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Reconfigurable Multiband Patch Antenna

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***Abstract* - This paper presents the emergence of reconfigurable antenna for the developments in wireless technology. The proposed work deals with the design of low-profile, reconfigurable, tunable multiband patch antenna for different types of wireless applications such as Wi-Fi, Wi-max, Bluetooth ,3G within a microwave L, S, C, and X frequency bands in Electromagnetic Spectrum, cognitive radio applications. Today, different antennas are preferred for different wireless applications. The major issues are increased complexity and the size of the devices. By using proposed technique, the selection of different frequency band in communication systems can be conveniently served by only one antenna. The proposed antenna consists of rectangular patch designed with U-shape slot with three RF PIN diodes placed at different position on the ground plane to achieve frequency reconfigurability i. e. to select different frequency band depending upon wireless applications.The analysis are performed using Agilent Advanced Design System software. The main advantage of this design is that the proposed antenna is having low profile, light weight, and easy to fabricate.**

Keywords* - *ADS Software, Microstrip Patch Antenna, Multiband, Reconfigurable, RF PIN Diode.

I. INTRODUCTION

In today's world all the systems are going wireless for good compatibility and flexibility. A successful emerging trend in the wireless communication system is the reconfigurable antenna system. Reconfigurable Antennas that can be used for multiple purposes like select several frequency bands, tune resonances, change polarization and modify their radiation patterns, made their development imperative in modern telecommunication systems. Conventional antennas are more costly and complicated because it uses external variable power and phase distribution network which feeds antenna elements.To resolve above issuses proposed a reconfigurable antenna which uses external variable power and phase distribution network which feeds antenna elements and resonate at different frequencies at different time by using switches therefore reduces the cost and overall size of the system [1]-[4].

Reconfigurability of an antenna is achieved by the use of micro electromechanical systems (RF-MEMS),RF PIN diodes ,varactor diodes, photoconductive elements, or on the physical variation of the antenna radiating structure or on the use of other materials such as ferrites and liquid crystals redistribution of the currents ,or equivalently, the electromagnetic fields on the/antenna's effective aperture. Among them RF PIN diodes are mostly used for swithcing because of its characteristics like compact dimensions, low cost, low insertion loss, reasonable isolation, very reliable and high switching speed [5].

In this paper rectangular patch is designed with U-shape slot with three RF PIN diodes placed at different position on the ground plane to achieve frequency reconfigurability. This proposed antenna can radiate different frequencies for different wireless applications with stable radiation characteristics and considerable bandwidth and low operating frequency ratio in OFF and ON states of the PIN diodes [6]-[8]

In the rest of paper is organised as follows: Section II provides design and simulation result of Simple rectangular patch antenna. Section III provides design of reconfigurable multiband patch antenna. Section IV provides simulation and measured result of proposed reconfigurable antenna. Section V provides the conclusion followed by references.

II. MICROSTRIP PATCH ANTENNA DESIGN AND ITS RESULTS

Proposed rectangular patch antenna designed on FR4 substrate with relative permittivity of εr = 4.34 and height of substrate is h = 1.5 millimeter (mm). To design this antenna, Agilent Advanced Design System (ADS, Ver. 2011.05) software is used. Fig.1 shows the simple microstrip patch antenna [9]-[10].

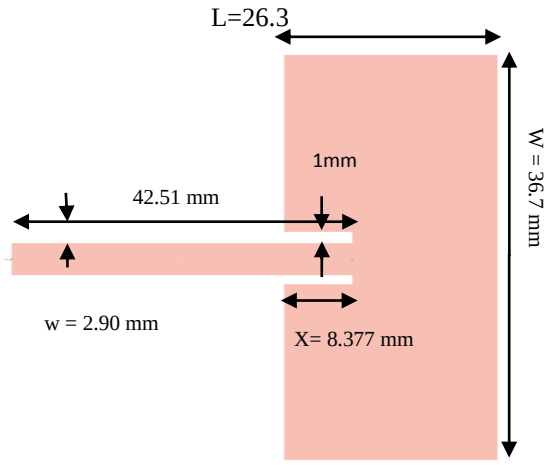

Fig. 1 Designed Microstrip Patch Antenna

Above rectangular patch antenna is a designed using following equations,

Width of Microstrip patch antenna is calculated by following equation,

$$W = \frac{c}{2 \times f_r} \times \sqrt{\frac{2}{\varepsilon_r + 1}} = 36.7 \text{ mm} \qquad (1)$$

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Where 'c' is the speed of light (3 x 108 m/s), fr is the resonate frequency 2.7 GHz and 'εr' is the dielectric permittivity of 4.34.

