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Design Of A Pattern Reconfigurable Antenna For Intelligent Wi-Fi Communication And Commercial Wlan Applications

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ABSTRACT

In this letter, a pattern reconfigurable antenna system is presented. The reconfigurable structure provides compact size, and effective isolation between different wireless standards. The proposed reconfigurable antenna is designed in ANSYS High Frequency Structure Simulator (HFSS) Software and by controlling the states of two Pin diodes; the antenna can switch between one omnidirectional mode and two unidirectional end- fire radiation modes. The experimental measurements demonstrate the return loss of -10.91 dB, -34.76 dB at frequency of 4.25 GHz and 5.76 GHz respectively. The proposed antenna is very much suitable for intelligent Wi-Fi communication and commercial WLAN applications.

Keywords: *Pattern reconfigurable, pin diodes, omnidirectional, unidirectional and end –fire radiation modes.*

1. INTRODUCTION

A reconfigurable antenna is an antenna capable of modifying its frequency and radiation properties dynamically, in a controlled and reversible manner [1],[2] therefore it is widely used in various wireless communication services. In order to provide a dynamic response and support for communication system, reconfigurable antennas integrate an inner mechanism such as RF switches, varactors, mechanical actuators or tunable materials that enable the intentional redistribution of the RF currents over the antenna surface and produce reversible modifications of its properties. Reconfigurable antennas can be classified according to the antenna parameter that is dynamically adjusted, typically the frequency of operation, radiation pattern or polarization [3],[4]. The reconfigurable antenna designed in this paper [5] consists of PIN diodes placed at different position on the ground plane to achieve frequency reconfigurability. Based on the switching state of the PIN diode the antenna is capable of operating at different frequency ranges. To support for Local wireless communication system, radiation pattern of the antenna is nearly omnidirectional for the entire frequency band. A novel antenna with pattern reconfiguration is developed [6]-[8]. By switching OFF or ON status of the two Pin diodes, the antenna can work in "Positive End-fire", "Negative End-fire," or "Omnidirectional" state. Omnidirectional antennas have a doughnut shaped radiation pattern and are ideal for connecting devices that are on the same plane and to either side of each other. These are commonly misused in in-building and mobile applications. Most of the areas use unidirectional antennas.

Unidirectional radiation is obtained by combining two particular characteristic modes with a phase difference of 90° [9]. In mobile applications, omnidirectional dipole antennas fail to have the proper patterning needed in order to connect to a tower that is on a much higher elevation. The [10] antenna design is a modified swastika-shaped structure. Four parasitic arc-shaped [16],[17] elements are loaded around the radiator, and each parasitic arc-shaped element is loaded with a PIN diode switch for controlling the antenna radiation field pattern [18-20]. In this paper, developed antenna consists of I-shaped which consist of Pin diodes for evaluating its radiation pattern [21]. Due to its low cost, compact size, easy integration and effective isolation between different wireless standards we used this antenna.

2. PROPOSED WORK

A novel design of a pattern reconfigurable antenna is proposed for Wi-Fi applications. The antenna is composed of a ground plane, a dielectric substrate, and patch.

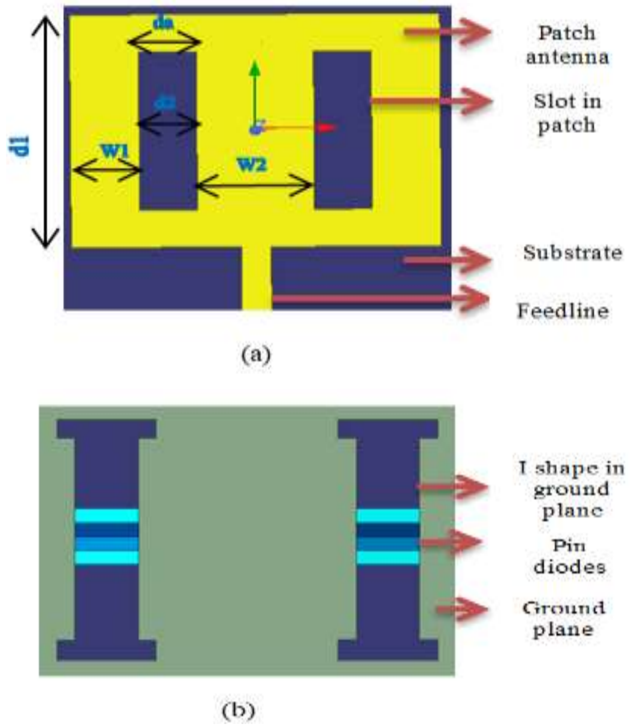


Figure 1. Geometry of proposed Reconfigurable antenna (a) Top layer (b) Bottom layer

To ensure efficient signal transmission and reception, a 50Ω microstrip feed line based on a modified rectangular patch is implemented on the top side of an FR4 substrate with εr=4.4 and a height of 1.6mm utilizing an insert feed method represented in Figure1. The design configuration and feeding technique contribute to enhanced performance characteristics and improved impedance matching [22-23].

