a bandwidth of 7.1 & 9 GHz, a gain of 2.385& 4.433 dBI, and a polarization of Z. The measured results were found to be consistent with the simulation results, indicating that the antenna met the design specifications. This project demonstrates the feasibility of designing and fabricating a patchantenna for X-band application using PCB technology.

Keywords—Patch antenna, X-band, high gain, low profile, wide bandwidth, design process, electromagnetic simulation software, printed circuit board (PCB), network analyzer, polarization, feasibility.

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I. Introduction

Wireless communication systems are rapid growing systems in industry specially the cellular systems. In 2019, the number of mobile phone users in the world is 4.68 billion and it is expected to reach 4.78 billion at the end of 2020. If we analyze the term wireless communication literally, we find that it consists of two words: The first is communication, which means sending and receiving different messages between two points. The second word is wireless that means there is no tangible connection between the two points of contact and the lack of cable between them. Based on the above, we can define wireless communication as a process of communication between two different points without a tangible link between them. Numerous remote specialist organizations have talked about the selection of polarization diversity and recurrence differing qualities conspires set up of space diversity approach to take favorable position of the restricted recurrence spectra accessible for correspondence

II. Antenna

A. Microstrip Patch Antenna

This printed patch antenna is low profile antenna, contented to planar and non- planar surfaces, straightforward and modest to manufacture from exhibit day printed innovation. It is absolutely inexpensive to manufacture and plan. For improved radio wire work, a wide dielectric substrate having a low dielectric reliable disadvantageous this gives better ability, unrivaled data transfer capacity and better radiation. Still, such a proposed configuration prompts a greater radio wire measure. In designing a minimized fix receiving wire, the materials having higher estimation of dielectric consistent must be utilized which are less dexterous and results in limit data transmission. Hence conciliation must be come to between antenna measurements and reception apparatus execution.

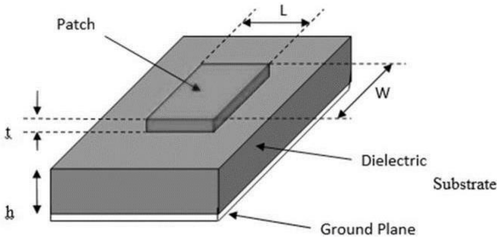

Fig. 1. Structure of Microstrip Patch Antenna

B. Differet types of Patch Antennas

Keeping in mind the end goal to improve examination and execution forecast, the fix is for the most part square, rectangular, roundabout, triangular, circular or some other normal shape as in below figure. Microstrip fix receiving wires transmit basically in light of the circumscribing fields between the settle edge and the ground plane. For good accepting wire execution, a thick dielectric substrate having a low dielectric relentless is appealing since this gives better efficiency, greater transmission limit and better radiation. In any case, such an outline prompts a greater accepting wire evaluate. Remembering the true objective to arrange a traditionalist Micro strip settle accepting wire, higher dielectric constants must be used which are less profitable and result in littler transmission limit. From now on an exchange off must be come to between radio wire estimations and receiving wire execution.

III. Fabrication of Antenna

The fabrication of antenna takes the following major steps

1. Choice of Antenna Substrate
2. Choice of Antenna Type
3. Antenna Design
4. Far-field Radiations Pattern
5. Fabrication of Antenna

A. Choice of Antenna Substrate

Comply with flexible technologies, integrated components need to be highly flexible and mechanically robust; they also have to exhibit high tolerance levels in terms of bending repeatability and thermal endurance. A plethora of design approaches of flexible and conformal antennas were reported in the literature including Electro-textile, paper-based, fluidic, and synthesized flexible substrates. In 150 mm ×180 mm flexible Electro textile antenna based on a 4 mm felt fabric is proposed. The antenna operates in the ISM 2.45 GHz band. Although it is suitable for wearable and conformal applications, fabric substrates are prone to discontinuities, fluids absorption, and crumpling.

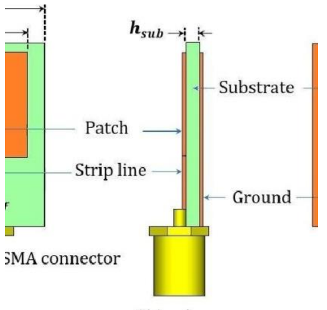

Fig. 3.3D view of Micro strip Antenna with FR4 Substrate used in the proposed Antenna

B. Choice of Antenna Type

Needless to say, conventional microstrip antennas are not a practical solution for flexible electronics due to their inherently narrow bandwidth which is a function of the substrate's thickness. In a flexible aperture coupled antenna is reported. This technique is known to enhance the impedance bandwidth significantly. however, it leads to an increase in the overall profile; moreover, it involves multi layers, which complicates the fabrication process.