The effective dielectric constant is obtained by referring to equation:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12 \times \frac{h}{w}\right)^{-\frac{1}{2}} = 4.02 \quad (2)$$

Where,' εreff 'is the effective dielectric constant and 'h' is the thickness of dielectric substrate.

Effective Length of Microstrip Patch antenna is calculated by following equation,

$$Leff = \frac{c}{2 \times f_r \times \sqrt{E_{reff}}} = 27.68 \text{ mm} \quad (3)$$

$$\Delta L = 0.412 \times h \times \left(\frac{E_{reff} + 0.3}{E_{reff} - 0.258}\right) \times \left(\frac{\frac{W}{h} + 0.264}{\frac{W}{h} + 0.8}\right) = 0.68 \text{ mm} \quad (4)$$

Where, ΔL is length extension.

Actual length of Microstrip patch antenna is,

$$L = Leff - 2 \times \Delta L = 26.32 \text{ mm} \quad (5)$$

Width of feed for an impedance of 50 Ω is calculated using following equations,

$$A = \frac{Z_0}{60} \times \sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1} \times \left(0.23 + \frac{0.11}{\varepsilon_r}\right) = 1.5214 \quad (6)$$

$$B = \frac{377 \times \pi}{2 \times Z_0 \times \sqrt{\varepsilon_r}} = 5.69 \quad (7)$$

W=

$$\frac{2 \times h}{\pi}\left\{B - 1 - \ln(2 \times B - 1) + \frac{\varepsilon_r - 1}{2 \times \varepsilon_r} \times \left[\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} = 2.90 \text{ mm} \quad (8)$$

Distance between feed and lower side of antenna is calculated using following equation,

$$X = \frac{L}{\pi} \times \arccos\frac{\sqrt{3}}{3} = 8.377\text{mm} \quad (9)$$

III. SIMULATION RESULT OF SIMPLE PATCH ANTENNA

After analysis it resonant at of 2.7 GHz frequency with -38 dB returns loss as shown in Fig.2 This antenna can be used for Wi-Max application.

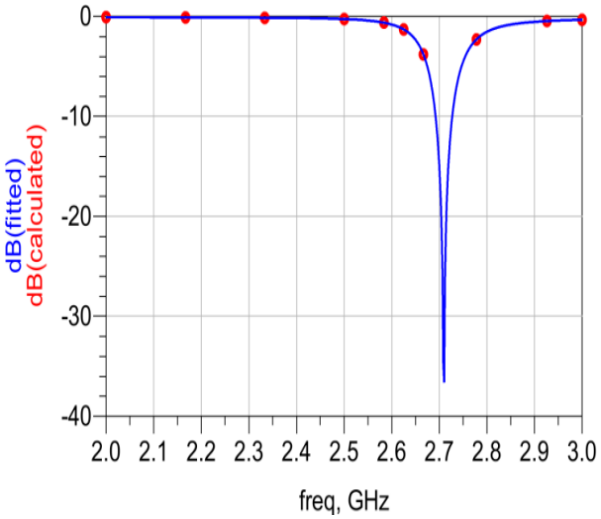

Fig.2 Frequency characteristic (S11 parameter)

IV. RECONFIGURABLE MULTIBAND PATCHE ANTENNA DESIGN

CASE A: When all diodes are in OFF conditions

To achieve dual frequency operation U-shape slot is inserted in simple patch with three RF Pin diodes D_1, D_2, D_3 which is placed in middle of each slot in above design. Fig.3 shows the U-shape slotted Microstrip Patch Antenna Design with three RF PIN diodes. In this case all three pin diodes are in off conditions. For this designed FR4 dielectric material is used for substrate of height h = 1.5 mm and εr = 4.34. Antenna is fed with a 50Ω coaxial cable. Slot should be placed carefully to obtain multiband frequency [11].

