Quad-band Frequency Reconfigurable Microstrip Patch Antenna Using Modified Ground Plane for the WI-FI, Wi-Max, RF-Altimeters, and WLAN Applications

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Abstract— In this paper a novel design of frequency reconfigurable microstrip patch antenna is presented. The antenna consists of a square patch with modified ground structure having four PIN diodes and a DC blocking capacitor. This modified ground structure reduces overall size of antenna. By miniaturization of antenna it is able to operate at lower frequency. The antenna provides stable radiation at 2.61 -2.68 GHz (BW=2.7%) (Wi-Fi), 3.37-3.63 GHz (BW=7.71%) (Wi-MAX) and 4.14-4.65 GHz (BW=12.31%) (RF-altimeters), 5.24-5.64GHz (BW=7.63%) (WLAN). In the proposed method feeding is done by microstrip feed line of 50-ohm impedance. Overall dimension of proposed antenna is 20 X 20 mm^2 .The results are simulated using CST Microwave studio V. 2017. In proposed paper we computed different parameters like S_{11}, VSWR, Surface current and Gain Plot which are significant for different wireless applications.

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Index Terms—Microstrip antenna, reconfigurable, PIN diode, DC blocking capacitor; WiFI, WiMax, WLAN, RF-Altimeters.

1 INTRODUCTION

RECONFIGURABLE microstrip patch antennas has caught great attention in recent years and because of different kinds of gadgets in our everyday life and increases the use of reconfigurable antennas [1]. These antennas have several merits as compared to the conventional antennas. In such types of antenna, we can use single radiating element for different applications thus reducing the system complexity. The reconfigurable patch antenna has the capability to switch in between various standards, it also has the advantage of reducing the noise and increasing the gain of system. It also saves the energy of the system[2].

Reconfigurable antennas can be classified as:

- Electrical Reconfigurable antennas: In these antennas switching is done with the help of switches such as PIN diodes, varactor diodes, RF-MEMs, etc.
- Optical Reconfigurable antenna: In these the optically operated switches are used.
- Physicaly reconfigurable antenna: In these the physical dimension of the radiating element is altered.
- Material Reconfigurable antennas: Here the substrate material used, is altered.

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The patch can be fed by several techniques such as coaxial probe feeding, microstrip feeding, proximity coupling and aperture feeding technique.

The main advantage of the transmission line feeding is that the impedance of the line can be easily changed by varying the width of the line. Also it can be made as a part of the planar fabrication technique [3].

While using the same radiating element for varous applications having different operating bands, there must be sufficient isolation in between the adjacent band to avoid any interference. These features can be easily achieved by using the reconfigurable antennas.

Several research is carried out in case of multiband antennas. To obtain the multiband behavior for a particular antenna several techniques have been devised which includes the use of multiple radiation sections, cutting slots on the radiating element or the ground, etc.[4].

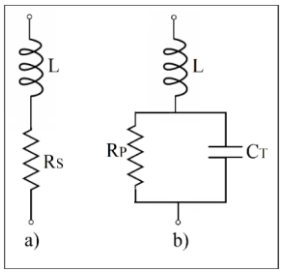


Figure 1-Equivalent circuit of PIN diode a) ON b) OFF state

TABLE 1
PARAMETERS OF THE PROPOSED ANTENNA

Parameter	Wsub	W	Wf	Wfs	Ws	Wc
Value(mm)	20	10	1.5	0.5	17	10
Parameter	Wc1	W1	W2	W3	Lsub	Lf
Value(mm)	1	14	1.5	8	20	3
Parameter	Ls	L1	L2	L3	L4	l1
Value(mm)	11	1.5	2.5	1.5	2	1
Parameter	l2	Lc1	Lc2	Lc3		
Value(mm)	1	1.5	3	1.5		

The unique property of this antenna is that the alteration is carried out in the ground plane instead of the radiating patch element. This is the main reason behind the single band operability at a time having different switching conditions.

The PIN diodes are used as a switching element in the round plane. The main advantage of using these types of diodes is that they behave as a pure resistance in the microwave frequency range. Usually these resistance ranges from 1Ω to 10kΩ. Also due to its low cost it is widely used in many applications [5][6]. The equivalent circuit of the diode is shown in the Figure1.

In order to avoid the increase in the dimension of the antenna for lower frequency application, the ground plane is modified without affectng the patch element. This technique is known as the Miniaturization Technique [7] [8]. The proposed antenna can be used in four different application i.e. WiFi, WiMax, RF altimeters and WLan.

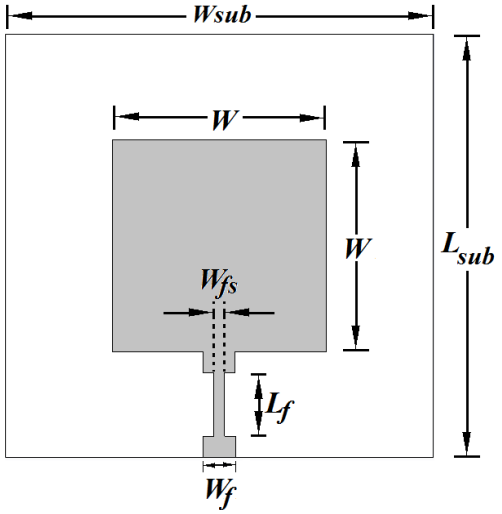
In this paper a new microstrip quad-band antenna is proposed. This uses four PIN diodes and one capacitor to make modified ground structure. The resonant frequencies of antenna can be controlled by switching of diodes.