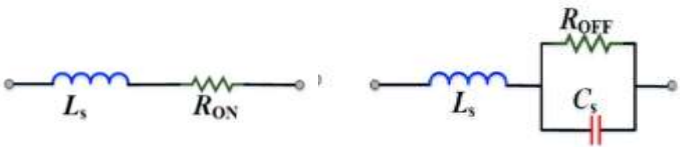


Figure 2. Equivalent circuit for reconfigurable condition (a) ON Condition and (b) OFF Condition

For ON condition inductor LS and resistor RON connected in series. For OFF condition resistor ROFF and capacitor CS connected in parallel and inductor LS is connected series with that parallel connection. The value inductor Ls is 0.15nH and resistor value R_{ON} is 5.2 ohm. The value of resistor R_{OFF} is 1500 ohm and capacitor value are Cs 0.025 pF. The Design equation of proposed antenna is given below,

Width of the patch is calculated using equation (2.1).

$$W = \frac{c}{2f_0}\left(\frac{2}{\sqrt{(\varepsilon_r+1)}}\right) \quad (2.1)$$

Where, f_0 is the operating frequency

Effective dielectric constant is calculated using equation (2.2).

$$\varepsilon_{eff} = \left(\frac{\varepsilon_r+1}{2}\right)+\left(\frac{\varepsilon_r-1}{2}\right)+\left(1-\frac{12h}{w}\right) \quad (2.2)$$

where, ε_r is the relative permittivity

Extension length of patch is obtained using the equation (2.3).

$$\Delta L=0.412h\left(\frac{(\varepsilon_r+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_r-0.258)\left(\frac{w}{h}+0.8\right)}\right) \quad (2.3)$$

Where, h is the substrate thickness

Effective length is obtained using equation (2.4)

$$L_{eff} = \frac{c}{2fr\sqrt{\varepsilon_{eff}}} \quad (2.4)$$

Patch length is achieved using equation (2.5),

$$L = L_{eff} - 2\,\Delta L \quad (2.5)$$

Table 1: Structural parameters of proposed antenna

Parameters	**Dimensions**
D1	17.0
D2	38.0
W1	4.1
W2	10.1
da	13.0

The design flow of the reconfigurable antenna is illustrated in Figure 3.

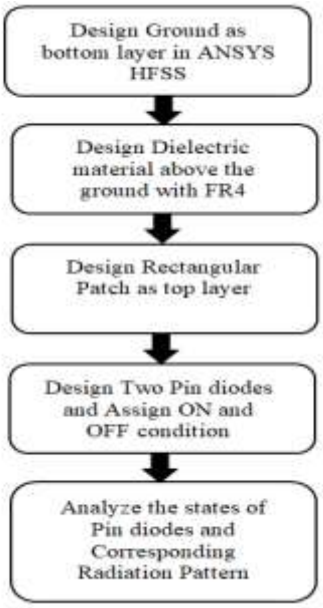


Figure 3. Design flow of the Reconfigurable Antenna

The Reconfigurable antenna is designed using HFSS software and ground is designed as bottom layer and above FR4 substrate is designed with rectangular patch and two I-shaped patch is designed under the rectangular patch with space between two I-shaped patch is d2 where two pin diodes are designed using lumped parameters in HFSS which is used to analyse the radiation patterns.

3. RESULTS AND DISCUSSION

This section helps to analyze the effectiveness of the proposed pattern reconfigurable antenna for Wi-Fi applications. By evaluating the reconfigurable antenna's performance such as radiation pattern for ON-OFF condition, OFF-ON condition, OFF-OFF condition of diode and Reflection Coefficient, etc.

3.1. Reflection Coefficient (S_{11}) of the Proposed Antenna:

S-parameters are used to describe the behavior of linear electrical networks, such as antennas and transmission lines. They provide a convenient way to analyze and characterize the performance of these networks in terms of power transmission, reflection, and impedance matching.The proposed antenna exhibits same reflection coefficient for all the three conditions.

