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Compact Reconfigurable Monopole Antenna Design and Simulation Analysis for Wireless Applications

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ABSTRACT
This paper introduces a Dual-band Frequency reconfigurable monopole antenna. By using RF PIN diodes and an electrical reconfiguration technique, frequency bands are created. When the RF PIN diode-1 is turned on, RF PIN diode-2 is turned off, and the antenna resonates at the 2.45 GHz Wi-Fi center frequency and the 3 GHz Wi-MAX center frequency. When both RF PIN diodes are in the OFF state, a wide range of operation from the 2.2 to 3.5 GHz frequency bands can be achieved[1-3]. In contrast, a rectangle shaped patch radiator is employed to resonate the designed antenna at 2.4 and
GHz. By changing the J-shaped resonator's electrical length, the generated bands can be adjusted. Small, low-profile, and lightweight printed monopole reconfigurable antennas are ideal for usage in electronics (such as mobile cell, apple iPads, and laptops PDAs, computers, and wearable technology (safety and rescue operations). HFSS employs the numerical (FIT) and (FEM) to assess the far-field characteristics and antenna scattering.
Keywords: Lumped RLC, PIN Diode, Frequency reconfigurable antenna.

I. INTRODUCTION

A present day communication systems(such as a mobile phone, apple IPAD, PDA, or laptop) is required to handle multiple services, hence an antenna that can transmit and receive at various frequency bands is necessary. Personal Communication System (PCS working at 1.86-1.99 GHz), Global System for Mobile (GSM at 1.712.17GHz), Universal Mobile Telecommunications System (UMT Sat 1.923-2.175GHz), Bluetooth (at 2.4-2.48GHz), Wireless Fidelity (Wi-Fi at 2.4 GHz), and other specific wireless applications require a specific frequency for operation. [2-4]. Researchers concentrated on constructing effective frequency reconfigurable planar monopole antennas because of these appealing characteristics (cost, size, and numerous frequency bands). [2-4]. Such antennas have been designed in the past using radiating elements of various forms with original switching mechanisms. Double T-shaped, B- shaped, F-shaped, E-shaped and G-shaped are some examples as well as C-shaped antennas.

Due to its low profile, decreased size, less weight, and ease of system integration, planar monopole antennas are more ideal for accommodating many wireless technologies in a single antenna hardware [2-4]. The majority of dual band antennas are linearly polarized for the dual band operation. In order to turn OFF or ON a specific frequency band, switches (PIN diodes, optical, and varactors) are incorporated within the antenna's radiating element. These multi-band antennas fall under the category of frequency reconfigurable antennas.

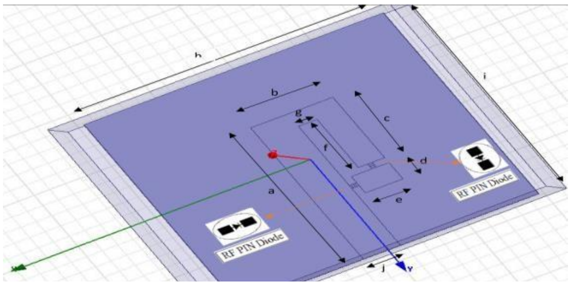

Fig. 1. Schematic representation of the proposed reconfigurable antenna

Dimensions- A is 65 mm, B is 26 mm, C is 29.5 mm, D is 8 mm, E is 12 mm, F is 23.6 mm, G is 6 mm, H is 26.5 mm, and I is 29.6 mm in size.
The resonating components' and slots' lengths can be changed to achieve frequency reconfigurability [7, 8]. Radiation pattern reconfigurability is a different type of reconfigurability in which the pattern's nulls and beam pattern can be changed.
Wi-Fi, WLAN, and Bluetooth frequency bands can all be received or transmitted utilizing the proposed antenna's RF PIN Diodes. Since optical switches don't require biased lines, like PIN diodes do, and are simple to integrate into the structure, they can also be used to achieve reconfigurability. Other sophisticated switching methods, such as RF-MEMS, structural or material modifications [11], have also been applied in the past to the task of reconfiguring antennas for a variety of frequencies.

Table I provides a summary of the most well-known and popular switching mechanisms.

Table I. Reconfiguration Techniques

S	SWITCHING TECHNIQUE	DESCRIPTION
1	Electrical	RF-MEMS, varactor, PIN Diodes
2	Optical	Photo conductive
3	Physical	Geometrical variation
4	Material	Liquid crystals, Ferrites

The frequency reconfigurable task is done by changing the length of slots by making use of RF PIN diodes.