This paper is organized as follows: section-II contains antenna design and different parameters; section-III contains simulated results i.e S11, VSWR, Gain and Surface Current Distribution; and the last section contains Conclusion.

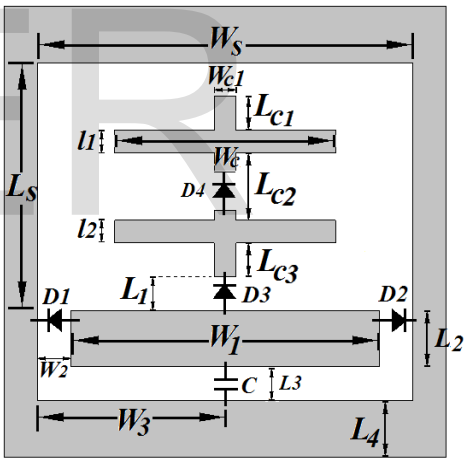
2. ANTENNA DESIGN

The Figure-2 shows the schematic diagram of the proposed antenna with a) top view showing the design of the patch and b) shows the bottom view of ground plane. The antenna is designed on an FR-4 substrate having thickness 0.8, dielectric constant of 4.4 and loss tangent of about 0.02. Figure 2(a), showing that it use a simple square shaped patch along with 50ohm impedance feed line and Figure 2(b) shows the modified ground structure. Later two cross shaped sleeve is introduced in the ground plane with four pin diodes and one capacitor at specified position which is used for frequency switching. Switching of diodes achieve by connecting and disconnecting a metallic strip. The dimensions of this metallic strips used for diodes switching in simulation are same i.e. width=1mm and length=1.5mm.

By applying parametric method over different parameters the appropriate value of different parameters is obtained. These optimized parameters are shown in Table.1.



(a) Front view



(b) back view

Figure 2- Arrangement of proposed reconfigurable antenna (a) Front view, (b) back view.

Table 2 show the four different frequency bands over which proposed antenna are resonates. These frequencies are achieved by different positioning of the diodes i.e.by putting diodes in ON and OFF states.

TABLE 2-
DIFFERENT RESONATING FREQUENCIES AT DIFFERENT SWITCHING CONDITIONS

D1	D2	D3	D4	Resonant Frequency(GHz)
Off	On	On	On	2.60GHz
On	On	Off	On	3.40GHz
On	On	On	On	4.36GHz
On	On	On	Off	5.40GHz

3.SIMULATION RESULTS

The design and results of antenna have been simulated using Microwave CST Studio 2017 [8]. Here the antenna is designed for the operation in the four bands namely 2.6GHz (2.61-2.68 GHz) Bluetooth, 3.4GHz (3.37-3.63 GHz) WiMAX, 4.36GHz (4.14-4.65 GHz) RF Altimeters and 5.5GHz (5.245.64GHz) WLAN.The S11 plot of which is shown in the Figure 3.

The proposed antenna has four different switchable frequency responses that are suitably separated from each other. Inserting four p-i-n diodes to the proposed structure as depicted in Figure 1, creates a reconfigurable antenna that is able to cover Bluetooth (2.6 GHz), Wi-MAX(3.4 GHz), RF Altimeters (4.6GHz) and WLAN (5.4 GHz) systems. The simulated frequency response of the proposed reconfigurable antenna for different bias conditions of the PIN diodes are plotted and shown in Figure 3.

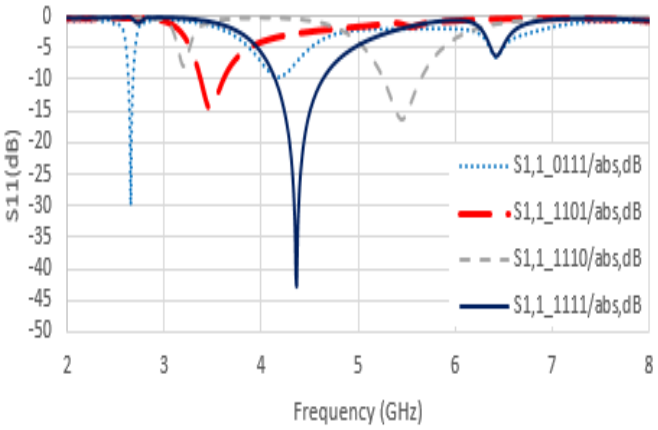


Figure 3- S11 plot of the design

Using CST Studio 2017, the simulated VSWR is shown in Figure 4. The values of VSWR for resonant frequencies should be less than 2. Hence the simulated results are in correlation with theoretical results. The working principle of antenna is better understood by studying the surface current distribution. The surface current distribution of the antenna is shown in the

