DESIGN OF A RECONFIGURABLE MICROSTRIP ANTENNA FOR FUTURE MOBILE APPLICATIONS

Preeti Vyas, Ashok Kumar Kajla, Rahul Raj Choudhary

Abstract
The 802.11 working group currently documents use in five distinct frequency ranges: 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz bands. Each range is divided into a multitude of channels. This paper introduce the antenna that work on spectrum bands above 6 GHz that might be suitable for future mobile communication services, often referred to as 5G (the 5th generation of mobile services). The antenna is composed of a circular patch with circular ground plane is used. One half circle is inserted in ground & than intersection is subtracted from full ground plane. After the circular ground, two identical slots are used on the ground to make the proposed design suitable for high frequency applications which is shown in figure. Two pin diodes are mounted across the slot in the ground for development of reconfigurability. when both diodes PD1 and PD2 are OFF then it radiate on only one frequency that is 6GHz and return loss is -30db. When PD1 is ON and PD2 is OFF it radiates on two frequencies. First is 2.1 GHz and second frequency is 8.9GHz and return loss are -27 and -52 dB respectively. When PD1 is OFF and PD2 is ON it almost radiates on same frequencies with low return loss. The substrate used for this antenna is FR-4 having the relative permittivity of 4.4, loss tangent of 0.02. The simulation and measurement results confirm a good performance of the antenna.

Keywords— Reconfigurable antennas;PIN diode; broadband impedance matching; 5G mobile services;

I INTRODUCTION

The exact nature of 5G is not yet defined, but to lay the foundations for its future introduction we need to understand how it might use spectrum. 5G is likely to provide much faster mobile broadband speeds than the current generation of mobile technology (4G), and the use of large blocks of spectrum is likely to be important to achieve the fastest speeds. Engineers has already identified possible bands below 6 GHz for future mobile services, including 5G, as part our Mobile Data Strategy, but large blocks of spectrum are difficult to find at lower frequencies. Therefore higher frequency bands, e.g. above 6 GHz, are also likely to be important. However, those bands are already used by a wide range of services that benefit citizens and consumers.

Now we have come to the main topic that for utilization of 5G technology we require antenna that work on frequency above 5.9 GHz. In this article we design an antenna that work above 5.9 GHz frequency with addition of reconfigurability.

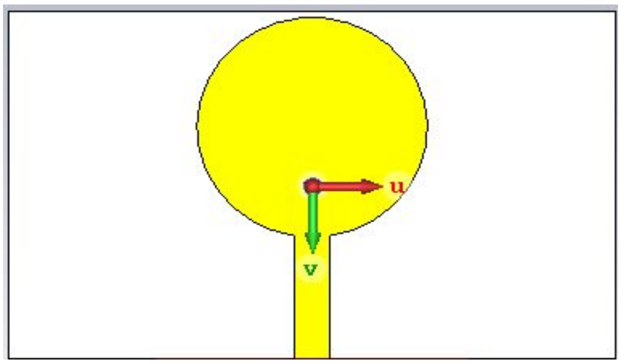
In this article, a wide band antenna with multiple no of frequencies is presented. The proposed design operates at frequency 6 & 7.5 GHz with a sharp output. The overall dimension of this antenna is (50 × 30 × 1.6) mm^3. This antenna is compact and is based on two diodes and two patches. The 50mm × 30mm wide band PCB antenna discussed below features a parabolic-shaped ground plane to generate directional patterns. On the other hand, an L-shaped ground plane was adopted in design a directional planar antenna. All the parameters of this proposed designed are simulated and optimized by a software tool CST Microwave Studio 2011.

II DEVELOPMENT OF DESIGN

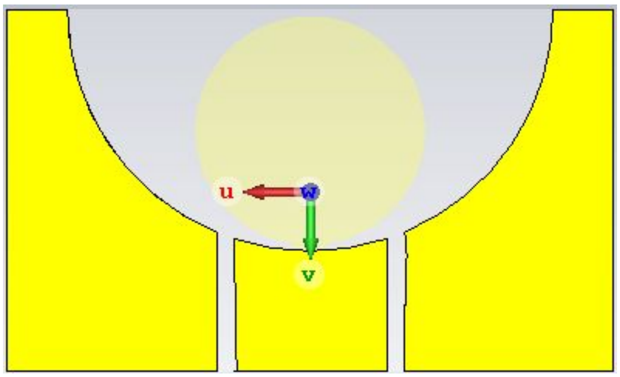
The designing of the proposed structure is divided into two steps. In the first step the circular micro strip patch antenna with circular ground plane is used. One half circle is inserted in ground & than intersection is subtracted from full ground plane. After the circular ground, two identical slots are used on the ground to make the proposed design suitable for high frequency applications which is shown in figure. In second step two pin diodes are mounted across the slot for the desired band selection. Now let us discuss these steps one by one.

