

FREQUENCY RECONFIGURABLE U SLOT CIRCULAR MICROSTRIP PATCH ANTENNA FOR LTE, WLAN AND WIMAX APPLICATIONS

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Abstract – A compact frequency reconfigurable U slot circular microstrip patch antenna is proposed for LTE, WLAN and WIMAX applications. PIN diodes are appropriately positioned to alter the electrical length of U slot arm to achieve the frequency selectivity. The proposed antenna is radiated for 4.3-5.1 GHz LTE band, 5.5-5.85GHz WLAN band and 3.5 GHz WIMAX band. FR-4 substrate with dielectric constant $\epsilon_r=4.4$ and thickness $h=1.6\text{mm}$ parameters are employed for the proposed design. The overall dimension of the antenna is $33 \times 20\text{mm}^2$ including ground plane. A good impedance match (return loss ≤ -10 dB) for all the bands is achieved. The Ansoft HFSS 12 is used to model and simulate the proposed antenna.

Index Terms – Circular microstrip patch antenna, Frequency reconfigurable antenna, Return loss, HFSS 14.

I. INTRODUCTION

Wireless communication has been developed rapidly in the past decade and it has already has a dramatic impact in our lives. In the past few years, the development of WLAN, LTE and WIMAX represents one of the principle interests in the information and communication field. Thus, specific antenna systems are recently developed to comply with requirements dictated by such applications. The performances and advantages such as low profile, low weight and low cost and capability to integrate with microwave circuits made microstrip patch antenna the perfect choice for these wireless applications.

Reconfigurable antennas have recently received significant attention for their application in communication, electronic surveillance and counter measures adapting the properties to achieve selectivity in frequency, polarization and radiation patterns. Compared to broadband antenna, reconfigurable antennas offer the advantages of compact size and similar radiation for all designed frequency bands, efficient use of electromagnetic spectrum and frequency selectivity useful for reducing the adverse effects of co-site interference and jamming.

A lot of researches focus on frequency reconfiguration as future communication system such as cognitive radio needs an antenna that can do spectrum sensing and communication. Frequency reconfigurability can be

achieved by modifying physically or electrically the antenna dimensions using RF-switches, impedance loading or tuneable materials. Slot antennas can be used as building blocks in designing the frequency reconfigurable antenna. Frequency selectivity can be easily achieved by proper placement of switches on the slot so that the current distribution and electric length of the current path around the slot is manipulated.

In Ref [4] a circular disc-shaped reconfigurable antenna capable of both frequency and pattern reconfigurabilities is proposed. Using one set of switches to adjust the depth of the slot, the antenna can operate at two different resonant frequencies. Using the other set of switches to change the connection between the central patch and five surrounding parasitic patches, the pattern reconfigurable characteristic can be achieved.

In Ref [5] a reconfigurable split ring antenna using an integrated ON /OFF switch to control two different operation modes, namely a single-band mode to cover the 2.4 GHz WLAN system, a dual-band mode at 2.4/ 5.2 GHz WLAN is proposed. It exhibits omnidirectional H -plane patterns with relatively stable gain at each respective band.

In Ref [6] a frequency reconfigurable hexagonal patch antenna with switchable slot is proposed. By changing the slot status, two resonant frequency bands at 2.29GHz and 2.46GHz respectively can be obtained without special matching network, and the radiation patterns at the two frequency bands are very similar to each other.

In Ref [7] a circular patch antenna incorporated with two perturbation slits with polarization reconfigurability is proposed. Pair of copper strips, which act as the switches, are located at the particular length of the slits. Therefore, by further controlling the state of the switch, either in short or open, the antenna can be excited with LP, RHCP or LHCP polarization mode.

In Ref [8] a circular patch antenna with frequency reconfigurability feature is proposed. A slot is introduced underneath the circular patch and three switches are positioned in the slot. Six reconfigurable frequency bands are produced from the six different switch configurations.

