Frequency Reconfigurable Antenna with Partial Ground for WLAN, WiMAX, C-band, and Sub-6GHz Wireless Communications

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***Abstract*— This paper presents a microwave frequency band functioning monopole antenna with frequency reconfigurability. On an FR-4 substrate with a relative permittivity of 4.4 and a height of 1.6 mm antenna can be printed. An antenna can operate in various modes by placing two RF (PIN diode) switches between radiating patches. The antenna working in three modes that covers six different bands, with two dual bands of 3.8 GHz / 7.5 GHz, 3 GHz / 7.1 GHz in Modes 1 & 2 respectively, and 2.8 GHz / 6.7 GHz in Mode 3. The antenna has good Voltage Standing Wave Ratio (VSWR) for all working bands. The gain at comparable resonant frequencies ranges from 1.74 to 4.75 dBi. At each frequency, the achievable bandwidths range from 8.8 to 46.6 %. The structure is designed in High Frequency Structure Simulator (HFSS). The antenna can be used in WiMAX, WLAN, C-Band, 5G, and Sub-6Hz wireless communications.

Keywords—The Reconfigurable antenna, Sub-6GHz, WLAN, WiMAX

I. Introduction

The reconfigurable antenna has received much interest due to its versatility. Depending on the system's state, it can change its components' polarization, frequency, and emission pattern. Based on the size of the radiator, frequency-reconfigurable antennas can change their operating frequencies [1]. Reconfigurability in antennas requires RF switching elements such as PIN diodes, photoconductive switches, MEMS (micro-electrical mechanical systems), and FETs [2]. Researchers used PIN diodes [3, 4] over MEMS for reconfigurability due to their increased reliability, faster switching speed, ability to handle high currents and simplicity of fabrication. In [4]-[8], the antennas can change their frequency and pattern, but they have a narrow bandwidth. Despite their modest size, the antennas' drawbacks include a limited bandwidth and a complex structure. To achieve the ideal phase range with the most negligible return loss, [9] presents a patch element with numerous slots and dynamically changing dimensions. However, the approach has the issue of evolving antenna shape with a change in slot dimensions, making it a complex structure to examine [10]. A Three-bit reconfigurable antenna based on a Monopole antenna is presented in [11].

Frequency reconfigurable antenna with a partial ground plane is presented in this paper. Bandwidth enhancement is possible by using partial ground plane. Switching the diodes leads to variation in the length of the radiator. By selecting the state of diodes, the antenna could operate in three dual-band modes (3.8GHz/7.5GHz), (2.8GHz/6.7GHz) and (3GHz/7.1GHz). The antenna works in the six frequency bands covering the WiMAX band, WLAN band, C-band, and 5G wireless communications. The paper is organized as an Introduction, Methodology, Results, and Discussion.

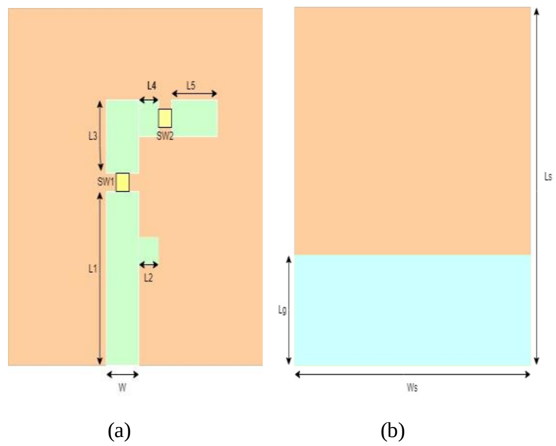
II. Methodology

The antenna's geometry and design are described in this section. The pin diodes lumped an element RLC equivalent circuit makes frequency reconfigurability possible in simulation. The intended antenna may work at many frequencies due to the diodes ON/OFF status. A partial ground plane has produced acceptable far-field results.

A. Antenna Design and Geometry

Figure 1 shows the antenna's geometrical structure. A Low-Cost and easily fabricable FR4 substrate with a 1.6 mm height is used in the design which has the dimensions of 40 x 32 x 1.6 mm^3 with permittivity of 4.4 and loss tangent 0.02.

In order to account for the pin diodes, a distance of 1 mm is left between the two patches. In order to activate the antenna, a 3 mm microstrip line with a 50Ω impedance is used. The simulations employ a pin diode (SMP1345-079LF) for switching.



