Frequency Reconfigurable Antenna Using PIN Diodes

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***Abstract*- A compact frequency reconfigurable double slot antenna for wireless communication is presented. The proposed antenna consists of double slot with six RF 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 eleven different frequency ranges. The radiation pattern of the antenna is nearly omnidirectional for all the frequency bands. The simulated return loss for all the frequency bands meets the optimum value. The overall dimension of the antenna is 30 x 25mm^2 including ground plane. For different switching state, the antenna can operate in both single and dual band mode. Without changing the size of the antenna the antenna can operate in single band and dual band mode by changing the state of the RF PIN diode. The antenna parameters such as VSWR return loss and radiation pattern are simulated. The analyses are performed using Ansoft HFSS v13.0 software.**

Keywords – Reconfigurable; RF PIN diode; single band; dual band; switching state

I. INTRODUCTION

In recent years, there is a huge demand for frequency reconfigurable antenna especially for wireless communication. The reconfigurable antennas provide the ability to dynamically adjust various antenna parameters such as radiation pattern, bandwidth, gain and polarization. Reconfigurability can be achieved by using RF PIN diodes, varactor diode and Radio Frequency Microelctromechanical System (RF MEMS) switch. Reconfigurable antenna offers extraordinary features such as small size, same radiation pattern for all the operating frequency bands and reduces the effects of jamming and co site interference.

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A compact, electronically tunable and single fed resonant slot antenna for higher frequency application has been reported [1]. In [2], a reconfigurable antenna array with two printed dipoles and PIN diode switches for Multiple Input and Multiple Output systems has been addressed. Annular slot antennas with PIN diodes are designed to achieve both pattern and frequency reconfigurability [3]. Though this antenna achieves both pattern and frequency reconfigurability but this antenna uses matching stub for impedance matching. In [4], a frequency reconfigurable slot antenna with five RF pin diodes for cognitive radio application has been reported. In [5], a microstrip slot antenna for Digital Television (DTV) application and a planar frequency reconfigurable microstrip loop antennas for Long Term Evolution (LTE) application has been addressed. Though single antenna covers both DTV and LTE application the size of the antenna is large. An E-shaped circular polarization microstrip patch antenna for wireless application has been demonstrated [6]. In [7], a reconfigurable stacked microstrip patch antenna with two feed and two short pins for satellite communication and terrestrial land mobile application has been addressed. In [8], a reconfigurable, single feed, dual band hexagonal slot loaded microstrip patch antenna has been addressed. This antenna consists of hexagonal patch with one RF PIN diodes was used. Though this antenna uses only one PIN diode, it covers only two frequency bands. In literature [9], a wideband and multiband reconfigurable antenna with dual patch was reported. The antenna is realized switching between wideband and narrowband operation by using C-slot in the patch. The antenna structure is large. In [10], two U-shaped slots on the ground plane to achieve frequency reconfigurability have been addressed. A reconfigurable antenna is one of the best antennas to obtain wide bandwidth by using different ON and OFF switching conditions. Normally the switching condition can be achieved using PIN diode, RF MEMS switch and varactor diode. Though varactor diode and RF MEMS switch have advantages like low insertion loss and Q-factor, the fabrication is difficult and expensive. In this paper we make use of RF PIN diode which have many benefits and low cost. By using different switching condition in the antenna wideband and multiband operation with compact size can be achieved. In this paper, a new design of frequency reconfigurable antenna with two slots on the ground plane

with six RF pin diodes are placed at different positions is designed and presented.

The primary advantages of the proposed reconfigurable antenna is that this antenna resonant at eleven different resonant frequency. Instead of using two or three antenna, single antenna is used to radiate at eleven different frequency bands and the size of the antenna is small. RF PIN diodes are used to resonate at different frequency bands. The rest of the section is organized as follows: Section II covers the reconfigurable antenna design and analysis of PIN diode. Simulation results and discussion are described in Section III. Section IV depicts the conclusion.