II. ANTENNA STRUCTURE AND DESIGN PROCEDURE

By shifting RF PIN diodes, the length of the rectangular and inverted J-shaped radiator patch is adjusted. These two strips' lengths match the operational frequencies in bands' quarter wavelengths [4]. A RF PIN diode can be mounted in between two segments of a J-shaped strip or rectangular patch if the space between them is 2.4 mm[4]. The monopole is printed in FR4 that is 1.6 mm thicker and has a thickness and dielectric constant of H. It is fed by a lumped port. The design makes use of a metallic (copper) ground plane to achieve maximum efficiency and gain. To obtain a more precise response at 2.4 GHz and 3 GHz, we improved the estimated values of the antenna size. It is the antenna A microstrip line feeds the antenna that is printed on the substrate[3]. The substrate is above a radiator and a microstrip line, while the ground plane is below the substrate.

The following formulas were used to create the conventional patch antenna:
To determine the patch's width,

$$W = \frac{C}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

Where C=3x10 m/s & ε_r= dielectric constant, f_r = Resonating frequency. The length of the patch can be obtained by

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

Where,

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} + 0.258)\left(\frac{W}{h} + 0.8\right)}\right] \quad (3)$$

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left[1 + 12\left(\frac{h}{W}\right)\right]^{-0.5} \quad (4)$$

$$L_{eff} = \frac{C}{2 f_r}\sqrt{\frac{2}{\varepsilon_{reff}}} \quad (5)$$

The patch antenna's microstrip feed line was found to be fed for a 50 line impedance (Z0). The formulas for feeder length (Lf) and feeder width (Zo) for microstrip feed line are shown in equations (6) and (7).

$$L_f = \frac{6h}{2} \quad (6)$$

$$Z_o = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left[\frac{5.98h}{0.8W_f}\right] \quad (7)$$

Only when the width and length of the patch have been determined can the substrate dimensions be estimated. The ground and substrate are both calculated using the same formulas because their dimensions are the same ([10]). The substrate's breadth, Wg

$$W_g = 6h + W \quad (8)$$

The length of the substrate, L_s

$$L_s = 6h + L \quad (9)$$

Lumped elements were utilized in HFSS to mould the pin diode. the equivalent circuit for both OFF state(Reverse bias)and ON state(Forward bias) were shown in Fig.2

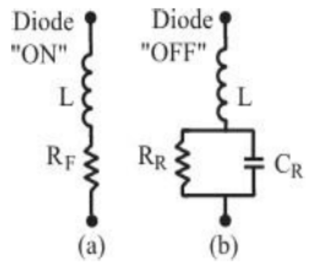

Figure 2 shows an equivalent circuit model for an RF PIN diode in a "ON" condition. (b) An equivalent circuit model for the "OFF" setting. L = 0.4nH, R = 1.35, and C = 33 pF are the parameters for the (ON) condition.

As depicted in Fig. 1, a slot of 2.4 mm length is set aside so that the switches can be installed within the framework at the proper location. The theory transmission line model is utilized to determine the monopole antenna's effective length. The impedance of antenna is far lesser than the impedance of the RLC system, therefore the effects of the lumped parts on antenna performance are minimal[7].

Table II. Summary of measurements of the proposed antenna in Fig. I

Lengths	Values(mm)
L1(a)	65
L2(b)	26
L3(c)	29.5
Length of the radiator(d)	8
Width of the radiator(e)	12
L5(f)	23.6
L5(g)	6
W_g(h) Width of the ground plane	26.5
L_g(i) Length of the ground plane	29.6
Width of the feed line(j)	12
Lenth between the slots(RF PIN diode)	2.4

III. SIMULATIONS AND RESULTS

The electromagnetic wave equations are solved in the time and frequency domains for the proposed frequency reconfigurable planar monopole antenna[9] utilizing the (FIT) used in CST MWS and the Finite Element Method (FEM) used in HFSS.

Microstrip feed line is given a waveguide port for the purpose of excitation of the antenna. VSWR, surface, gain (H- and E-plane), scatter parameter, and return-loss. Transient solver and open add space boundary conditions are used to evaluate electric fields. The suggested antenna work in dual-band frequency modes (2.45 and 3 GHz)[10] with a return loss of -15.3 and -13.5dB, respectively, when the PD1 switch is ON and the PD2 switch is OFF. At 2.45 and 3 GHz, respectively, the suggested antenna's peak bandwidth (return loss -10 dB) is 20 and 19 percent.