(a) (b)

Figure 1. Geometry of Antenna (a) Front view (b) Back view

In Table 1, the dimensions of the suggested antenna are shown in full detail. Transmission line model theory [12] is used to calculate the lengths at intended frequencies. The length of $L_f = \lambda/4$ used for each bands or one-fourth of the guided wavelength.

TABLE I. THE DIMENSIONS OF ANTENNA

Parameter	Value(mm)
L1	22.8
L2	1.5
L3	7.3
L4	1.5
L5	2.5
W	3
Ls	40
Ws	32
Lg	12.5

B. *Principle of Reconfigurability*

The reconfigurability can be attained by changing states of each PIN diode, which results an open and short circuit . The offered antenna includes five operational modes, each with distinct features. In Mode1, the antenna runs at 3.8 GHz/ 7.5 GHz. In Mode 2, the proposed antenna resonates at 3 GHz/7.1 GHz, and 2.8 and 6.7 GHz at Mode 3.

C. *Switching Technique*

SMP1345-079LF two-pin diodes are utilized for switching as they work like an ON/OFF switch in the radio frequency range. These pin diodes exhibit open and short circuit behavior at the locations where they are inserted, changing the antenna's effective resonant length and, as a result, its operating frequency.

In Figure 2, it can be seen that the pin diode switches look like when they are turned ON and OFF. It is merely a series circuit for the ON state, consisting of an inductor L and a low-value resistor RL. The diode has an inductor "L" and a capacitor "C" in parallel with a high-value resistor "RL" and a SMP1345-079LF pin diode. When turned off, it operates based on the values specified in its datasheet, with RL = 1.5 kΩ, L = 0.7 nH, and C = 0.15 pF. This configuration has been modeled in HFSS.

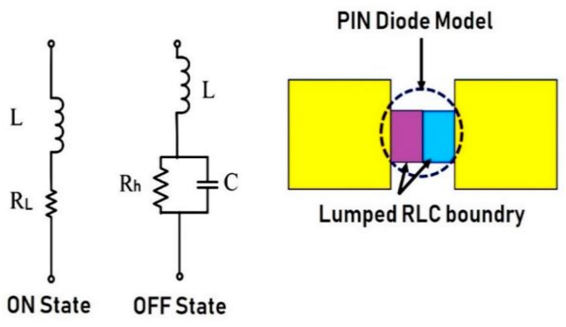


Figure 2. P-i-n diode configuration

III. Results and Discussion

HFSS Tool is used in the design and analysis of the proposed structure. Boundary conditions are used to get the performance metrics, such as return loss, VSWR, and gain.

A. *Bandwith and return Loss*

Figure 3 depicts the simulated return loss of each modes. The suggested antenna operates in Mode 1 with a simulated bandwidth of 940 MHz (3.46-4.38GHz) and a return loss of 29.5 dB and 1600 MHz(7.18-8.78 GHz). The antenna resonates at 3 GHz and 7.1GHz in Mode 2, with a return loss of 29.18 dB and 32.92 dB and a bandwidth of 700 MHz (2.67–3.37 G Hz). The suggested antenna operates at two separate bands, namely 2.8 and 6.7 GHz, with 28.7 dB and 31.6 dB return loss and bandwidth of 660 MHz (2.52-3.18 GHz) and 1900 MHz(6.48-8.38 GHz) in Mode3.

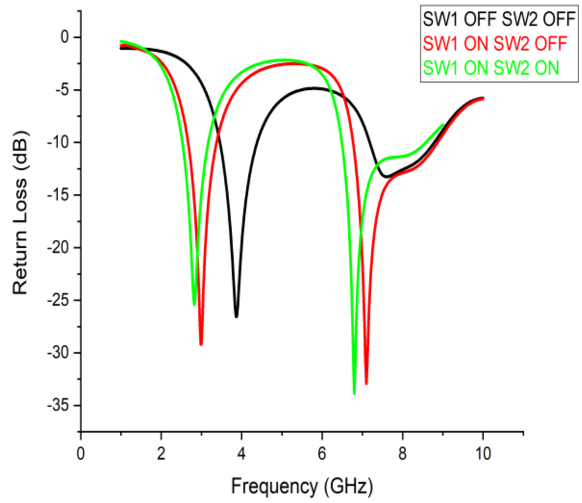


Figure 3. Return loss plots at different modes

In Figure 4, VSWR of less than 2 for all of the working frequency bands is achieved, which denotes the impedance matching of the antenna.