In Ref [9] a frequency reconfigurable antennas with conical beam radiation is proposed. The design is based on

the TM_{02} mode of a coplanar annular-ring microstrip antenna, and several shorting strips are symmetrically placed along the circumference of the radiating patch to vary its resonant frequency. The resonant frequency of the microstrip antenna has an increase of 33% when the number of the shorting strips is varied from 0 to 16.

In this paper presents a circular microstrip frequency reconfigurable antenna. This antenna employs PIN diodes to switch its resonating frequency for different standards like WIMAX (3.5 GHz), WLAN (5.15-5.785 GHz) and LTE (4.5-5.1 GHz) bands with return loss below -10dB and VSWR below 3. The software used to model and simulate the proposed antenna was Ansoft HFSS 12.

II. RECONFIGURABLE ANTENNA DESIGN

The proposed reconfigurable antenna is designed using the FR4 substrate with the dielectric constant of 4.4 and the substrate thickness of 1.6mm on a ground dimension of 33x20mm².

Antenna is fed by microstrip transmission line feed technique with transmission line width of 1mm and length 17mm.

The radius of the circular patch antenna is calculated by using the following formula:

$$r = \frac{a}{[1 + \frac{2h}{\pi \epsilon_r a} \{\ln(\frac{\pi a}{2h}) + 1.7726\}]^{\frac{1}{2}}} \tag{1}$$

where,

$$a = \frac{8.971 \times 10^9}{f_r \times \sqrt{\epsilon_r}} \tag{2}$$

where,

- r=effective radius of the patch
- f_r=resonating frequency
- a=radius of the circular patch
- h=height of the substrate
- ε_r=dielectric constant of the substrate.

TABLE I
DESIGN SPECIFICATIONS OF ANTENNA

Parameter	Measurements
Radius of circular patch	7.15 mm
Substrate	FR4-epoxy
Input impedance	50 ohm
Dielectric constant of FR4	4.4
Height of substrate	1.6mm
Conducting material	Copper
Feeding Technique	Transmission Line method
Feed Length (Lf)	17mm
Feed Width (Wf)	1mm
Ground Length (Lg)	33 mm
Ground width (Wg)	20 mm
L	28mm
W	16 mm
W1	1mm

The resonant frequency of an antenna is heavily determined by the length of the current path. Therefore, it is possible to adjust the length of the current path to change the resonant frequency of the antenna. The modification of the depth of the side slot in the U-shaped loop has a great influence on the current path. If the switches are inserted in the side slot, the resonant frequency of the antenna could be changed by controlling the states of the switches.

Design specifications of U slot is given in table II.

TABLE II
DESIGN SPECIFICATIONS OF ANTENNA

Parameter	Measurements
L1	1mm
W1	6mm
L2	7mm
W2	1mm

The geometry of the proposed antenna is shown in figure 1.

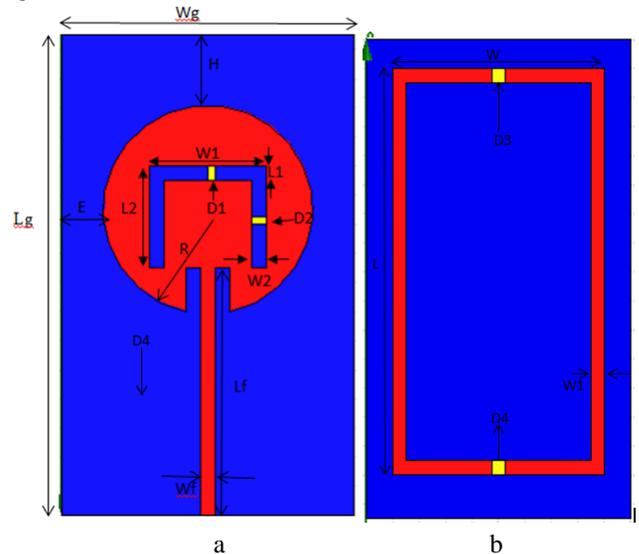


Fig. 1 The geometry of the proposed antenna (a) Top View (b) Bottom View.

