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Performance Improvisation of Microstrip Patch antenna for 2.4GHz wireless Application

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Abstract

The primary aim of this study is to develop a compact rectangular microstrip patch antenna (MPA) tailored for Internet of Things (IoT) applications, operating at a resonance frequency of 2.4 GHz. A defective ground structure (DGS) featuring a rectangular slit in the ground plane was employed to effectively shift the antenna's resonance frequency from 3 GHz to a lower frequency during the optimization phase. The novel proposed design exhibits a 28% reduction in length and an 18% reduction in width, surpassing conventional 2.4 GHz microstrip antennas in terms of size reduction. The design underwent evaluation using the high-frequency structure simulator (HFSS) program. The chosen substrate material is RT/Duroid 5880, characterized by a thickness of 1.575 mm and a dielectric constant of 2.2. Owing to its diminutive size and robust wireless communication capabilities, the resulting antenna is highly suitable for Internet of Things applications.

Keywords — *Miniaturized, Microstrip patch antenna, HFSS*

I. Introduction

With the exponential growth of the Internet of Things (IoT) technology, there is a growing need for compact and efficient antennas that can seamlessly integrate with IoT devices. Antennas serve as the crucial interface for wireless communication, enabling the transmission and reception of data between IoT devices and the surrounding environment. Therefore, the design and development of miniaturized antennas with optimal performance characteristics are essential for successful IoT applications.

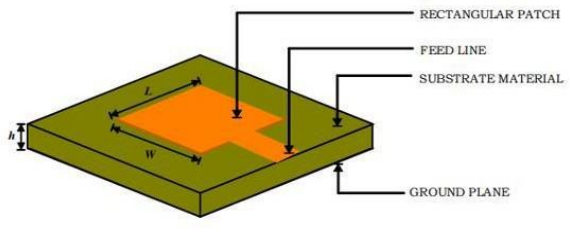

Fig.1. Basic Geometry of microstrip patch antenna

From context of IoT, antennas should exhibit specific features such as low return loss, good bandwidth, and high gain within the frequency range[2,3]. The MPA emerged as a favored choice for wireless communication in IoT due to its advantageous attributes, including its compact size, lightweight construction, affordability, durability, and ease of manufacturing [4].

II. Implementation

We present a comprehensive approach to designing a small, rectangular microstrip patch antenna (MPA) optimized for operation at 2.4 GHz. To achieve optimal performance, this design approach utilizes an RT/Duroid 5880 substrate with a thickness of 1.575 mm and a dielectric constant of 2.2.

To develop the MPA, we explored different design models, including the cavity model and the transmission line model. In this study, we primarily used the transmission line model as the initial framework for designing the rectangular patch with an intended resonance frequency (f_r)of 3 GHz.

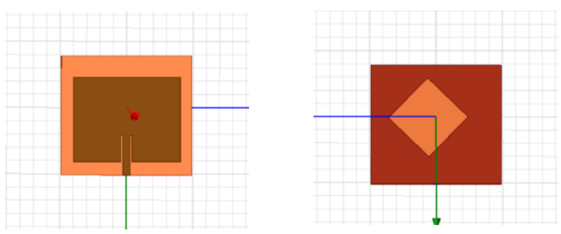

Figure 2 illustrates the top and bottom views of the miniaturized rectangular MPA, which is designed to operate at a resonance frequency of 2.4 GHz.

We present a Defected Ground Structure (DGS) designed to reduce the MPA's operating frequency from 3 GHz to a f_r of 2.4 GHz. This structure features a metallic ground plane with a rectangular-shaped slot, as depicted in Figure 2, to achieve a more compact antenna profile. By modifying the current distribution of the microstrip antenna, the DGS alters the transmission line's capacitance and inductance. These changes in effective capacitance and inductance impact the antenna's input impedance and current flow, enabling the design of a smaller antenna while maintaining the desired resonance frequency.

Inset feeding is a technique employed in the proposed methodology to improve the input impedance of the microstrip antenna. By strategically positioning the feed point within the patch, impedance matching can be enhanced, resulting in improved overall performance. Inset feeding refers to the placement of the feed point within the MPA, as opposed to the traditional edge feeding technique. By strategically positioning the feed point, the input impedance of the antenna can be improved, resulting in better impedance matching and reduced return loss. This technique offers several advantages and has become a widely used method in antenna design. Additionally, inset feeding gives designers of microstrip patch antennas additional creative freedom. The antenna's resonant frequency, impedance bandwidth, and radiation characteristics can all be adjusted to match specific design requirements by changing the placement of the feed point.

Our goal is to successfully accomplish downsizing of up to 18% along the width and 28% along the length and compared to a conventional 2.4 GHz microstrip antenna by repeatedly modifying the antenna parameters and optimizing the DGS.

The optimization process involves fine-tuning the dimensions and inset feeding to achieve the desired resonance frequency and impedance matching.

The proposed antenna design is simulated and analyzed using HFSS. HFSS provides a powerful platform for accurately predicting and evaluating the antenna's performance, including its impedance bandwidth, return loss, VSWR, and gain..