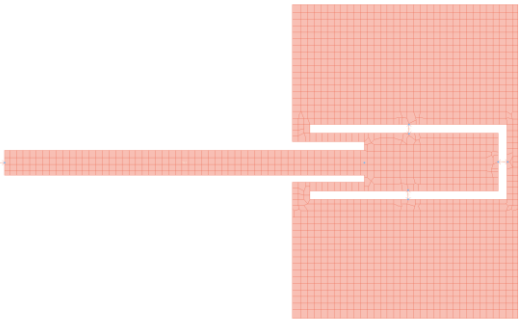

Fig. 3 U-Slot Antenna with three pin diodes in off conditions

Fig.4 shows the Simulation and measured result of antenna given in Case A. Multiple frequencies are obtained in various bands such as *C* band (4 to 8 GHz) and *X* band (8 to 10GHz) by inserting the U-shape slot.

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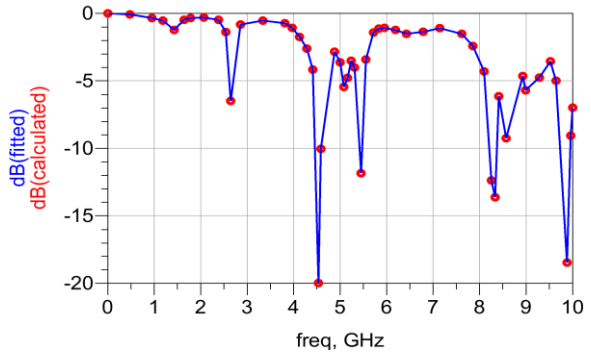

Fig. 4 Frequency characteristic (S_{11} parameter)

In this case A, all Pin Diodes are off. Fig. 4 shows the simulated and measured return loss of optimized reconfigurable antenna as given in Table I.

TABLE I. RESONANT FREQUENCY AND ITS RETURN LOSS

Frequency (GHz)	Return loss (dB)
4.5	-20
5.5	-12
8.2	-14
9.9	-19

CASE B: When all diodes are in ON condition

In this case, three pin diodes D_1, D_2, D_3 are in on conditions and dimensions of Microstrip Patch Antenna are same as shown in Fig. 3. Fig. 5 shows the position of pin diodes inserted in U-shape slot of Microstrip Patch Antenna.

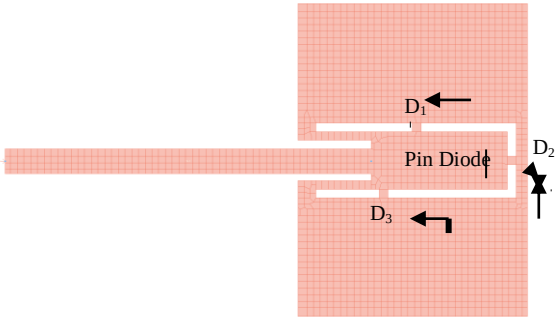

Fig. 5 Microstrip patch antenna with 3 pin diodes in on conditions inserted in U-shape slot

In Fig. 5, 111 correspond to ON- ON- ON state of diodes. In Fig. 3 (Case-A) pin diodes are absent hence it can name as 000/OFF-OFF-OFF state. '0' means pin diode is OFF and '1' means pin diode is in ON state.
Fig.6 shows current distribution of all the frequencies obtained when diodes D_1, D_2, and D_3 are ON state.

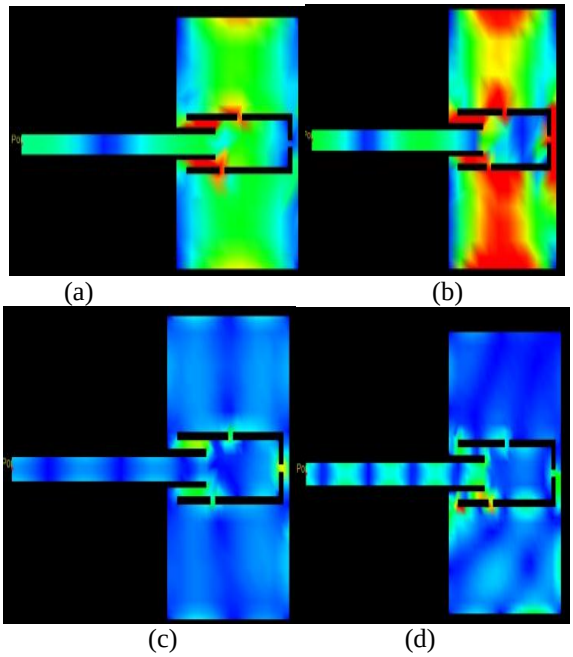

Fig. 6 Current distribution at a) 2.9 GHz b) 3 GHz (c) 5.1 GHz (d) 7.35GHz

Fig. 7 shows the Simulation and measured result of antenna given in Case B. The ON status of pin diodes D_1, D_2 and D_3 gives 2.9 GHz, 5 GHz, 7 GHz, 7.3GHz, 7.5 GHz, 8. 8 GHz, 9.5GHz frequencies as shown in Fig.7. Thus the frequencies are obtained in all the bands simultaneously.

