Performance Analysis of Frequency Reconfigurable Circular Microstrip Patch Antenna for Wireless Devices

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Abstract

In this paper, the circular microstrip patch antenna is designed for wireless devices and cognitive radio application purposes. In the proposed structure, a circular microstrip patch antenna with pin diodes, circular slot having the centre frequency at 10 GHz was designed. The frequency reconfiguration is achieved by switching the pin diodes on/off states and the simulated results are obtained between the frequency ranges from 10.15 GHz to 10.711 GHz for two diodes case, 10.089-10.44 GHz for three diodes case, 9.82-10.66 GHz for four diodes case. The patch antenna is designed on FR4 substrate with εr=4.54 and thickness t=1.6 mm. The proposed simulation model is constructed on HFSS13.0 simulation software.

Keywords: *PIN diode, Frequency reconfiguration, Circular patch, Cognitive radio, Wireless devices*

INTRODUCTION

Recently multifunctional antennas with controllable features like frequency tuning, pattern reconfigurability, or polarization reconfigurability received much attention as it can work for multi functions with a single antenna [1]. The redistribution of the currents or electromagnetic fields of the antennas can be used to change the impedance or radiation properties to introduce reconfigurability in the antennas.

A microstrip antenna exhibits many attractive features such as small size, light weight, conformability to planar and non-planar surfaces and rigid [2]. They have a wide range of applications especially in mobile communication devices.

The techniques that can be used for reconfigurability in antennas are many such as by using active switches, PIN diodes, varactor diodes or even using a photo-conductive switch [3][4].

Now in this paper, Frequency reconfiguration technique is proposed by using slot configuration in the microstrip patch antenna [5][6][7]. Inside the slot two pin diodes are connected with on and off state working strategy. In the fabrication process diodes are replaced by microstrip lines for on and off working strategy [8].

PIN DIODE CIRCUIT DIAGRAM

(a) Forward bias (b) Reverse bias

Fig1: Equivalent circuit of a packaged PIN diode in its two bias conditions. (a) on-state (forward bias). (b) Off-state (reverse bias)

The equivalent circuit of the PIN diode in forward bias and reverse bias is shown in fig (a) and fig (b) respectively. To achieve the reconfigurable capability, switching components must be used. PIN diodes the most commonly used switching devices for RF and microwave front-end application systems. The RF equivalent circuit of the PIN diode for the ON (forward bias case) and OFF (reverse bias case) states is shown in fig11. The PIN diodes which include self-protect resistors of forward-biased current, PF choke inductors, and dc block capacitors should be isolated from the RF signal [9].

In Forward bias, PIN diode acts as closed switch and the induced current redistributes around the circular slot and diode contact. The simulated return loss depends on the circular patch configuration and switching capacities of the diodes. In Reverse bias condition, PIN diode acts as open switch and the induced current distributes only around the circular patch structure.

ANTENNA DESIGN

The circular microstrip patch antenna is designed by using FR4 substrate with $\varepsilon r=4.54$ and the height is 1.6 mm. The dimensions of circular microstrip patch element are calculated at centre frequency 10 GHz. The PIN diodes located at specific positions are used to create short circuits across the slot and by carefully controlling these diodes, the induced current distribution around the slot can be changed. Thus, a pattern reconfigurable antenna can be achieved resulting in different antenna radiation patterns.

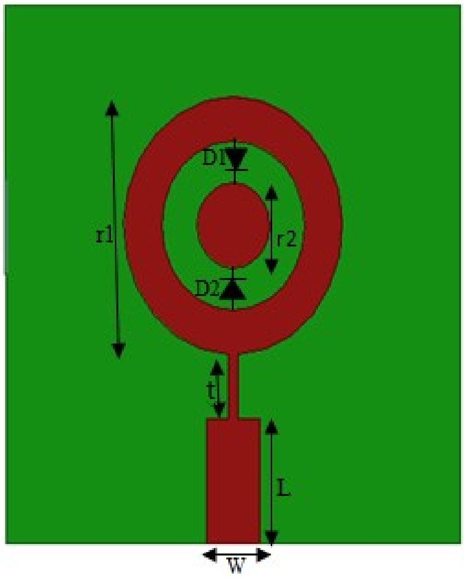

Fig1: Patch antenna with D1 & D2 diodes

The optimized radius of circular patch is r1=6.1 mm. The port excitation is kept at a distance of 8.9 mm from the circular patch antenna.

The length of Quarter line transformer is 3 mm and width is 0.5 mm. The length of microstrip feed line is L=5.9 mm and width is W=3 mm.