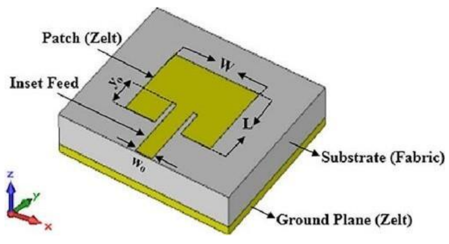

Fig. 4. Choice of antenna type to the proposed Antenna

C. Antenna Design

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The antenna consists of a square split ring shaped radiating element fed by a CPW. The winding lengthens the current path which in turn reduces the structure size without significant efficiency degradation or disturbance to the radiation pattern. The separation distance between the arms is optimized as 5 mm to achieve the least return loss. It is worth mentioning that a smaller separation leads to an increased capacitive coupling between the arms which in turn degrades the impedance matching. The split ring monopole is fed by CPW feed, which adds the merit of fabrication simplicity since both the radiating element and ground plane are printed on the same side of the substrate. This figure shows the Dielectric vs frequency as shown in fig 4.4

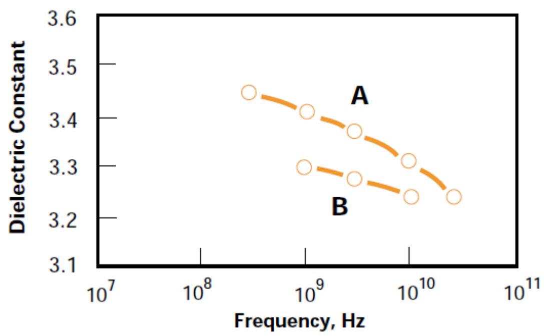
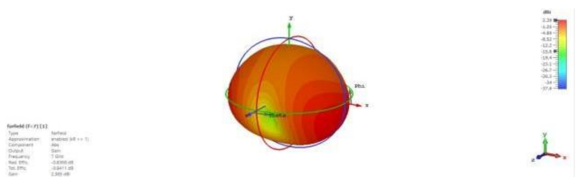


Fig. 5. Dielectric vs Frequency

D. Far Field Radiations Pattern

The radiation pattern is defined as a mathematical function or a graphical representation of the far field (ie, for r ≫ 2D2/λ,with D being the largest dimension of the antenna) radiation properties of the antenna, as a function of the direction of departure of the electromagnetic (EM) wave. A radiation pattern can represent several quantities, such as gain, directivity, electric field, or radiation vector. Consequently, the terms gain pattern, electric field pattern, or radiation vector pattern are used, respectively.



$$a = \frac{F}{\{1+\frac{2h}{\pi\varepsilon_r F}[\ln(\frac{\pi F}{2h})+1.7726]\}^{\frac{1}{2}}}$$

Where, $F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$

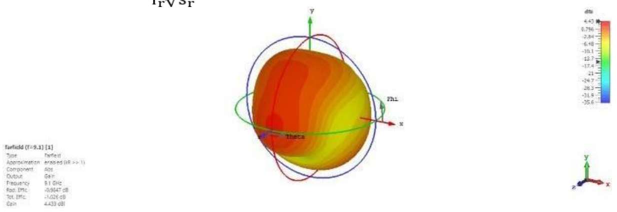


Fig. 6. 4 X 4 Wallace Tree Multiplier

E. Fabrication of Antenna

FR-4 is a commonly used substrate material for printed circuit boards (PCBs). PCB fabrication with FR-4 substrate. PCB fabrication is designing the circuit board layout using computer-aided design (CAD) software. This involves placing components and traces, and defining the drill holes and board dimensions. The FR-4 substrate is prepared by cleaning and roughening the surface to ensure good adhesionof the copper layers. Copper is deposited onto the substrate using a process called electroplating or by using a copper cladlaminate. The copper is then etched away using a photolithographic process, after that the drilling process willbe include. A solder mask is then applied to the board to protect the traces and pads during soldering

IV. Literature Review

Many different microstrip antennas have been proposed for x band applications over the literature survey. Microstrip Patch Antenna is fabricated for x band applications.