The equivalent circuit of pin diode is shown in figure 2.

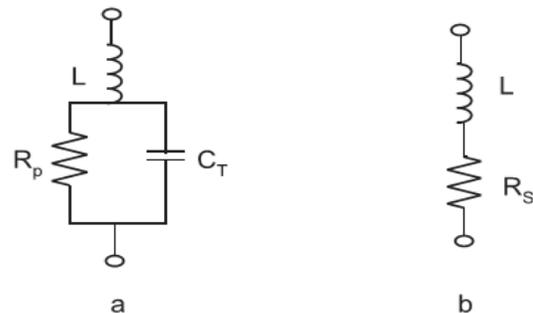


Fig. 2 PIN diode equivalent circuits: (a) OFF state, (b) ON state.

By properly biasing the PIN diode, ON and OFF state of the PIN diode is realised. For ON state, PIN diode is forward biased which provide low impedance and acts as a short. For OFF state, PIN diode is reverse biased which provide high impedance and acts as open circuit. The equivalent circuit of pin corresponds to an inductance L in series with a resistance R_s for the ON state and an inductance L in series with the parallel connection of a capacitor C_t and a resistance R_p for the OFF state. According to the manufacturer, the diode parameters are $L=0.6$ nH, $R_s = 1.2\Omega$, $R_p = 15$ k Ω and $C_t = 0.3$ pF. The equivalent circuit of pin diode is shown in figure 2.

The software used to model and simulate the proposed antenna was Ansoft HFSS 12, which is an industry-standard simulation tool for 3D full-wave electromagnetic field simulation.

III. SIMULATED ANTENNA PERFORMANCE

The performance of the proposed antenna is characterised by its electrical properties such as bandwidth, radiation pattern and return loss.

Return loss is way of expressing the mismatch in transmission line. It is the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line. The return loss of the proposed antenna is below -10dB. Bandwidth of an antenna is the range of frequency over which the antenna can operate correctly.

When PIN diode D3 is ON U slot is not varied. It operates in the 3.5 GHz band with the return loss of -23.85 dB, VSWR of 1.2 and bandwidth of 168MHz. Fig.3, Fig.4.and Fig.5.shows simulated results for Return loss, VSWR and Radiation pattern when all the diodes are OFF of the proposed antenna at $\theta = 0$ deg.

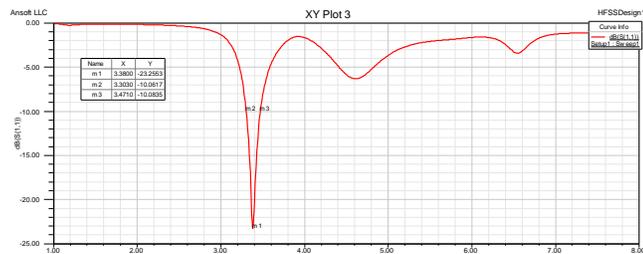


Fig.3 Return loss when diode D3 is ON.

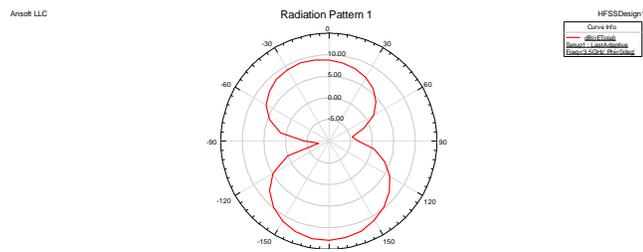


Fig.4 Radiation pattern when diode D3 is ON.

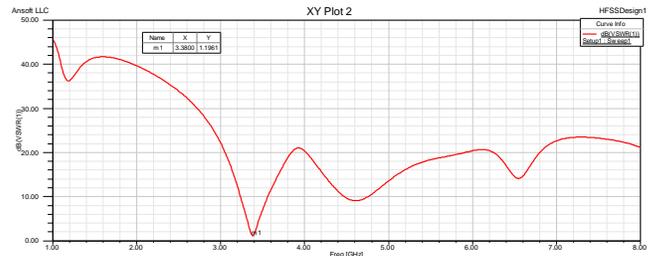


Fig.5 VSWR when diode D3 is ON.