The inner radius and outer radius of circular slots are 2 mm and 4 mm respectively is inserted in the patch element. The PIN diodes are placed between the inner and outer circles in the circular slot structure to control the induced current distribution of the patch antenna

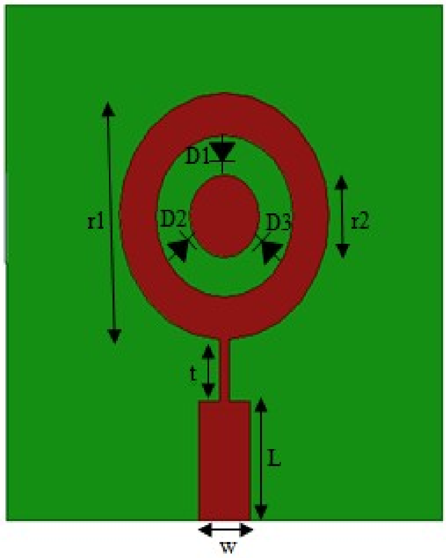

Fig2: Patch antenna with D1, D2& D3 diodes

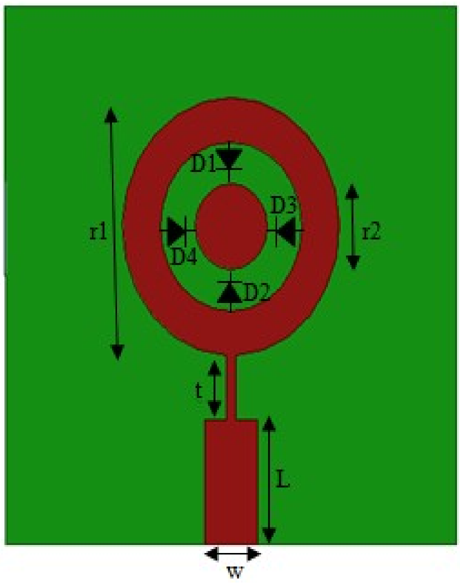

Fig3: Patch antenna with D1, D2, D3& D4 diodes

SIMULATED RESULTS

The proposed design of frequency reconfigurable circular micro strip patch antenna with PIN diodes is simulated by using HFSS 13.0 simulator.

Case1:

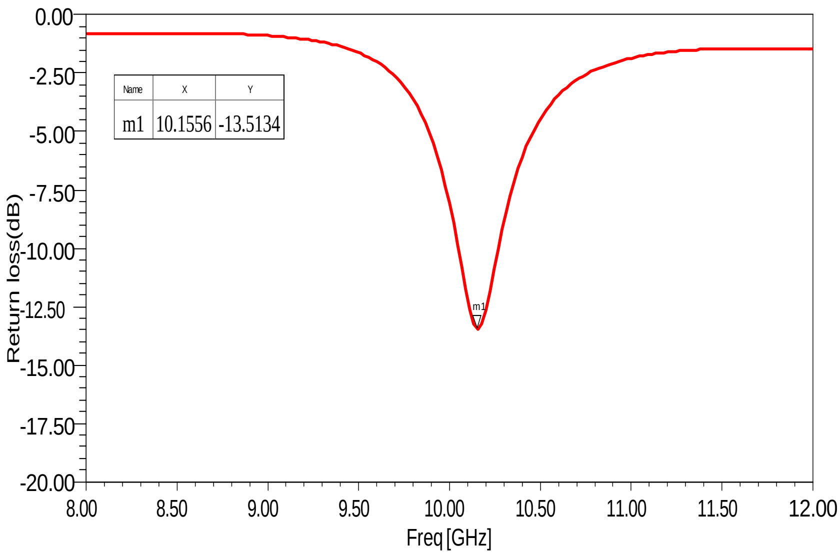

Fig4: Return loss for both diodes OFF condition

When diodes D1 and D2 are in off-state then both diodes are act as open circuits. Fig4 shows the return loss for both diodes off-state case; the loss is -13.2 dB at the resonance frequency 10.15 GHz.