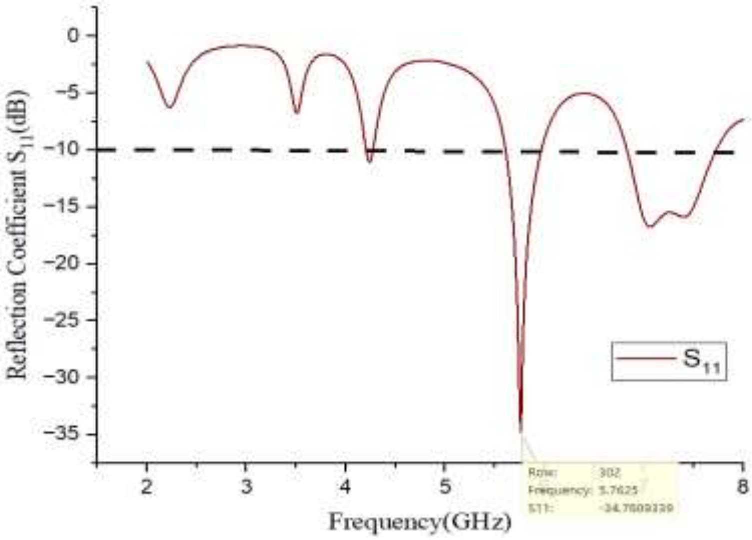


Figure. 4: Reflection Coefficient of the proposed antenna

The antenna operates at two distinct frequencies: 4.25 GHz, 5.76 GHz. Figure 4 illustrates the stimulated Reflection Coefficient S_{11} at these frequencies, indicating a significant return loss of -10.91 dB, -34.76 dB respectively. The Reflection coefficient is same for all the three states of the pin diode which is depicted in the table 2. This observation offers valuable insights into the impedance matching and power reflection properties of the antenna at that specific frequency.

3.2 Voltage Standing Wave Ratio (VSWR) of the Proposed Antenna:

The Voltage Standing Wave Ratio (VSWR) analysis investigates the standing wave pattern and impedance matching of the antenna system. It discusses the VSWR measurement technique, the interpretation of VSWR values, and their impact on antenna performance.

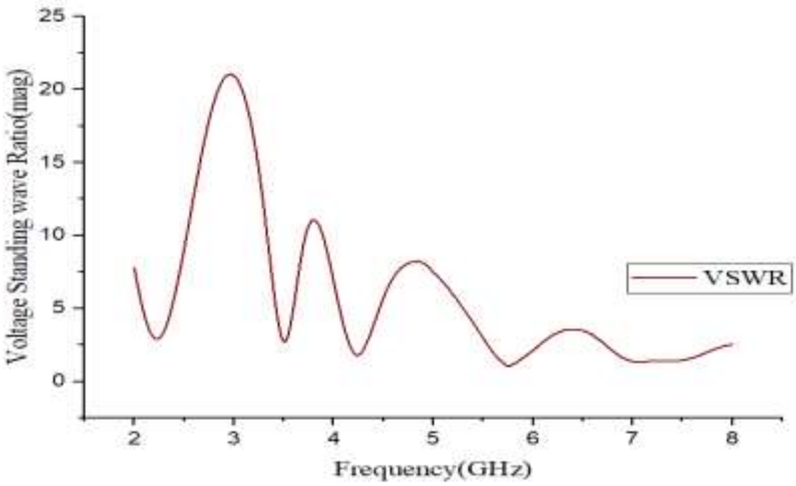


Figure 5. VSWR of the proposed antenna

The VSWR results are succinctly presented in Figure 5, specifically highlighting the operating frequencies of 4.25 GHz, 5.76 GHz with corresponding VSWR values in terms of magnitude as 1.84 dB, 1.04 dB correspondingly.VSWR is same for all the condition of pin diodes which is depicted in the table 2. Notably, the VSWR value must be less than 2 dB indicating good impedance matching, suggesting efficient power transfer between the antenna and the transmission line.

3.3 Surface Current distribution:

The electric field analysis focuses on the TE_{20} mode, one of the dominant modes of operation for the patch antenna. The flow of charges on the antenna surface determines the surface currents of the antenna.