When all PIN diodes are ON U slot is varied. It operates in the 5.6 GHz band with the return loss of -34.82 dB, VSWR of 1.82 dB and bandwidth of 242MHz. Fig.6, Fig.7 and Fig.8.shows simulated results for Return loss and Radiation pattern when all diodes are ON of the proposed antenna at $\theta = 0$ deg.

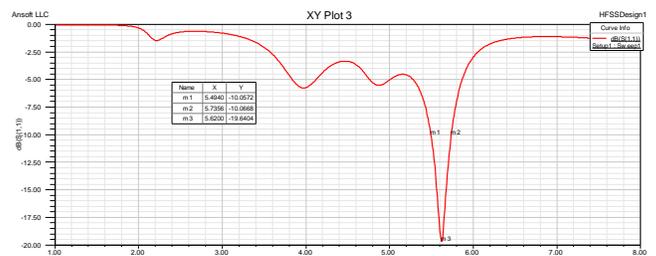


Fig.6 Return loss when all diodes are ON.

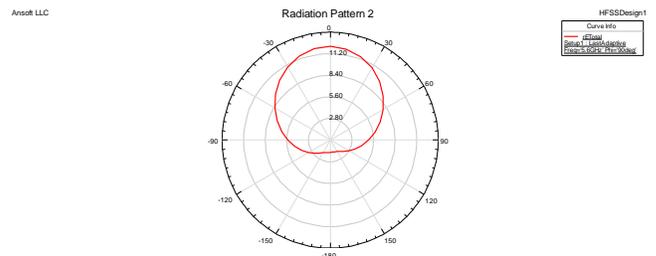


Fig.7 Radiation pattern when all diodes are ON.

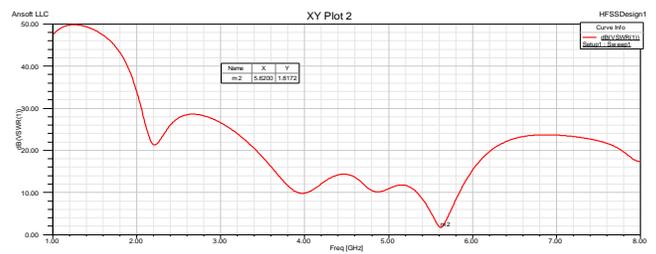


Fig.8 VSWR when all diodes are ON.

When PIN diodes D2, D3 and D4 are ON U slot is varied. It operates in the 4.6 GHz band with the return loss of -21.75 dB, VSWR of 0.3 dB and bandwidth of 635MHz. Fig.9.and Fig.11.shows simulated results for Return loss, VSWR and Radiation pattern when D2, D3 and D4 are ON of the proposed antenna at $\theta = 0$ deg.

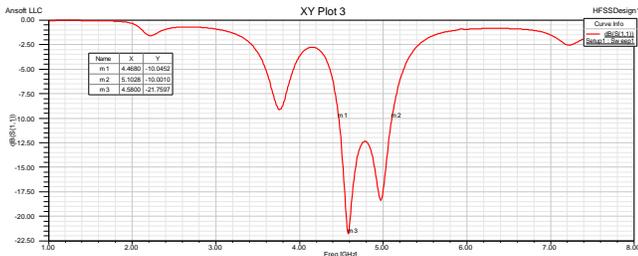


Fig.9 Return loss when diodes D2, D3 and D4 are ON.

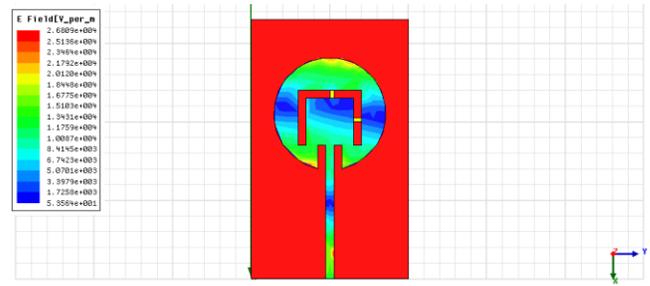


Fig.14 Electric field distribution when all diodes are ON.