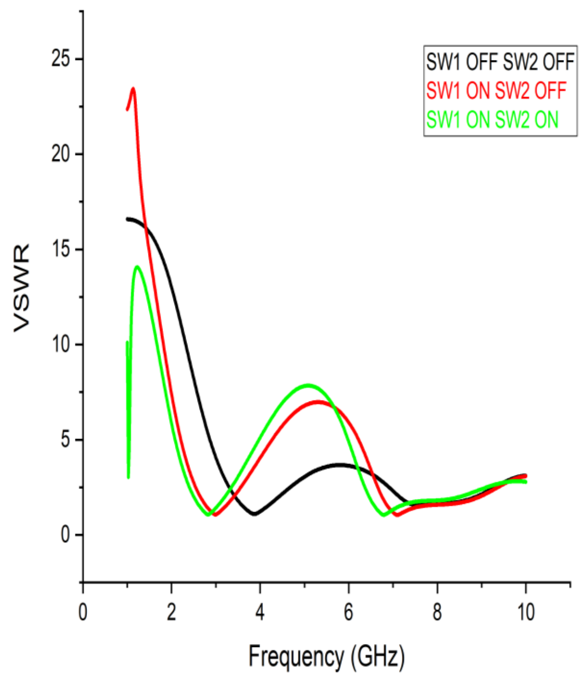


Figure 4. VSWR plots at different modes

B. *Radiation patterns*

Figure 5 illustrates the 2D radiation patterns of the antenna in the E-plane. It is evident that the pattern takes on the shape of the number eight at frequencies of 2.8, 3, and 3.8 GHz. The radiation properties of the antenna in the H-plane are usually omnidirectional across most frequency bands.

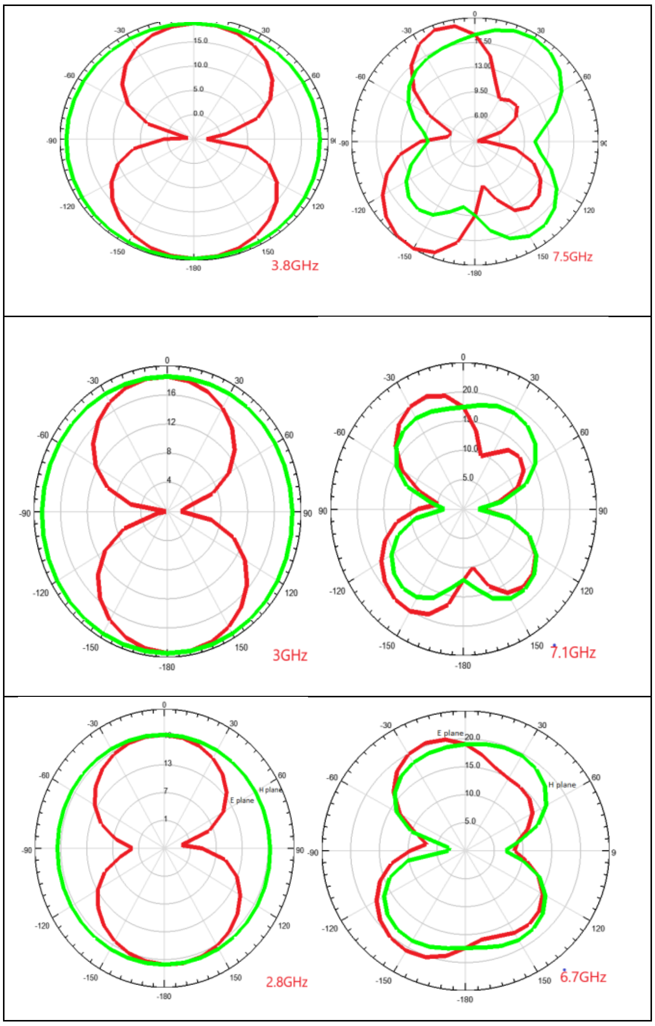


Figure 5. Radiation pattern corresponding to E-plane and H-plane

The 3-dimensional gain plots in Figure 6 at the resonant frequencies shows the radiation properties of the antenna. The antenna has good gain at all frequencies.