(A) Step I- Circular Patch with Partial Ground Plane

In the beginning a simple microstrip patch antenna was designed and optimized with circular ground plane. The substrate used in this design is FR-4 with dielectric constant of 4.3 and loss tangent of 0.02. The length of ground plane 'Lg' is taken as 30 mm. On substrate at the bottom face a thin layer of copper is present. A half circle of radius 20mm is inserted at that face & then insertion is subtracted from full ground plane. The microstrip feed is used in this design. The width of the microstrip line used is 3 mm. Now two slots are cut at the ground with 1.4mm width. The structure is shown figure 1.



(a)



(b)

Fig. 1 Circular patch with circular ground plane (a) top view (b) bottom view.

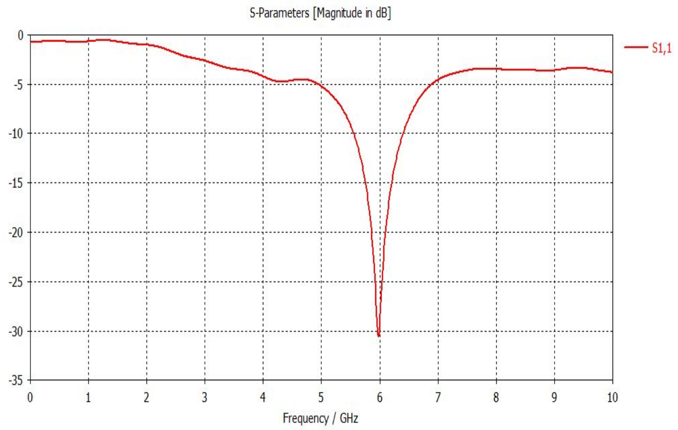


Fig. 2 Return loss curve for step-I of the proposed design

The Return loss curve for Step-I is shown figure 2. The above figure clearly shows that the return loss curve is lower than -10 dB for very small operable band in the 5.5–6.5 GHz range is obtained. Now it requires tuning so as to achieve a reconfigurable antenna. Hence PIN diodes are used in step-II for tuning of the design.

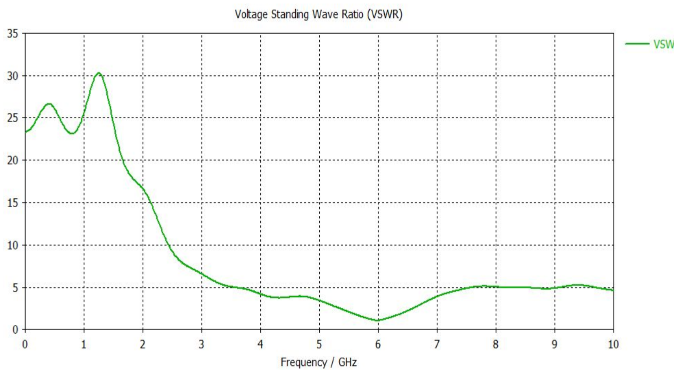


Fig. 3 VSWR curve for step-I of the proposed design

The Voltage Standing Wave Ratio (VSWR) Curve for the Step-I of the proposed antenna is shown in figure 3 given above. For this antenna its value is less than or equals to 2 in range of 5.5 to 6.5GHz.

(B) Step II- Mounting Two Identical PIN diodes on Radiating Patch

In this step two identical PIN diodes are mounted in the middle of slots on the ground along with the structure of step-I. PIN diodes provide fairly good matching of impedance between the radiating patch and the ground plane and hence the bandwidth change. The structure of the step-II is shown in figure 4. The figure top view and bottom view of the structure of step-II. Although there are various methods of switching of microstrip patch antenna but because of ease of fabrication of the structure PIN diodes were chosen. RLC parameters also use for switching but in this antenna RLC parameter is not chosen. In this structure the PIN diodes are not utilized on top corners of the rectangular slot because when the diodes are mounted on that place then return loss increase.

