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A compact high-gain parasitic patch antenna with electronic beam-switching

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ABSTRACT

A high beam steering antenna using HPND PIN Diode is proposed with a capability of steering its beam into three different directions -40 º, 0º and 40 º with respective switching condition. The reconfigurable parasitic antenna consists of a driven element and two reconfigurable parasitic elements, is designed with operating range of 9.5GHz. The parasitic elements act as reflectors or director depending on the switching conditions. Both parasitic elements are connected to ground plane via shorting pins. The reconfiguration is controlled by the two HPND PIN Diode switch that embeds to the parasitic element. An average gain value of 8dBi is achieved at all reconfiguration scenarios. All the simulated design has been carried out using CST software.

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1. INTRODUCTION

Reconfigurable antenna is flexibility to environments conditions, policies, network capabilities and other parameters [1]. A reconfigurable antenna is an antenna that produces an internal mechanism to redistribute the RF-currents over its surface and thus alter the electromagnetic fields over the antenna impedance or radiation properties [1]. The reconfigurable antenna can be integrates in various categories such as frequency, radiation pattern and polarization. This is a very important approach for the antenna which can integrate multiple applications [1-6]. Moreover, reconfigurable antenna is potential to improve the reconfiguration and capable to be adjusted independently [1-5]. This research proposed on the beam steering antenna with high beam. The radiation pattern reconfigurable can be achieved by using PIN Diodes as switching techniques. The function of the switch is to control the RF current flow to the desired path. By performing as ON-state or OFF state condition [3].

This paper presents a compact reconfigurable antenna that capable to steer the beam 40º and the ability to maintain a good reflection coefficient. A compact and low complexity antenna has been proposed in this work as compared to the previous designed [1-6] [8]. Only two switches are needed to steer three different directions with maximum beam tilt angle of 40º.Apart from that, high gain is obtained at each steered direction while operating at 9.5 GHz. In previous work [1], [6], most of the beam steering antenna faced the problem to achieve tilt angle more than 30º where the steering beam is in the range of -30º to +30º. Only a few works have able to achieve the beam steering capabilities is more than ±30º [2], [5].

However, the mentioned work has high complexity in terms of design techniques and the amount of switches. To the author's best knowledge, none of beam steering antenna has achieved low complexity and has a constant reflection coefficient. Therefore, this research proposed a compact reconfigurable antenna to achieve both motivations.

2. DESIGN STRUCTURE

Figure 1 shows the structure of the proposed antenna design. The antenna consists of a circular patch driven element located at the centre and parasitic elements on the right and left of driven element with slightly smaller radius. The proposed antenna has dimension of 25 mm x 50 mm and designed using Taconic dielectric substrate with a thickness of 1.6mm and dielectric constant of 2.2. The driven element is fed with an SMA probe from the back of the antenna with an appropriate 50 Ω matching point. The feed location is based on the significant impedance matching and better antenna efficiency. The driven patch radius is 5.5mm; meanwhile the entire parasitic elements radius is 5.4mm. This lead to the push and pull factor of the EM wave by changing an electrical wavelength that controlled by the switches. The gaps between the parasitic and driven elements are kept at 3 mm to ensure an optimized tilt angle.

Two Pin diode switches are located at the parasitic elements which are connected to the ground plane via shorting pins. The location of the PIN diode is crucial determining the tilt angle. Moreover, the switching location is to ensure the currents flow from the parasitic elements to the ground. Parasitic elements in the On state act as reflector, while in the Off state act as director that will push and pull the radiation pattern, respectively. In the simulation, the On state of the PIN diode is represented as serial RL circuit with 4.7 ohms series resistor and the OFF state is simulated as 0.017pF parallel capacitor as suggested in the manufacturer's datasheet [7]. Two inductors (L) with value of 39nH are integrated on each of the parasitic element. These to ensure smooth biasing direct to flow to the switches through the parasitic elements and acts as RF choke.