II. RECONFIGURABLE PATCH ANTENNA

A. Antenna Design

In this section, design of proposed reconfigurable antenna is presented. Fig. 1(a), shows the front view of proposed antenna. Fig. 1(b), depicts the back view of the proposed antenna. Fig. 1(c), shows the side view of the proposed reconfigurable antenna. The dimensions of the antenna such as the length of the ground plane, width of the ground plane, length of the patch and width of the patch are calculated using Transmission line model [11] and the values are optimized to achieve optimum value of antenna parameters. The antenna is fabricated on FR4 substrate with a thickness of 1.5mm, with permittivity of 4.4 and loss tangent of 0.02. The antenna is fed with 50Ω microstrip feed line. FR4 substrate is used for miniaturization of antenna size, because of high dielectric constant of the substrate. The proposed antenna consists of two slots on the copper clad ground plane with six Micro-semi MPP4203 PIN diode placed in the slot. MPP4203 PIN diodes are high isolation switch and very high attenuator. To achieve frequency reconfigurability PIN diodes are used. PIN diodes are used because of its high speed switching, reliability and compact size make it most appropriate for this application. The size of each slot is 12mm x 2mm. The length of the microstrip feed line is 10mm and width is 2.5mm. The patch size is $12x12mm^2$. The dimension of ground plane is $30 \times 25mm^2$. Three switches SW1, SW2, SW3 are placed in the first slot and another three slots SW4, SW5, SW5 are placed in the second slot. The diode switching configuration is shown in Table I.

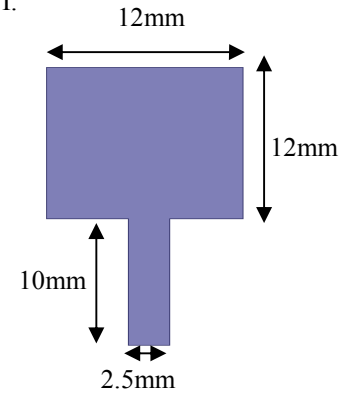


Fig. 1(a). Front view of proposed antenna

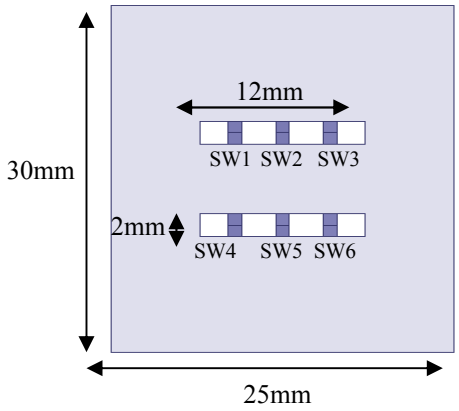


Fig.1 (b). Back view of proposed antenna

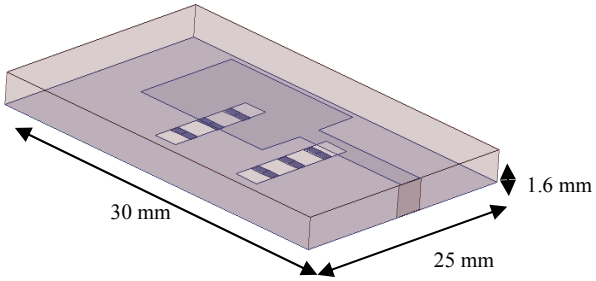


Fig.1 (c). Side view of proposed antenna

TABLE I. DIODE SWITCHING CONFIGURATION

Frequency	Frequency Range (GHz)	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6
F1	3.7-4.1	OFF	OFF	OFF	OFF	OFF	OFF
F2	3.6-3.9	OFF	OFF	OFF	ON	ON	OFF
F3	8.9-9.2	ON	ON	OFF	ON	ON	ON
F4	7.3-7.9	ON	ON	ON	OFF	ON	OFF
F5	7.7-8.5	ON	ON	ON	ON	ON	OFF
F6	4.3-4.6 & 7.7-8.2	ON	OFF	OFF	ON	ON	ON
F7	4.8-5.0& 8.5-8.8	OFF	ON	OFF	ON	ON	ON
F8	4.3-4.5& 7.4-8.4	OFF	OFF	ON	ON	ON	ON