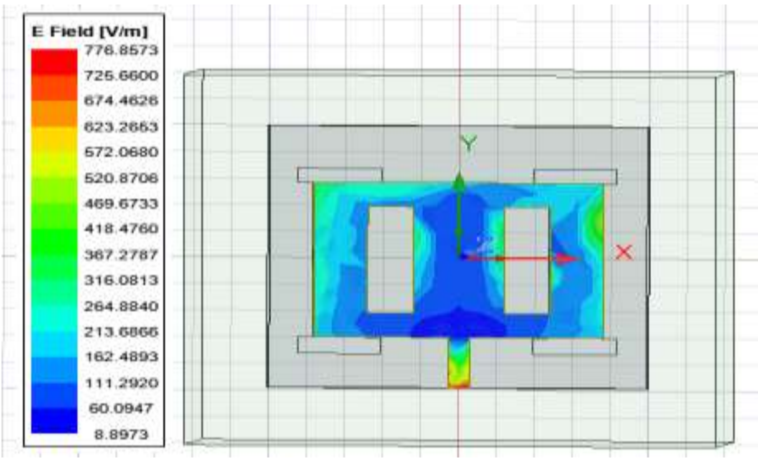


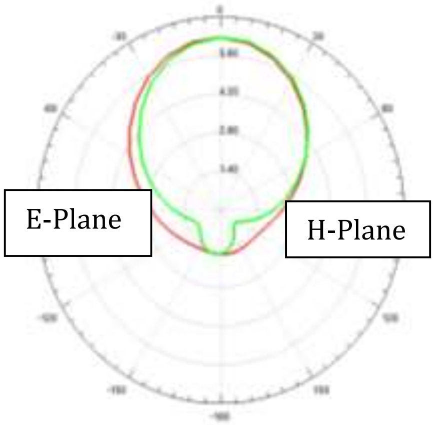
Figure. 6: Current distribution of the proposed antenna

It investigates the Field distribution and polarization characteristics of the proposed antenna.

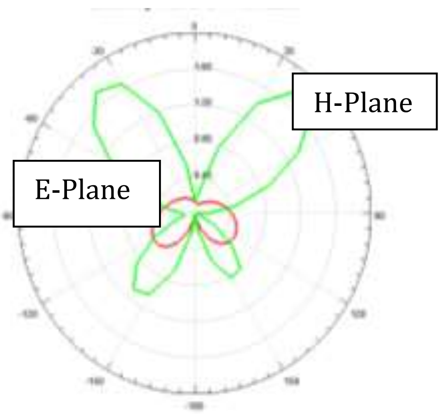
The figure 6 presents the surface current distribution of the proposed antenna. The maximum electric field value recorded in the analysis is 776.8573 V/m.

3.4 Radiation Pattern of Proposed Antenna:

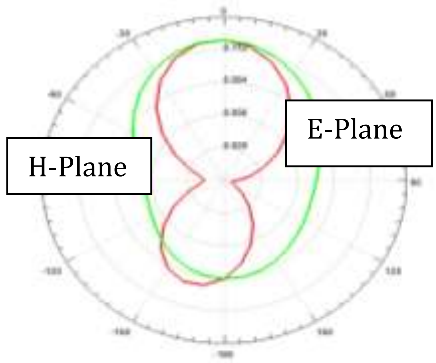
Radiation Pattern refers to the emission or reception of electromagnetic waves characterized by their strength or power. It demonstrates the antenna's ability to convert electrical energy into waves and propagate them in specific directions.



(a)



(b)



(c)

Figure 7. Radiation pattern of the reconfigurable antenna (in degree) (a) radiation pattern for ON-OFF state (b) radiation pattern for OFF-ON state (c) Radiation pattern for OFF-OFF state

The radiation pattern of an antenna describes the spatial distribution of its radiated or received power, offering insights into directivity, beam width, and polarization characteristics. In Figure 7(a), the radiation pattern for ON-OFF state is depicted, Figure7(b), the radiation pattern for OFF-ON state is depicted, Figure7(c), the radiation pattern for OFF-OFF state is depicted, indicating the direction or angle where the antenna exhibits the highest power or gain.

4. CONCLUSION

The Pattern Reconfigurable antenna for Wi-Fi applications is demonstrated. The proposed antenna design offers several advantages, including different radiation pattern for various cases and also operate at 4.25GHz – 5.76GHz that reconfigurable nature is well-suited for Wi-Fi and 5G application as well. This antenna operates within the desired frequency range, ensuring compatibility with Wi-Fi applications.

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