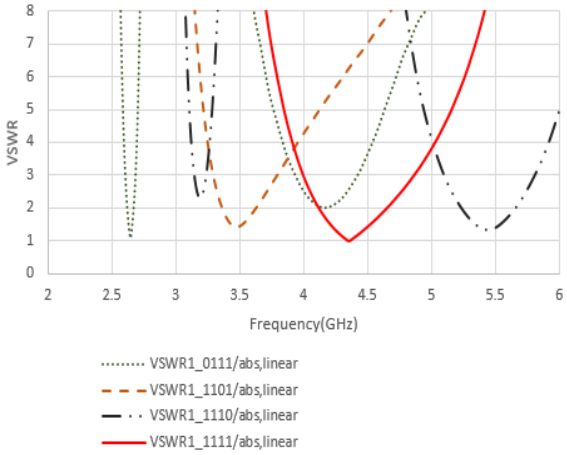


Figure 4- Plot of VSWR Vs Frequency

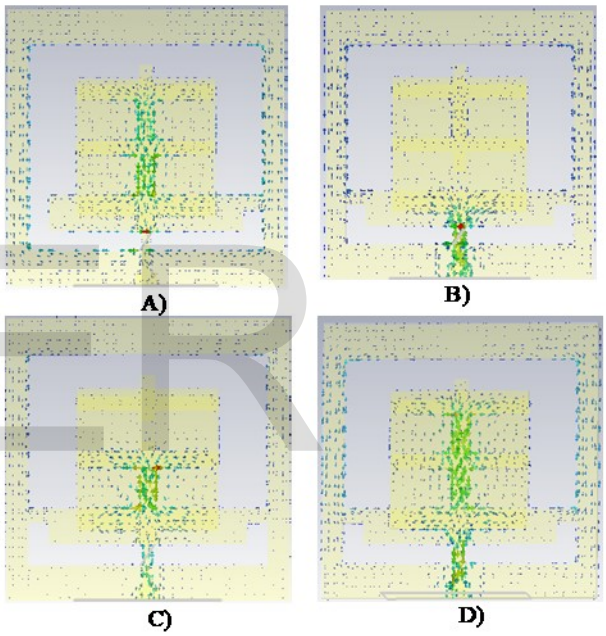


Figure 5-Surface Current Distributions are-
A) *0111 B) 1101 C) 1110 D) 1111*

Figure 5. The maximum current density is given for the frequencies of 2.6 GHz, 3.4 GHz, 4.36 GHz and 5.4 GHz. At these frequencies the return loss is minimum, hence the current density is more as compared to other frequencies. The ground plane the currents are distributed more around the slots instead of the whole ground area. This is the main cause of the multiband behavior of the antenna.

The measured maximum gain for various switchable performances of the fabricated antenna is presented in Figure 6. For all resonant frequencies the gain has positive value. As it can be observed from the figure, the proposed antenna has suitable gain characteristics in its different switchable frequency bands of operation.

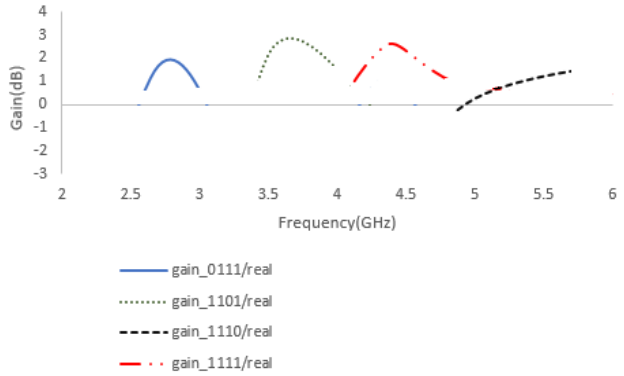


Figure 6. Gain Plot of reconfigurable antenna.

TABLE 3
COMPARISON BETWEEN PROPOSED WORK AND LITERATURE

Ref.	No. of Switchable frequency band	Diodes used	Dimensions (mm^3)
[4]	3	4	30x30x1.6
[8]	3	4	40x40x1.6
Proposed Design	4	4	20x20x0.8

The comparison of the proposed design and the published literature are shown in Table 3. This table concluded that proposed design having the least physical dimension and also operated for four different frequency band.

4. CONCLUSION

The Microstrip Patch Antenna has been successfully designed and implemented using CST microwave studio v.2017 [8]. The antenna works satisfactorily for all the four applications i.e. Wi-Fi, Wi-Max, RF Altimeters and WLAN at frequencies equal to f1=2.6GHz (2.61-2.68 GHz), f2=3.4 GHz (3.37-3.63 GHz), f3=4.36 GHz (4.14-4.65 GHz) and f4=5.5 GHz (5.245.64GHz).The main advantage of the proposed work is smaller size while covering four different frequencies with significant isolation between these frequencies. The antenna is successfully made reconfigurable by using four pin diodes and one DC blocking capacitor in the ground plane.

5. References

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