Design of Proximity Coupled Patch Antenna for Sub 6 GHz Applications

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Abstract—*A proximity coupled patch antenna is proposed in this paper. Miniaturization is a great demand in today's world. Hence, an antenna of compact size of 50 x 40 x 1.6* mm^3 *is proposed. The antenna is developed using Arlon AD 430 with a permittivity of 4.3 and thickness of 1.6 mm. The antenna operates at 3.5GHz with a return loss of 13 dB and a gain of 5.22 dBi. The antenna covers a band of 136 MHz. The antenna is designed using the EM simulator tool CST. The outlined antenna is appropriate for sub 6 GHz applications.*

Keywords— Proximity coupled, patch antenna, sub-6 GHz, CST

I .INTRODUCTION

Microstrip patch antennas play a vital part in wireless communication systems in the quickly changing world of wireless communication technologies because of their various qualities, which include bandwidth, multiband operation, compact size, low manufacturing cost and adaptability [1].The microstrip patch antenna has a directed radiation pattern, excellent efficiency, and good return loss. Patch antennas are capable of operating in multiple frequency bands [2].There are various techniques to feed the antenna. A microstrip line feed or a coaxial feed is used in the contacting method of providing power to the radiating patch directly. In a non-contacting approach, electromagnetic coupling is used to transmit power between the radiating patch and the feed line and the feeding methods are proximity-coupled feed and aperture-coupled feed [3].The advantage of proximity feeding in antenna design lies in its ability to efficiently couple electromagnetic energy into the antenna structure while maintaining a compact and low-profile form. This method involves placing the feeding point in close proximity to the radiating element, typically separated by a small gap or aperture. By doing so, proximity feeding minimizes losses associated with transmission lines and reduces the overall size of the feeding structure. Additionally, it enables better impedance matching and enhances the antenna's radiation characteristics, leading to improved performance in terms of gain, bandwidth, and efficiency [4]. Overall, proximity feeding offers a practical solution for achieving high-performance antennas suitable for various wireless applications.The primary objective of our proposed work is to design a patch antenna that resonates at 3.5 GHz, for sub-6 GHz application. By focusing on this frequency, the antenna aims to address the growing demand for wireless. communication systems operating in the sub-6 GHz spectrum. Through meticulous design and simulation, the goal is to achieve optimal performance in the areas of return loss, radiation pattern and efficiency ensuring reliable and robust communication capabilities.

II.METHODOLOGY

The patch, substrate and ground plane are the three components that make up a patch antenna and a feeding mechanism is included to excite the antenna. The designed antenna comprises two substrate layers. Height of the substrates is taken as 1.6 mm, and both upper-layer and bottom-layer substrates are constructed using Arlon AD 430 dielectric material with a dielectric constant (ε_r) of 4.3. The ground plane is designed at the bottom of the second layer substrate, while the proximity feed line is placed at the bottom of the first substrate and the radiating patch is etched on the top of the upper substrate. Specifically intended for Sub 6 GHz applications, the patch antenna resonates at 3.5 GHz band. The patch's length and width can be computed by taking these factors into account. The design equations are as follows [5]-[6]

$$w = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (2)$$

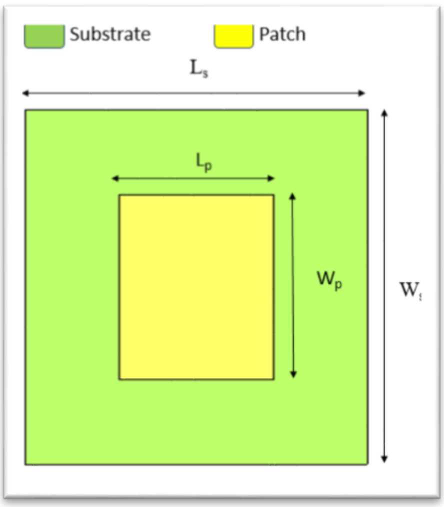
$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (4)$$