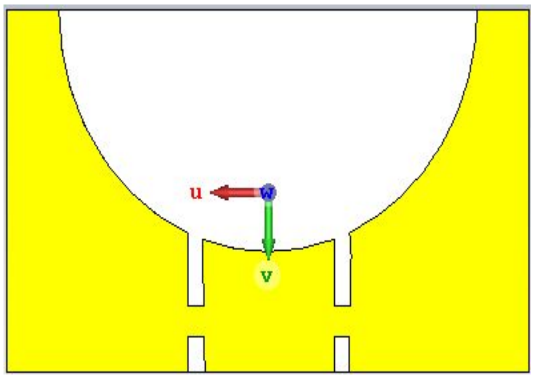


Fig. 4 Circular patch with circular ground plane & PIN diode bottom view

(C) Geometry of the Proposed Design with Optimized Parameters

The top view and bottom view of the proposed antenna is shown in figure 5 (a) and 5 (b) respectively. The overall dimension of proposed antenna is 50×30×1.67 mm^3. The proposed structure is easy to fabricate and less complexity which is the key feature of this design. The design was simulated by using FR-4 (ε_r = 4.3, tanδ = 0.02) with 1.6 mm thickness which is low cost material and easily available. In this design the thickness of the radiating patch and the ground plane is not omitted such that the simulated design becomes similar to the fabricated antenna. This design can also be used for lower S-band applications along with future mobile communication. The optimise values of the designing parameters is given in table 1.

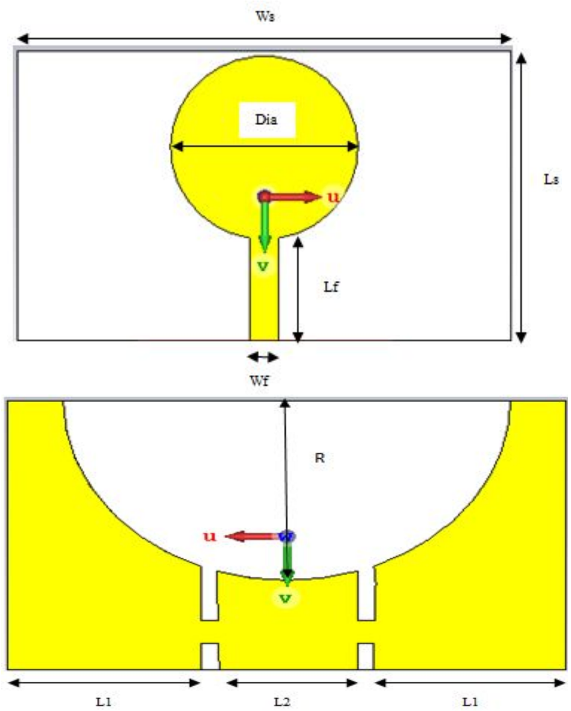


Fig. 5 (a) Geometry of the proposed structure (top view) (b) Geometry of the proposed structure (bottom view)

TABLE 1

OPTIMIZED DIMENSIONS OF THE PROPOSED STRUCTURE

Parameters	**Dimensions (mm)**
W_S	50
L_S	30
Dia	18
L_f	11
W_f	2.75
L_1	17.3
L_2	12.35
R	20
H	1.60
Mt	0.035

III WORKING OF ANTENNA & RESULTS

Two PIN diodes PD1 and PD2, are mounted across the slots, as indicated in Fig. 5. These switching devices are used in this design are very efficient. Table I shows the three switching conditions considered to achieve the desired frequency/pattern reconfigurability.

TABLE 2

OPERATING FREQUENCY, AND RETURN LOSS OF THE ANTENNA FOR EACH SWITCHING CONDITION

Case	I	II	III
PD1/PD2	OFF/OFF	ON/OFF	OFF/ON
Frequency	6GHz	2.1/8.9	2.1/8.9
Return loss(dB)	-30	-27/-52	-27/-35

As we can see in above table 1 when both diodes PD1 and PD2 are OFF then it radiate on only one frequency that is 6GHz and return loss is -30db as in figure 2.

In second case when PD1 is ON and PD2 is OFF it radiates on two frequencies. First is 2.1 GHz and second frequency is 8.9GHz and return loss are -27 and -52 dB respectively As shown in figure 6.

In third case when PD1 is OFF and PD2 is ON it almost radiates on two frequencies. First is 2.1 GHz and second frequency is 8.9GHz and return loss are -27 and -35 dB respectively As shown in figure 8.