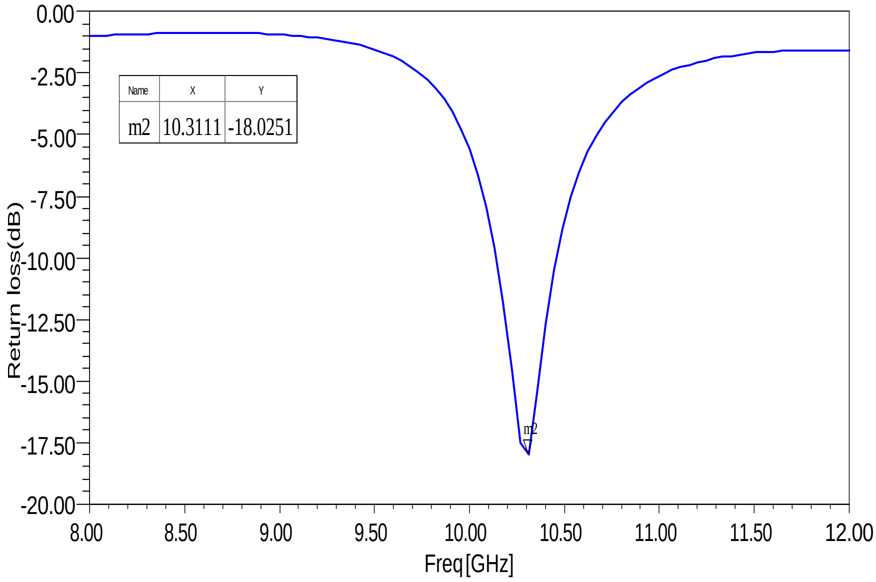

Fig5: Return loss for diode D1 is ON condition

When diode D1 is in ON state it acts as closed switch and D2 diode in OFF state acts as open switch and the return loss depends on the slot configuration and switchable characteristics of the diode D1 as shown in **fig5.** The simulated return loss is -18.75dB at resonance frequency 10.31 GHz.

When both diodes are in ON state, the two diode contacts acts as closed switches and the induced current around the slot is changed as a result simulated return loss is -16.83dB at resonance frequency 10.71 GHz.

Case2

The circular microstrip patch antenna design with three diodes is shown in figure2. The simulated return loss for the three diodes in OFF state is -24.56 dB at resonance frequency 10.06 GHz as shown in **fig7,** so diodes in off state acts as open switches and no induced current flows through the diodes.

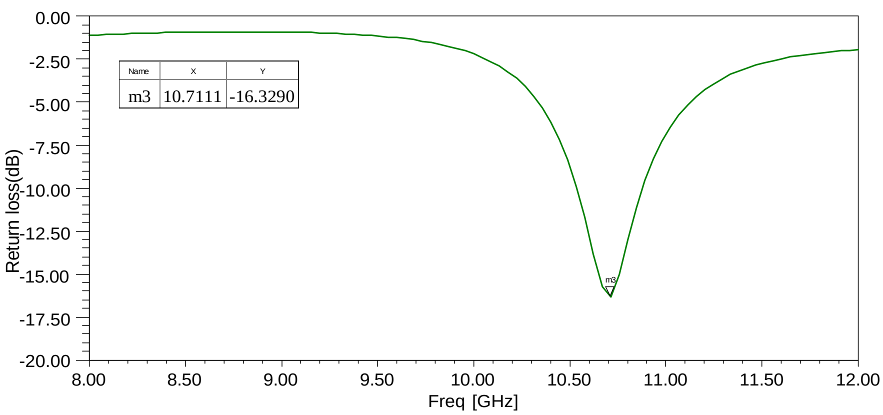

Fig6: Return loss for both diodes ON condition

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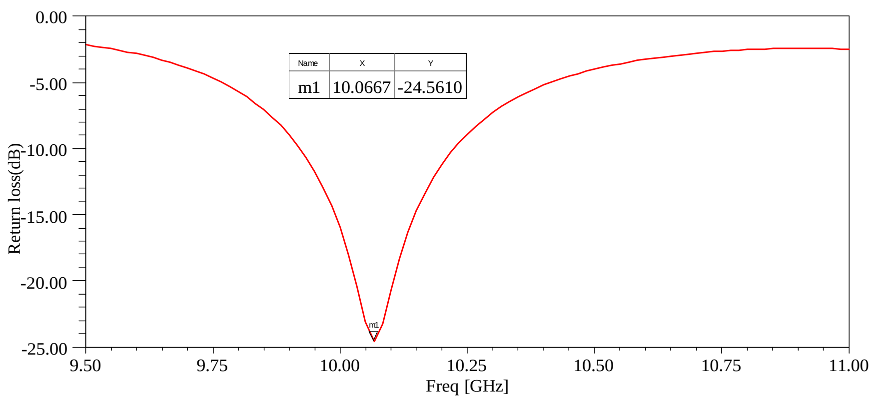

Fig7: Return loss for three diodes OFF condition

When diodes D1, D2 & D3are in ON state, because of the switchable characteristics of the diodes and circular slot configuration, the induced current redistributed around the circular slot as a result the resonance frequency is shifted to 10.46GHz with simulated return loss -14.62 dB as shown in **fig8.**

In between these two conditions we are getting different resonance frequencies with different simulated return losses for different switching conditions of the diodes. We can choose desired condition based on the requirements.