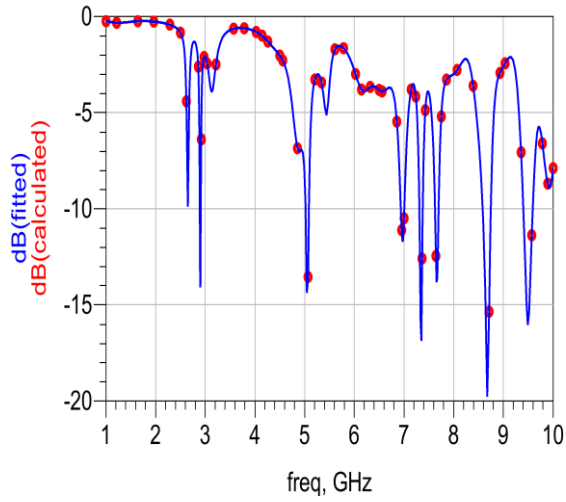

Fig. 7 Frequency characteristic for diode D_1, D_2 and D_3 (S_{11} Parameter)

CASE C: When two diodes are in ON condition

In Fig.8 diode D_2 and D_3 are in ON condition and diode D1 in OFF state. Hence Fig. 8 can also name as 011/OFF-ON-ON state.

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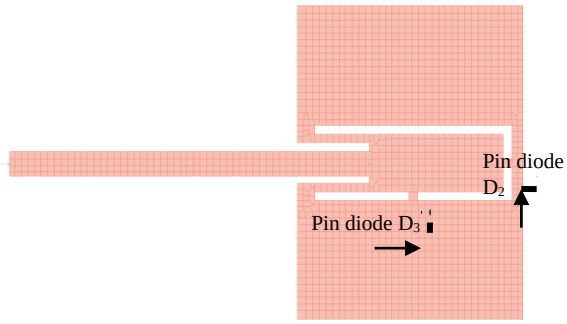

Fig. 8 Reconfigurable Patch Antenna with 011 state of pin diode.

Fig.9 shows current distribution of all the frequencies obtained when diodes D_2 and D_3 are ON state.

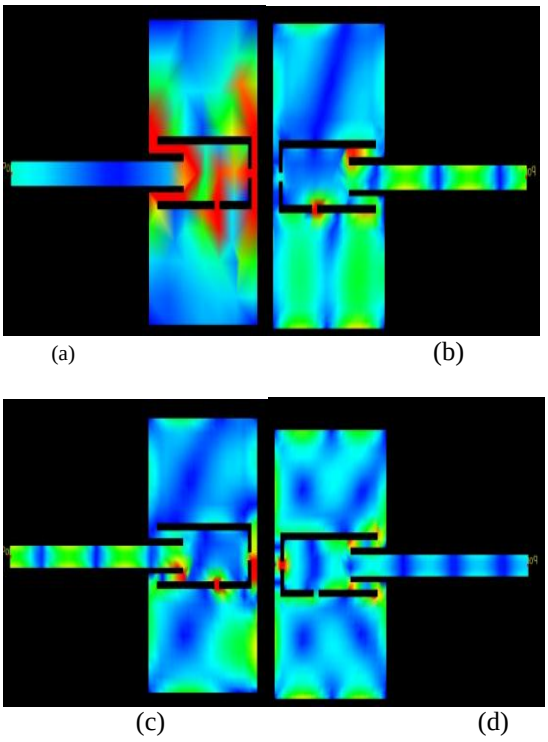

Fig. 9 Current Distribution of condition when diodes D_2 and D_3

Fig. 10 shows the Simulation and measured result of antenna given in Case C. When diode D_1 is in OFF state and diodes D_2 and $D_3$are in ON state gives resonant frequencies at 1 GHz, 5 GHz, 6.9 GHz, 7.7GHz, 8.8 GHz, 9.5GHz.