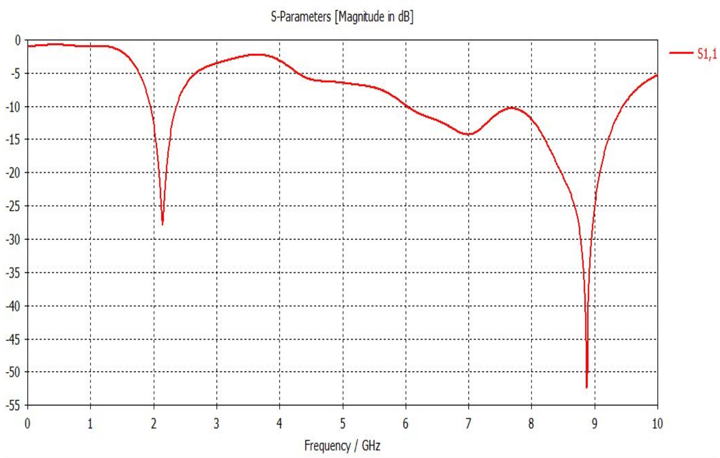


Fig. 6 Return Loss Curve When PD1 ON and PD2 OFF

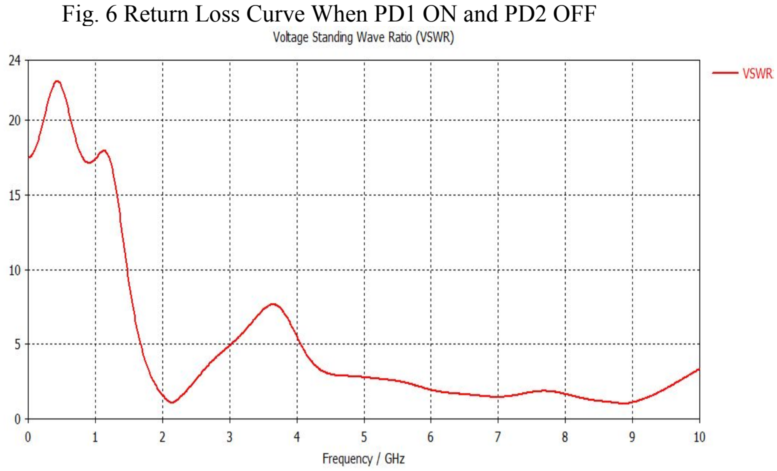


Fig. 7 VSWR Curve When PD1 ON and PD2 OFF

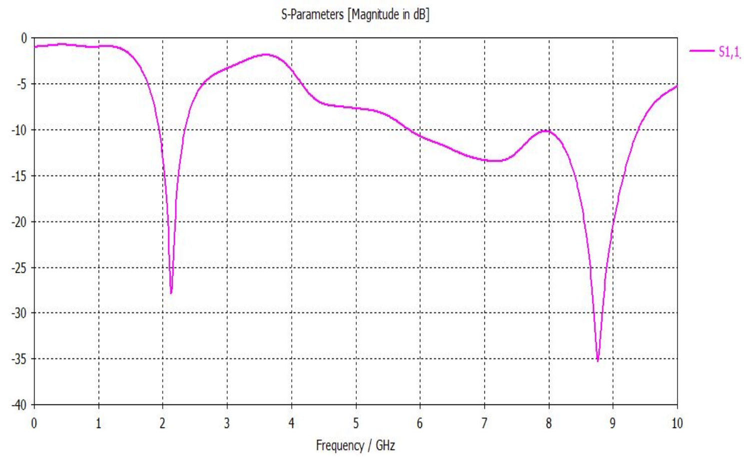


Fig. 8 Return Loss Curve When PD1 OFF and PD2 ON

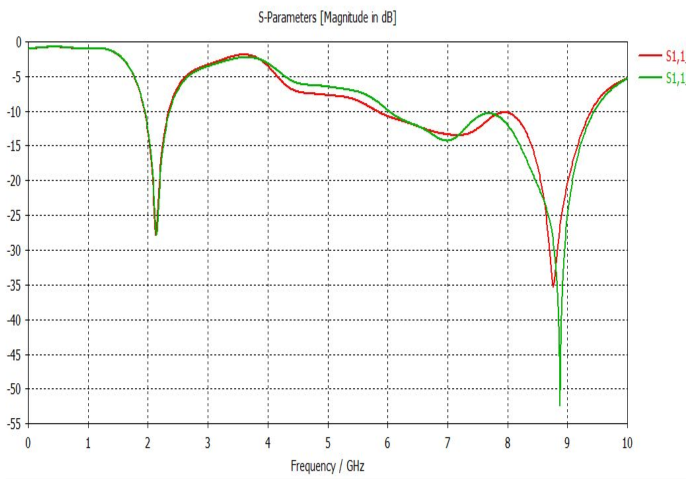


Fig. 9 Combine Return Loss Curve of Antenna of Case 2 and Case 3

IV RADIATION PATTERN & SMITH CHART

The radiation pattern depicting far field Gain at two different frequencies viz. 5 GHz, and 10 GHz are shown in figure 10 and figure 11. The radiation pattern is a measure of field strength transmitted or received by an antenna. The antenna shows slightly bidirectional radiation pattern at the frequency of 5GHz and Omni directional radiation pattern at the frequency 10 GHz.