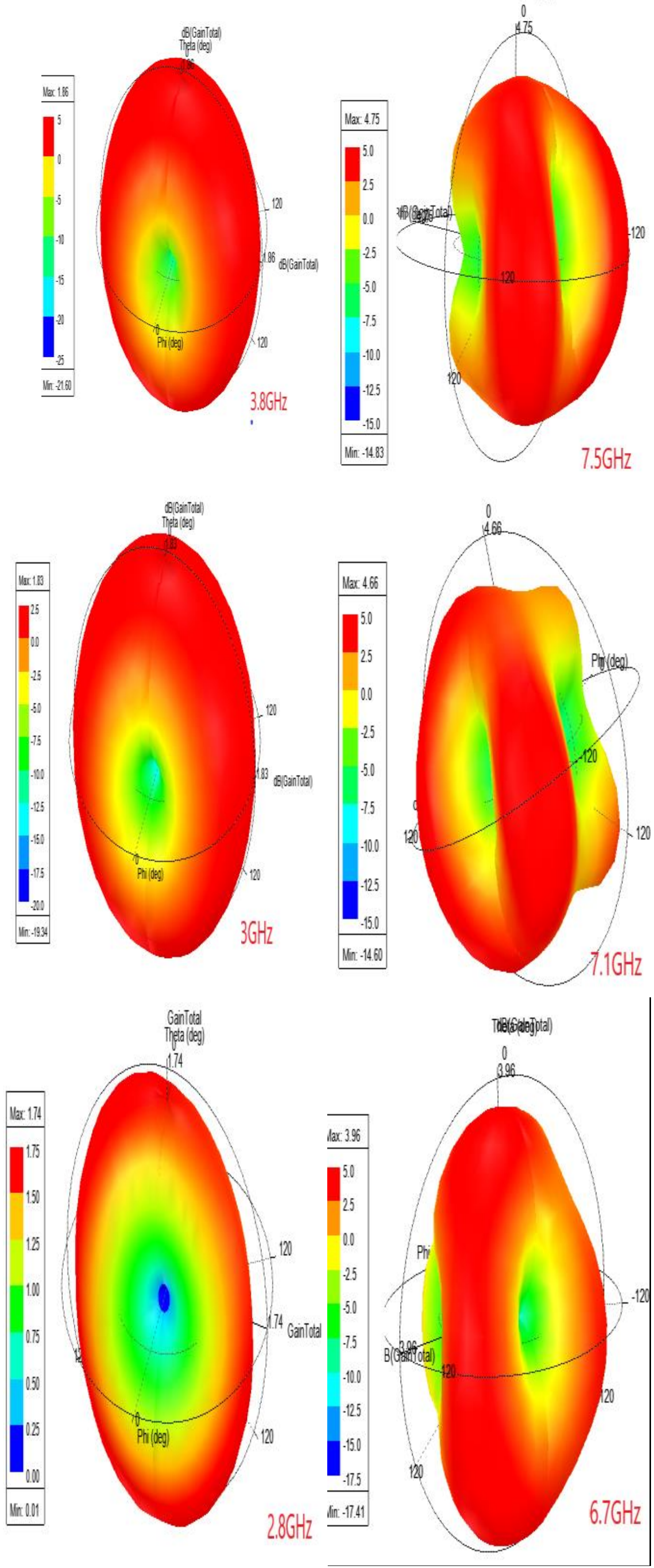


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Figure 6. Gain patterns in three dimensional view

Table II shows the comparision of various parameters of antenna which shows the good agreement to use in various applications.

TABLE II Comparision of different parameters of antenna

Mode	Return Loss (dB)	VSWR	Operating Bands (GHz)	Band width	Gain (dBi)
SW1 OFF SW2 OFF Mode 1	26.5/13	1.08/ 1.3	3.8GHz /7.5GHz	940MHz/ 1600 MHz	1.86/ 4.75
SW1 On SW2 OFF Mode 2	29.18/ 32.92	1.02/ 1.03	3GHz/ 7.1GHz	700MHz/ 2100 MHz	1.83/ 4.66
SW1 ON SW2 ON Mode 3	28.79/ 31.96	1.04/ 1.02	2.8GHz/ 6.7GHz	660MHz/ 1900 MHz	1.74/ 3.96

CONCLUSION

A Frequency reconfigurable antenna with low-profile is designed in this paper. The antenna operating in six bands w based on switching conditions of diodes. It has two dual bands 3.8GHz / 7.5GHz when both switches OFF. 3GHz / 7.1GHz bands achieved when SW1 ON and SW2 OFF. It works in 2.8GHz / 6.7GHz bands when both switches ON. The antenna attained good VSWR and gain at all working bands. So, the antenna is a good candidate for Wi-Fi, WiMAX, 5G and Sub-6GHz wireless Communications.

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