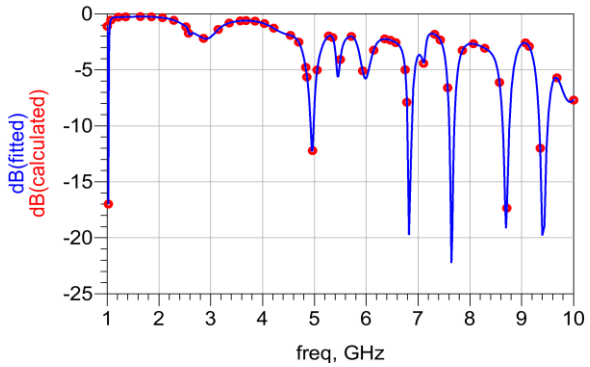

Fig. 10 Frequency characteristic for pin diode D_2 and D_3 (S_{11} Parameter)

V. RESULTS AND DISCUSSION

Table II shows all the possible combination of states of pin diodes D_1, $D_2$and D_3. Depending upon the status of diodes, same patch antenna can be used for different wireless applications only ON and OFF states will be changed of pin diodes as given in Table II.

TABLE II WIRELESS APPLICATIONS DEPENDING UPON PIN DIODE STATUS

SR .NO.	State of Pin Diodes (‘0’: ON ‘1’:OFF)			Wireless Application	Frequency Obtain (GHz)
	D_1	D_2	D_3		
1	0	0	0	UWB	4.5, 5.5 , 8.2 , 9.9
2	0	0	1	Wi-Fi	4.5
				UWB	8.8,9.9
3	0	1	0	UWB	7.1, 9.8
4	0	1	1	UWB	4.6, 8.2,8.3,9.9
				Wi-Max/Wi-Fi	5.5
5	1	0	0	UWB	4.5, 8.2,8.8, 9.9
6	1	0	1	Wi-Max	2.8
				UWB	8.2, 9.9, 9
7	1	1	0	Wi-Max/Wi-Fi	5
				UWB	6.8,7.7,8.8,9.4
8	1	1	1	3G	1
				UWB	7,7.3,7.5,8.8,9.5
				Wi-Max/Wi-Fi	2.9,5.1

This Reconfigurable antenna has many practical applications. By turning Pin diode ON and OFF, antenna structure provides band of frequencies for Wi-Fi, WI-Max, 3G, UWB applications and it’s useful in a variety of system [12]. Thus for having applications Wi-Max and UWB simultaneously, the status of D_3 can be anything. But D_1 and D_2 should be OFF. For applications like 3G, D_1 can have any state but D_2 and D_3 should be ON. This antenna can replace all the 4 patches of by only single patch. The main advantage of this design is that it is having low profile, light weight, and easy to fabricate.

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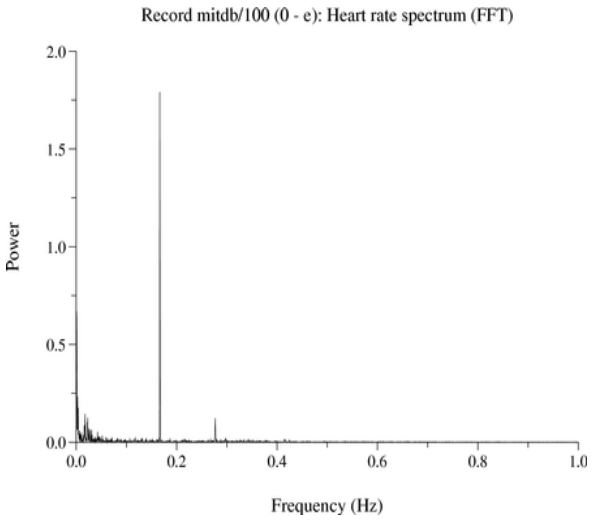
For smart reconfigurable antenna, Mat lab coding used which scan the frequency spectrum obtained from broadband antenna. The outputs of mat lab code which tell us what range of frequency spectrum meet. Based on this range, the configuration of proposed antenna will be selected.



V I. CONCLUSIONS

The proposed frequency reconfigurable antenna capable for changing frequency operation by using RF Pin diodes which is situated at different position on U-shape slot.Just by turning the pin diodes in ON and OFF state, the resonant frequency can be varied. This compact reconfigurable Microstrip patch antenna provides different band of frequencies such as L band, S band, C band and X band and used for different wireless applications.

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