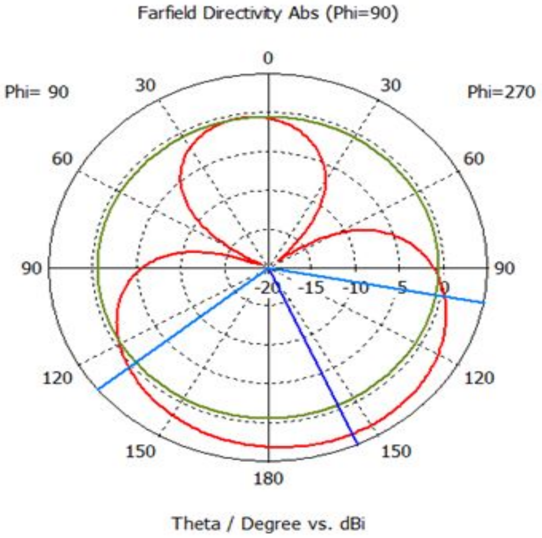


Fig. 10 Radiation pattern at 5 GHz

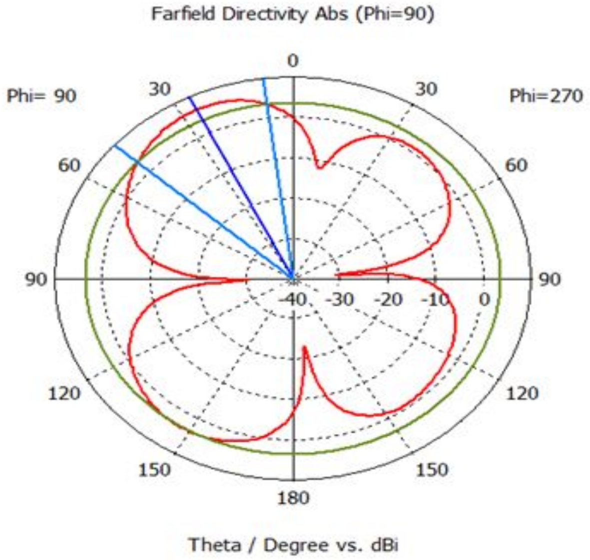


Fig. 11 Radiation pattern at 10 GHz

A Smith chart was developed by Phillip H. Smith in 1940's. The Smith chart is a method that graphs the reflection coefficient and impedance and is also used to examine the relationship between them. Since smith chart is defined only for the input and output reflection coefficient parameters (S_{11}, S_{22}), it represents that how the antenna impedance varies with frequency. It shows the complex reflection coefficient in polar form for arbitrary impedance. The center of the smith chart circle corresponds to reflection coefficient (Γ) which when equals to zero means a perfect impedance match. Thus the plot of Γ should be as close as possible to center of the smith chart. Figure 12 shows that the circle is close to VSWR =2 circle in the smith chart.

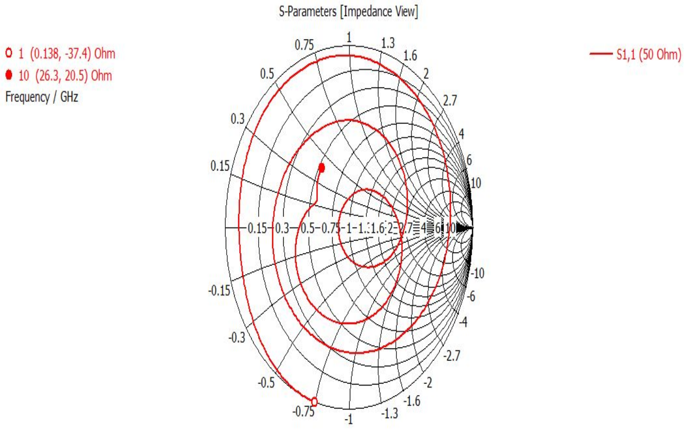


Fig. 12 Smith chart of the proposed antenna

V CONCLUSION

This antenna presented in this paper uses two PIN diodes for both frequency and pattern reconfigurability. The two diodes are mounted over two slots in the ground plane. In a first switching scenario, the antenna is operable over the 6 GHz band, whereas a dual-band operation, at 2.1 GHz and 8.9 GHz, is obtained in the other two scenarios. An omnidirectional radiation pattern with equal gain in the H-plane is obtained in all cases in the 6 GHz band. When operable at 2.1 GHz, the antenna has equal-gain E-plane patterns and 180◦-switchable H-plane patterns. Good gain and radiation efficiency values are obtained over the operable frequency bands.

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