Antenna performance is shown in table III.

TABLE III
PERFORMANCE OF ANTENNA

Switch condition	Frequency (GHz)	Return loss (dB)	VSWR	Bandwidth (MHz)
D3 ON	3.5	-23.86	1.196	168
D2, D3, D4 ON	4.6	-22.33	1.42	635
All diode ON	5.6	-34.85	1.82	242

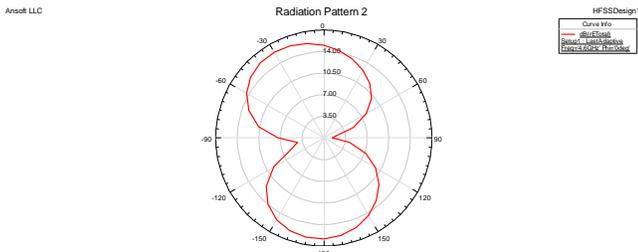


Fig.10 Radiation pattern when diodes D2, D3 and D4 are ON.

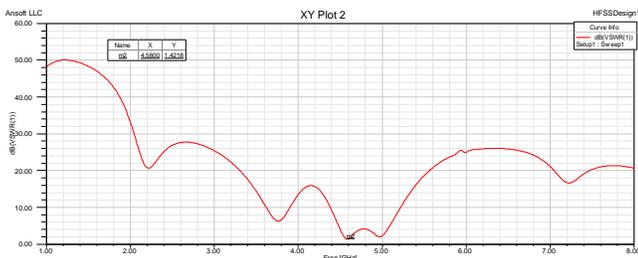


Fig.11 VSWR when diodes D2, D3 and D4 are ON.

Electric field distribution for each PIN diode condition is shown in Fig 12 to Fig 14. It can be concluded that as the PIN diode is ON field distribute over U slot arm is varied, hence electrical length of the patch decreases hence the resonating frequency increases.

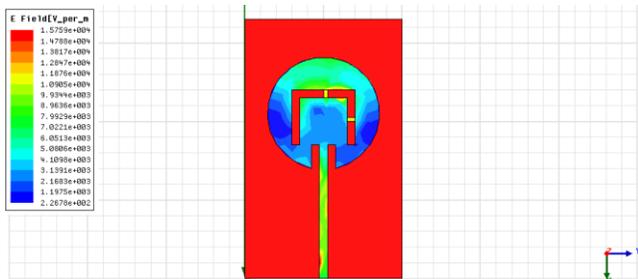


Fig.12 Electric field distribution when diode D3 is ON.

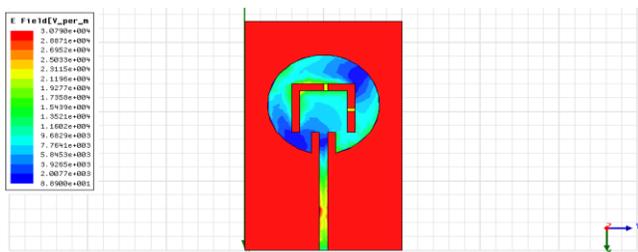


Fig.13 Electric field distribution when diodes D2 and D3 are ON

IV. CONCLUSIONS

The proposed antenna achieves its goals of obtaining frequency selectivity by electronically varying the effective length of U slot arm of the microstrip antenna by using PIN diodes, thereby resonating at different frequency. The resonant frequency is tuned by changing the effective length of the U Slot arm controlled by PIN-diodes switches. The proposed antenna can work on different wireless standards like WIMAX (3.5 GHz), WLAN (5.15-5.785 GHz) and LTE (4.5-5.1 GHz) bands. The proposed antenna is a simple structure with good radiation characteristics like return loss and bandwidth.

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