B. Analysis of PIN Diode

When all the diodes are switched OFF, the slot resonates from 3.7GHZ to 4.1GHz and omnidirectional pattern is obtained. When the switches SW4 and SW5 are switched ON the slots resonates at 3.6GHz to 3.9GHz. When SW1, SW2, SW3, SW4, SW5 are switched ON and SW6 is switched to

OFF the antenna resonates at dual band mode (4.3-4.6GHz) and (7.7-8.2GHz). PIN diodes are used as switching elements. When the switches are on the ON state, the length of the slot is changed. It behaves like a short circuit and there is a flow of current, therefore the effective length of the slot is reduced. Thus the antenna resonates at higher frequencies. When the diode is switched OFF, the effective length of the slot increases and resonates at lower frequencies. When more switches are in ON state, the antenna covers higher operating frequency bands. Without changing the dimension of the antenna, the antenna resonates at different frequency with the help of PIN diodes. The equivalent circuit of PIN diode in forward biased and reversed biased is shown in Fig. 2 and Fig. 3 respectively. The equivalent circuit for forward biased PIN diode consists of series inductance L_1 =0.45nH and series resistance of R_1 =3.5Ω and the reverse bias equivalent circuit consists of shunt Capacitance C_1 = 0.08pf and shunt resistance R_2 = 3.5Ω with series inductance L_1 = 0.45nH. We use Ansoft HFSSv13.0 software to simulate our design.

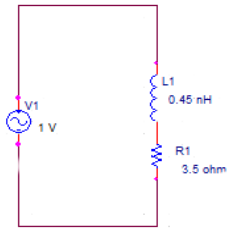


Fig. 2. Equivalent circuit of PIN diode in forward bias

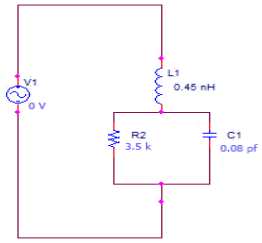


Fig. 3. Equivalent circuit of PIN diode in reverse bias

III. RESULTS AND DISCUSSION

In this section simulated results of VSWR, return loss (S_{11}) and radiation pattern are presented. Fig. 4, shows the S_{11} of proposed reconfigurable antenna. The simulated return loss for all the frequency bands are less than -10dB. Fig. 5 depicts the simulated VSWR value of proposed value. The simulated VSWR for all the frequency bands lies between 1 to 2. Return loss (S_{11}) and VSWR value for different frequency bands were summarized in Table II. Fig. 6 shows the simulated radiation pattern of proposed antenna with different switching state is plotted at 3.7GHz, 3.9GHz, 7.6GHZ, 7.9GHz, 4.4GHz, 4.9GHz and 9.1GHz. The radiation pattern is nearly omnidirectional for all the frequency bands. Table III summarizes the bandwidth for different frequency bands. The proposed antenna achieves wideband in single band mode.

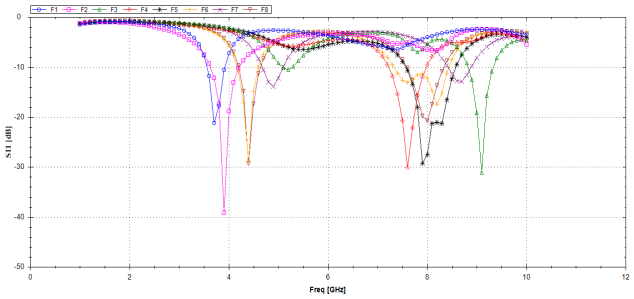


Fig. 4. Simulated S_{11} value of proposed antenna

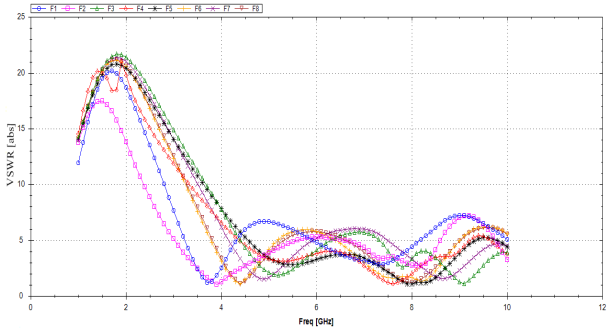
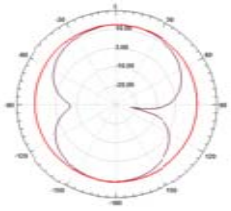