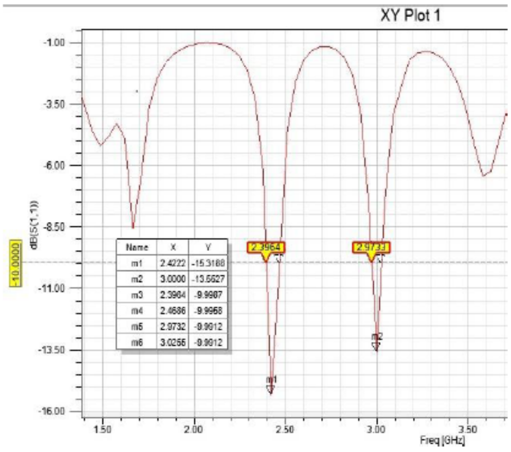

Fig.3 Graphical representation of Return loss Vs frequency of reconfigured antenna.

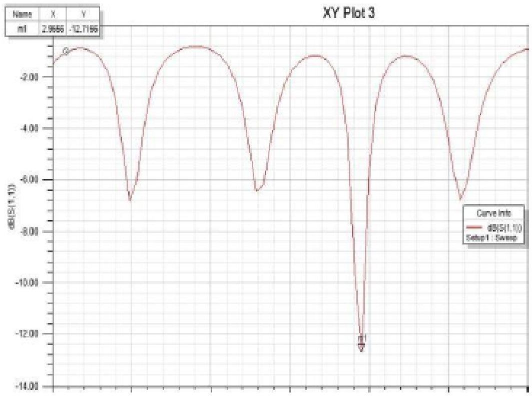

Fig. 8. Graphical representation of Return loss Vs frequency for proposed antenna (when both PIN diodes in OFF state)

Table III. Performance analysis of proposed antenna

Switch condition	Frequency (GHz)	Return loss(dB)	Band width(GHz)	VSWR (dB)
When Both the switches are OFF	**2.9**	**-12.71**	**0.057**	**4.092**
When PD1-ON and PD2-OFF	**2.4**	**-15.31**	**0.072**	**3.00**
	3.0	**-13.55**	**0.052**	**3.70**

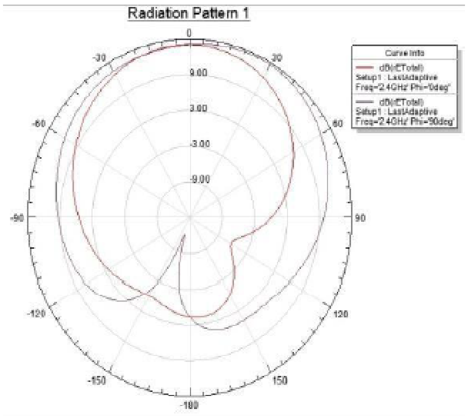

Fig.4 Radiation patterns for presented reconfigurable antenna (for PIN Diode 2 OFF and PD1 ON Condition)

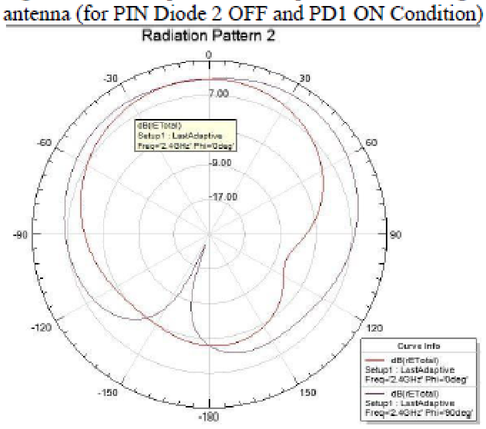

Fig.5 Radiation patterns for presented reconfigurable antenna (for PD1 OFF and PD2 2 OFF Condition)

Figures 4 and 5 depict the simulated radiation patterns for the proposed reconfigurable antenna. The figures demonstrate that for the H-plane, directed radiation patterns are obtained.

IV. CONCLUSION

The simulation results of a slotted antenna and a frequency-reconfigurable antenna are explained along with the straightforward construction of the provided antenna. Design, analysis, and evaluation are performed on a reconfigurable dual-band antenna for fixed Wi-Max 3.0 GHz and WLAN 2.4 GHz heterogeneous transceivers. In ansys HFSS, the planned antenna is emulated. With return loss between -15 and -13 dB for dual-band (2.4GHz) and single-band (2.4 and 3.0GHz), the reconfigurable antenna is effectively demonstrated. The ON and OFF modes of the PIN diode switches are set up to provide two operating modes. The intended antenna is appropriate for wireless L- and S-band microwave applications.

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