"A review of patch antennas for X-band applications" by A. Ansoft and J. R. Mosig (IEEE Transactions on Antennas and Propagation, 2005) - This paper provides a comprehensive review of the design and performance of patch antennas for X-band applications. The authors review varioustypes of patch antennas, such as rectangular, circular, and elliptical patches, and discuss their performance in terms of gain, bandwidth, and radiation pattern.[1]

"Design and analysis of patch antenna for X-band applications" by S. S. Saini and S. K. Agarwal (International Journal of Research in Engineering and Technology, 2015) -This paper presents a design and analysis of a rectangular patch antenna for X-band applications. The authors investigate the effect of various parameters, such as patch size, substrate thickness, and feed point location, on the antenna performance.[2]

"A compact, Broadband microstrip patch antenna for X-band applications" by S. K. Sharma et al. (Microwave and Optical Technology Letters, 2017) - This paper proposes a compact microstrip patch antenna for X-band applications. The authors optimize the patch shape and feed position to achieve a broadband impedance matching and high gain..[3]

IV. Methodology

In this paper A Rectangular microstrip patch antenna designing is easier than another patch configuration as we only need one design parameter i.e. radius of the patchThe procedure assumes that the specified information includes the dielectric constant of the substrate (εr), the operating frequency (fr) and the height of the substrate (h). To find theactual radius 'a' of the patch.

Overall, the architecture of designing and fabricating a rectangular microstrip patch antenna for X-band applications on an FR4 substrate involves a series of iterative steps, fromantenna design to simulation, fabrication, testing, and optimization. By carefully following this architecture, it is possible to create a high-performance antenna that meets the requirements of the specific application.

The Defected metallic RMP Antenna with Ground Plane Structure is shown.

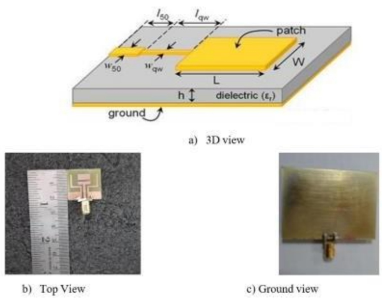


Fig. 7. Defected metallic rmp antenna with ground structure

V. RESUTS

A combinational analyzer is a tool used in the design and analysis of microstrip patch antennas. It allows the designer to analyze and optimize various parameters of the antenna, such as its resonant frequency, bandwidth, radiation pattern, and impedance matching. To use a combinational analyzer for a microstrip patch antenna, the designer typically starts bydefining the geometry and dimensions of the patch, the substrate material, and the ground plane. The analyzer then calculates the resonant frequency of the antenna, which is determined by the dimensions of the patch and the substrate material.

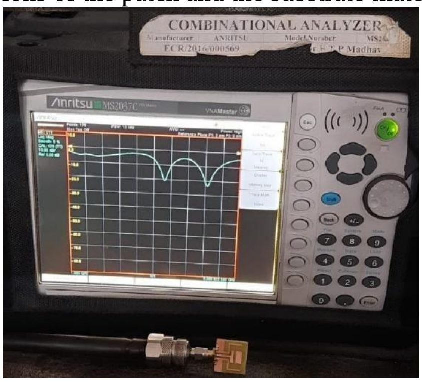


Fig. 8. S11 Parameter of RMPA in Combinational Analyzer

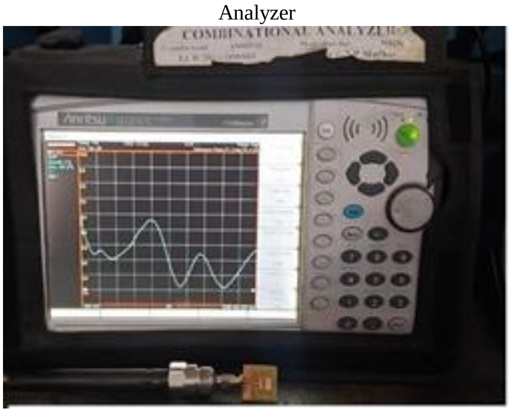


Fig. 9. VSWR of RMPA in Combinational Analyzer

VI. CONCLUSION

The rectangular micro strip patch antenna is an efficient and cost-effective solution for X-band applications due to its simple design, low profile, and easy fabrication. The FR4 substrate provides good mechanical strength, stability, and low dielectric loss, making it an ideal choice for the antenna'ssubstrate. The design and fabrication of a rectangular microstrip patch antenna using FR4 substrate for X-band application have been presented. An innovative single element Rectangular Microstrip Patch Antenna's (RMPA) resonating at 9.1 GHz has been successfully designed and simulated using CST software. The antenna's performance is affected by various factors, such as the substrate thickness, patch dimensions, and feeding techniques. Future research can focus on further optimizing the antenna's performance by exploring different feeding techniques, substrates, and patch shapes. Additionally, investigations into the antenna's radiation efficiency and bandwidth can lead to more advanced design.

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