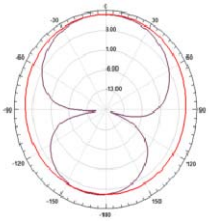
Fig. 5. Simulated VSWR value of proposed antenna

TABLE II. S_{11} AND VSWR VALUE FOR PROPOSED ANTENNA

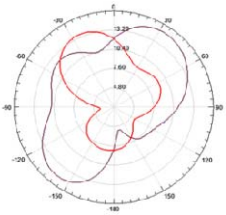
Frequency	Frequency ranges	S_{11} (dB)	VSWR
F1	3.7-4.1	-39	1.4
F2	3.6-3.9	-21	1.7
F3	8.9-9.2	-31	1.05
F4	7.3-7.9	-30	1.06
F5	7.7-8.5	-21	1.07
F6	4.3-4.6 &7.7-8.2	-20	1.07
F7	4.8-5.0 &8.5-8.8	-13	1.5
F8	4.3-4.5 &7.4-8.4	-28	1.07



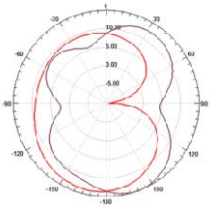
(a) f=3.9 GHz



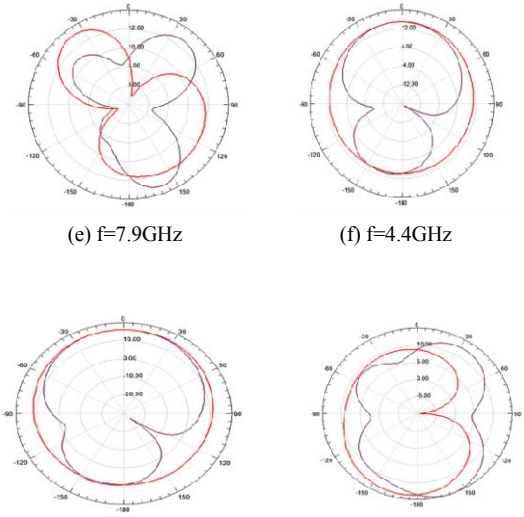
(b) f=3.7GHz



(c) f=9.1GHz



(d) f =7.6GHz



(e) f=7.9GHz (f) f=4.4GHz

(g) f=4.9GHz (h) f=4.4GHz

Fig. 6. Simulated radiation pattern of proposed antenna for YZ plane (red) and XZ plane (blue) (a) f=3.9GHz (b) f=3.7GHz (c) f= 9.1GHz (d) f=7.6GHz (e) f= 7.9GHz (f) f=4.4GHz (g) f=4.9GHz (h) f=4.4GHz

TABLE III: SIMULATED RESONANT FREQUENCY AND BANDWIDTH

Frequency	Frequency ranges	Bandwidth
F1	3.7-4.1	10.2%
F2	3.6-3.9	8.0%
F3	8.9-9.2	4.7%
F4	7.3-7.9	7.9%
F5	7.7-8.5	9.9%
F6	4.3-4.6 & 7.7-8.2	6.74% & 6.3%
F7	4.8-5.0 & 8.5-8.8	4.1% & 3.5%
F8	4.3-4.5 & 7.4-8.4	4.5% & 12.6%

IV. CONCLUSION

A new design of frequency reconfigurable antenna for wireless communication is presented. The proposed antenna consists of double slot on the ground plane with RF PIN diodes placed on the slot. The antenna radiate at eleven different frequency bands for different switching conditions. The radiation efficiency of the antenna ranges from 53% to 59%. The antenna meets the optimum value of VSWR and return loss. The antenna is compact and it also enhances the bandwidth. In future instead of PIN diode, varactor diode and RF MEMS switch will be used as switch and the hardware model of the antenna will be fabricated. The proposed frequency reconfigurable antenna is well suited for cognitive radio systems.

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