Table -1 Physical dimensions of proposed rectangular MPA

Parameters	Dimensions of conventional 2.4 GHz antenna in mm	Dimensions of proposed antenna for 3GHz in mm
Patch_width	49	40
Patch_length	41	32
Substrate_width	59	49
Substrate_length	51	45
Ground_width	59	49
Ground_length	51	45

III. EXPERIMENT AND RESULTS

Factors such as the reflection coefficient, bandwidth (BW), voltage standing wave ratio (VSWR), and gain are evaluated to thoroughly assess the performance of the proposed antenna. For narrowband antennas like such as the proposed work, a gain of 4.9347 dB, VSWR of 1.0531 and a return loss of -31.7447 dB, are considered acceptable performance criteria. Figure 4 provides a clear visualization of the proposed antenna's resonant frequency, which is observed to be 2.4 GHz, with a bandwidth of 85.0 MHz (ranging from 2.3550 GHz to 2.4400 GHz). This bandwidth indicates the range of frequencies within which the antenna can effectively operate, ensuring reliable and efficient communication within the IoT spectrum.

Gain: Gain, often described as an antenna's ability to concentrate and efficiently direct radiated energy in a specific direction, is a crucial parameter in antenna performance assessment. It quantifies the efficiency with which an antenna transmits or receives signals. Higher gain values signify a more focused radiation pattern and increased signal strength.

VSWR (Voltage Standing Wave Ratio): VSWR measures the impedance match between an antenna and the transmission line or system to which it is connected. It assesses the power reflection at the antenna interface, with lower VSWR values indicating enhanced impedance matching and minimized signal loss.

Bandwidth: The bandwidth of an antenna refers to the range of frequencies over which it can effectively operate. Within this range, the antenna maintains high gain and low return loss while meeting acceptable performance criteria. A wider bandwidth enhances the antenna's versatility and utility, allowing it to function efficiently across a broader spectrum of frequencies.

S_{11}: The reflection coefficient, also known as S11, quantifies the power reflected back from the antenna due to an impedance mismatch and is typically expressed in decibels (dB). Lower S11 values correspond to improved impedance matching and reduced signal loss. This metric illustrates the extent to which the antenna aligns with the impedance of the transmission line or system.

Cross-Polarization and Co-Polarization: Cross-polarization and co-polarization refer to the behavior of the antenna's radiation pattern in different polarization orientations. Cross- polarization refers to the radiation in a direction perpendicular to the desired polarization, while co- polarization refers to the radiation in the same direction as the desired polarization. Good antenna design aims to minimize cross-polarization radiation, as it can lead to interference and reduced signal quality.

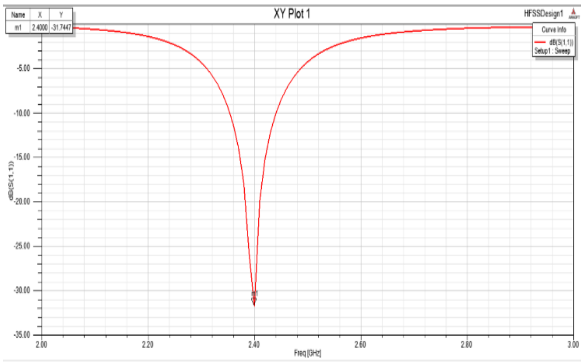

Fig. 3. Microstrip patch antenna resonating at 2.4 GHz

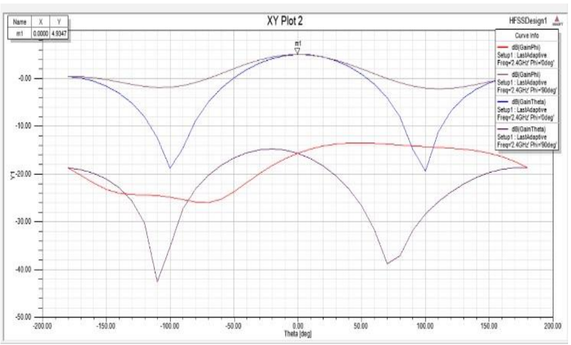

Fig. 4. Co and Cross pole polarization

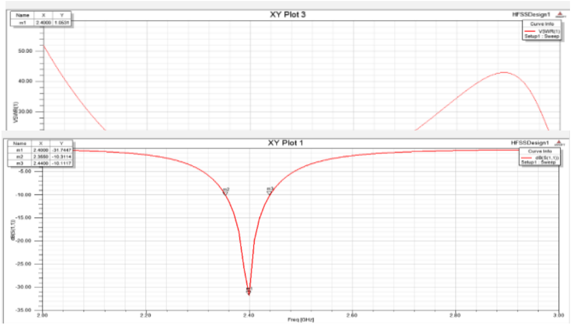

Fig5 VSWR and Bandwith

IV Conclusion

Using ANSYS HFSS, the geometric model of the antenna was created based on the defined design parameters. The software's simulation capabilities allowed for the analysis of the antenna's electromagnetic properties, including its radiation pattern, input impedance, and resonance frequency. Through iterative simulations and optimization techniques, the design parameters were adjusted to achieve the desired performance goals.

During the optimization process, ansys hfss provided valuable insights into the antenna's behavior, allowing for the identification of design modifications that would enhance its performance. Further its usage facilitated the successful implementation of the miniaturized microstrip patch antenna with a defective ground structure, enabling its suitability for wireless applications, particularly within the IoT domain.

Acknowledgment

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