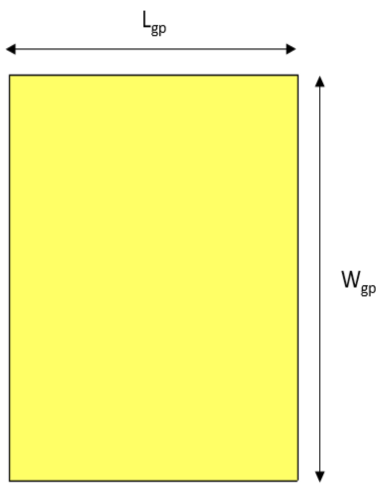
$$L = L_{eff} - 2\Delta L \quad (5)$$

TABLE I.ANTENNA PARAMETERS

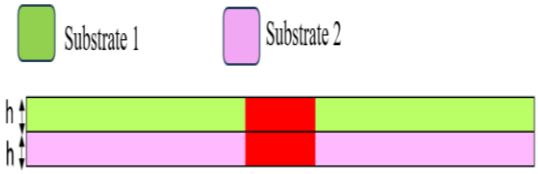
parameters	Measurements(mm)
W_p	26.08
L_p	18
W_s	50
L_s	40
h	1.6
W_{gp}	50
L_{gp}	40
w_f	2.27
l_f	18



a)Front View Design



b) Rear View Design



(c) Side View Design

Fig. 1. (a) Front (b) Rear (c) Side view of the proposed patch antenna.

Based on equations (1)-(5), the antenna parameters are calculated as listed in Table 1. The front and rear view of the antenna is depicted in Fig. 1. (a) and Fig. 1. (b) respectively. The side view of the antenna is displayed in Fig. 1. (c).

III.RESULTS & DISCUSSIONS

Results of the proposed antenna interms of return loss, VSWR, Gain and Radiation pattern are discussed.

A. S-Parameter

S_{11} Parameter of an antenna refers to the reflection coefficient, which quantifies the proportion of electromagnetic energy reflected from the antenna relative to the incident wave. It is a key metric used to evaluate antenna performance, particularly in terms of impedance matching. A lower S_{11} value indicates better impedance matching and reduced signal reflection, thereby enhancing antenna efficiency and overall performance.

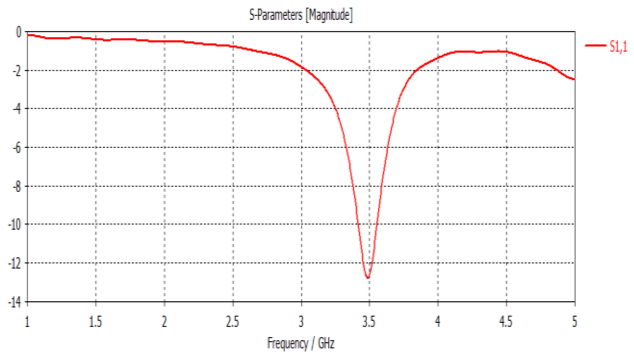


Fig. 2. S_{11} Parameter

As seen in Fig. 2. The proposed Patch antenna resonated at 3.5GHz, with return loss of 13dB, and a bandwidth of 136 mHz.

B. VSWR

Voltage Standing Wave Ratio, or VSWR, is a measurement used to determine how well an antenna matches the transmission line. It measures the difference in voltage between the line's maximum and minimum points. In wireless applications, maintaining a low VSWR is crucial for optimal performance. Ideally, VSWR should be kept as close to 1 as possible, ensuring minimal signal loss and efficient power transfer.

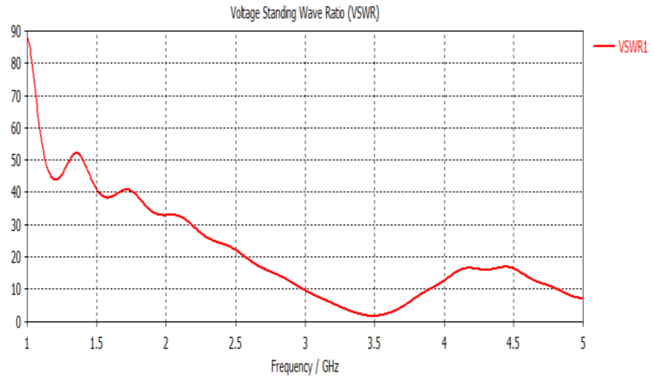


Fig. 3. VSWR

As seen in Fig. 3. at the resonant frequency of 3.5GHz, the VSWR value is 1.593, which is in acceptable range.

C. Gain

Antenna gain, which is often measured in decibels (dB), indicates how well an antenna transmits or receives electromagnetic signals in a specific direction. Greater concentrations of radiation are indicated by higher gain levels, which improve signal strength and reception quality.