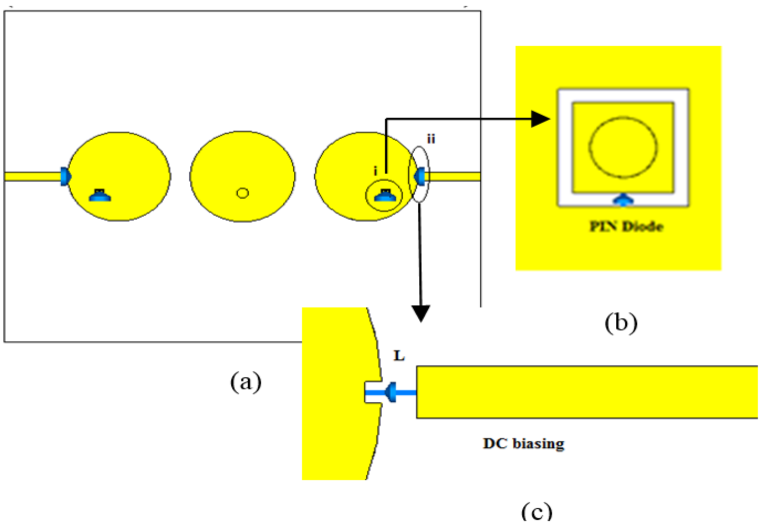

Figure 1. Geometry of the antenna, (a) Top view, (b) PIN Diode prototype, (c) DC biasing prototype

Below are the design formulas used to calculate the dimensions of the conventional circular patch:

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \quad (1)$$

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}} \quad (2)$$

The performance of PIN diode is based on the insertion and isolation loss of the switch. Each conditions of the PIN diode is changes the performance of reflection coefficient and transmission coefficient. The activation of switch in ON-condition leads to the maximum of the power transmission and transmission coefficient. Isolation loss defines OFF-conditions where the whole system is disconnected from power points. The insertion and isolation loss can be calculated using:

$$\mathrm{IL} = 20\log(1 + \frac{RS}{2Zo}) \quad (3)$$

$$\mathrm{ISO} = 10\log\left[1 + \left(\frac{1}{2wCsZo}\right)\right] \quad (4)$$

3. RESULTS AND DISCUSSION

The interaction between driven and parasitic elements is the key for good mutual coupling. In this work the mutual coupling effect is used to achieve better beam switching applications. Figure 2 shows the reflection coefficient result as respect to the beam pattern reconfiguration. It can be expected that the configuration result for beam steer 40º and - 40º is similar due to the symmetrical location of the switches. It can be noticed that the simulation results is able to achieve reflection coefficient below -10dB for the all three switch configurations. Moreover, these different stages share a common bandwidth from 600MHz to 700MHz. Based on the state of diode, the desired beam steering are obtained, as shown in Table 1.

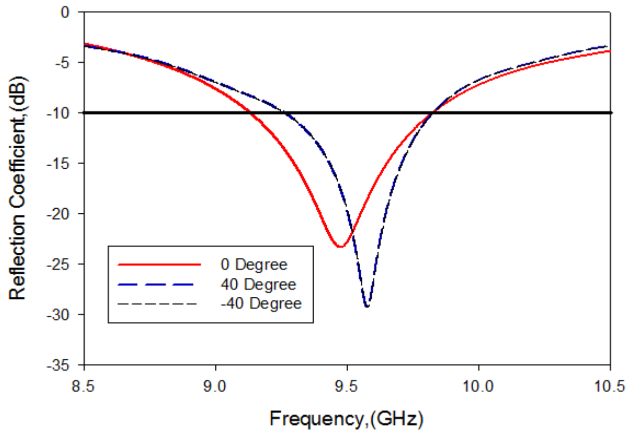

Figure 2. Reflection coefficient of the proposed antenna

Figure 3 shows the simulated pattern of reconfigurable parasitic antenna. The antenna is capable to steer at specific angle of -40º, 0º and 40º.When P1 and P2 are ON, the antenna steer to 0º with a gain of 7.2 dBi. By turning OFF P1 switch, the antenna steer to 40º with better gain of 8.1 dBi compare to 0º. While turning OFF P2 it steer to -40º with similar gain with 40º.The proposed antenna has improved the beam steering, reflection coefficient and gain from previous work [1], [6]. The shorting pin location is the key role to identify a significant steering angle. By shorting the parasitic elements to the ground, the parasitic, it performs as a reflector and director. The parasitic acts as a reflector will push the beam in an opposite direction where another un-shorted parasitic works as a director. These researches use a Yagi-Uda antenna concept as a reference which implements parasitic element to realize the reconfigurable radiation pattern. The Yagi-Uda antenna is consisting of a single driven element, five elements of director and a single reflector. The mutual coupling between the driven element and the parasitic elements leads to the beam forward. Figure 4 shows the simulated farfield result for the proposed antenna.