Case3

The circular slot patch element design with four diodes is shown in fig3.When the four diodes are in OFF state, the contacts acts as open circuits and the simulated return loss is -17.34 dB at resonance frequency 9.94 GHz shown in **fig9**

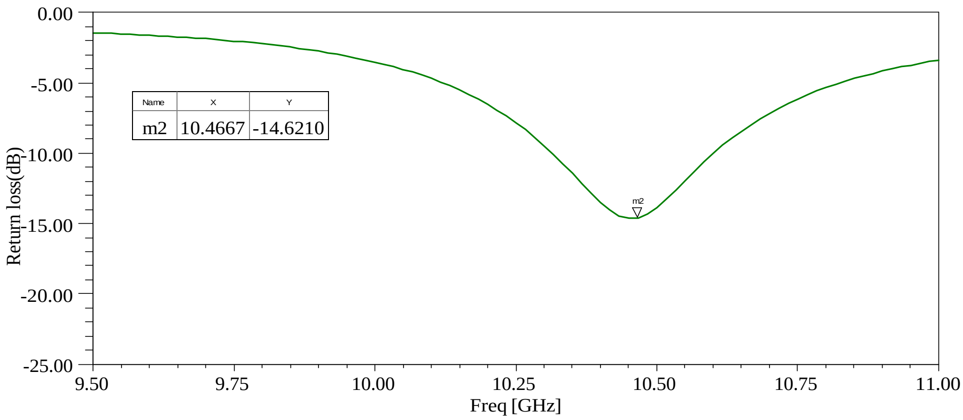

Fig8: Return loss for three diodes ON condition

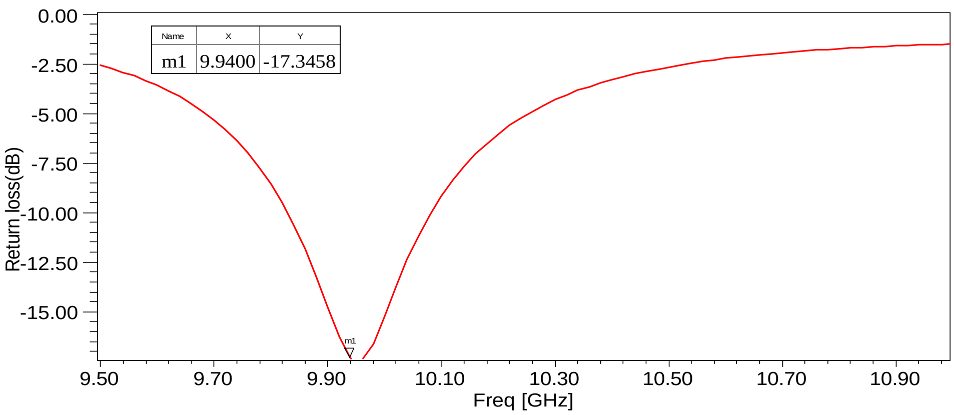

Fig9: Return loss for four diodes OFF condition

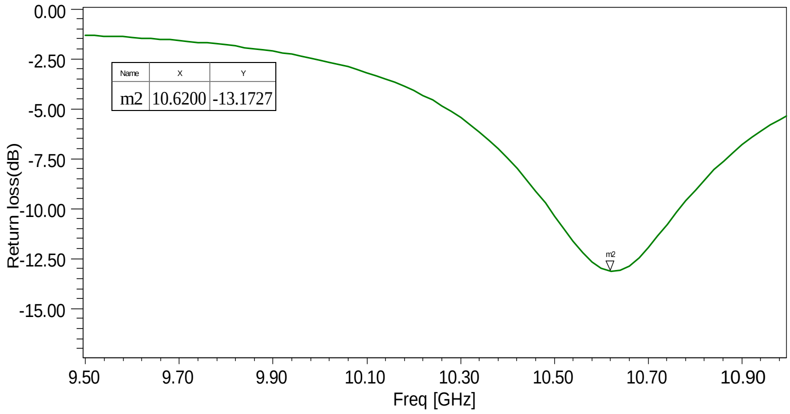

Fig10: Return loss for four diodes ON condition

When four diodes are in ON state, the diodes acts as closed switches and the induced current around the slot is changed as a result the simulated return loss is - dB at resonance frequency 10.62 GHz shown in **fig10.**

Reconfigurable microstrip antenna with four diodes has better frequency shift compared to the two diodes antenna and three diodes antenna.

CONCLUSION

In this paper, the frequency reconfigurable antenna structures have been described with their simulated results. These frequency reconfigurable circular antenna configurations can be a good candidature for different resonance frequencies with different switching conditions of the diodes with an overall gain of 4 dB. It showed that by using circular slot and diode switches the return loss shifts and hence the resonance frequency is also changed. This reconfigurable antenna can further be modified by using RFMEMS switches for fast switching purposes. Reconfigurable antennas establish a platform for applications based on the adaptability to changing conditions.

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