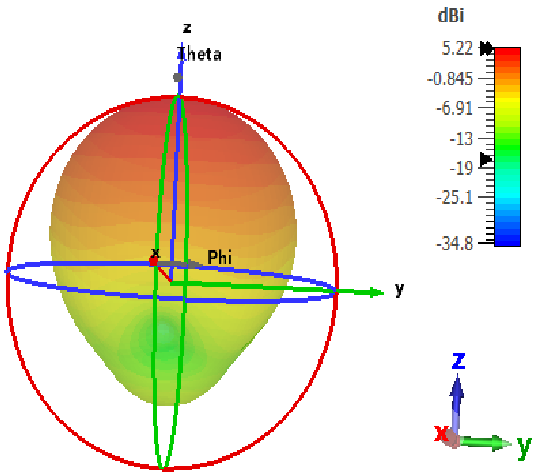


Fig. 4. Farfield

As seen in Fig. 4. The gain attained for the proposed antenna is 5.22 dBi for a resonating frequency of 3.5GHz. Patch antennas are known for their compact size and directional radiation characteristics, making them ideal for various wireless applications. A gain of 5.22 dBi indicates efficient signal transmission and reception, enhancing communication range and reliability. This gain level reflects effective design optimization and suitable operational parameters for the patch antenna's intended use.

D.E Plane

The angular distribution of electric field intensity perpendicular to the primary radiation direction of an antenna is described by the E-plane radiation pattern. It provides important antenna behavior details as gain, polarization characteristics, main lobe, side lobes, beamwidth, and directionality. This pattern, which is essential to antenna design, shows how electromagnetic energy is distributed and how it affects interference and coverage.

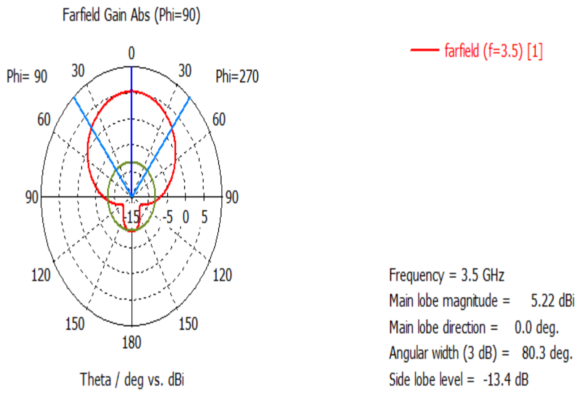


Fig. 5. Radiation diagram of E-Plane

E.H Plane

The angular distribution of magnetic field intensity perpendicular to the principal radiation direction of the antenna is represented by the H-plane radiation pattern. It displays the polarization attributes, gain, main lobe, side lobes, beamwidth, and directional characteristics of the antenna. This pattern, which shows how electromagnetic energy propagates and affects coverage and interference, is crucial for antenna design.

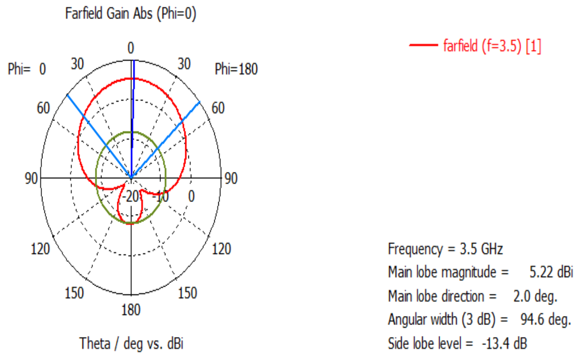


Fig. 6. Radiation diagram of H-Plane

Fig. 4-6 represents the Farfield radiation pattern, radiation diagram of E-Plane, and H-Plane of the antenna design.

TABLE II. OBTAINED SIMULATION RESULT OF THE DESIGNED ANTENNA

Parameters of antenna	Result values
S_{11}	-13 dB
VSWR	1.593
Bandwidth	136 MHz
Gain	5.22dBi

IV. CONCLUSION

The designed proximity-coupled fed patch antenna resonates at 3.5GHz. By incorporating two substrate layers made of material Arlon AD 430 with ε_r of 4.3, the antenna has a bandwidth of 0.136GHz (3.418-3.554GHz) with a resonant frequency of 3.5GHz. With a return loss of 13dB, the antenna achieves a respectable gain of 5.22 dBi. These results indicate the successful realization of the antenna which is appropriate for sub-6 GHz communication systems. Further optimization and fine-tuning could potentially enhance performance metrics such as return loss and gain. This work can be enhanced by implementing multiband resonances suitable for wireless communications.

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