Table 1. Switching Configuration

Beam Switching Angle (ø)	RF Switches Condition		
	P1	P2	Frequency Centre, fc (GHz)
40 degree	OFF	ON	9.57
0 degree	ON	ON	9.47
-40 degree	ON	OFF	9.57

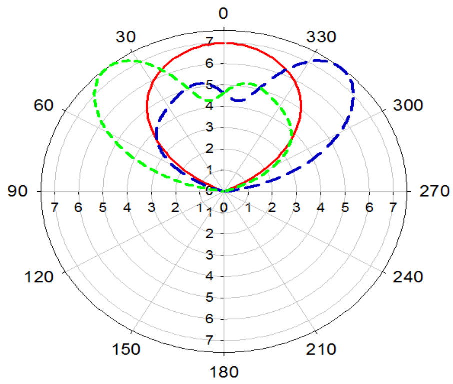

Figure 3. Radiation pattern for the proposed antenna

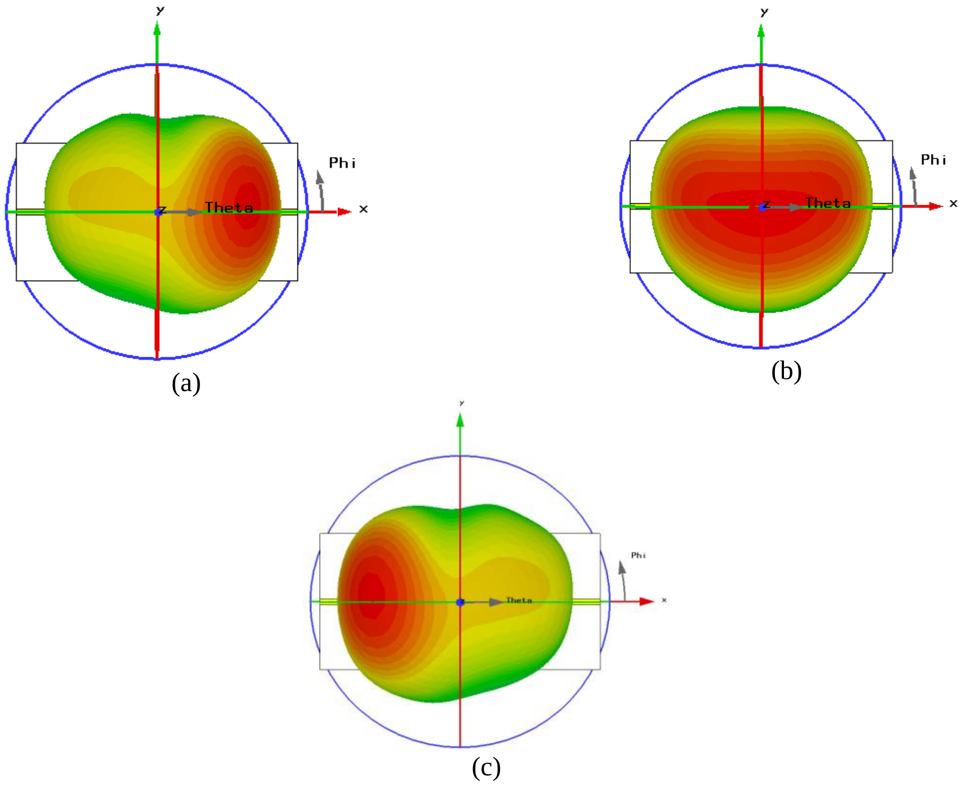

Figure 4. Simulated farfield result for the proposed antenna at (a) 40 degree (b) 0 degree and (c) – 40 degree

4. CONCLUSION

A compact reconfigurable antenna with high beam steering using HPND Pin Diode is proposed with an operating frequency of 9.5GHz. The proposed antenna able to steer the beam to three directions at -40º, 0º and +40º with an average peak gain of 8dBi. By optimizing the switching locations, the proposed antenna has successfully steer the beam at the best tilt angle while maintaining the reflection coefficient at the operating frequency of 9.5GHz.

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