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Frequency Reconfigurable Antenna for Vehicular Application

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Abstract: In this paper, a frequency reconfigurable microstrip patch antenna is designed with microstrip feeding technique. A stepped rectangular patch antenna having partial ground loaded with parasitic element is analysed in this article. The Proposed antenna is connected to a PIN diode on the flip side of the structure that is in between the parasitic element and the partial ground (DGS- Defective Ground Structure), the two cases ON, OFF are studied and analysed. In the ON case antenna works at (1.95GHz-2.27GHz,2.71GHz-3.2GHz,3.9GHz-4.1GHz,4.9-5.9GHz). In the OFF case antenna works at (1.3GHz-9.07GHz). The maximum gain of 3 dB is observed at 3.4GHz frequency in OFF case and the maximum gain of 4.4 dB is observed at 9 GHz frequency in ON case. In the ON case the efficiency of the antenna is 51.23% and in OFF case the efficiency of the antenna is 89.05%. In the ON case the maximum return loss is -43dB at 5.3GHz and in OFF case the return loss is -30dB at 8.2GHz. The proposed antenna Return loss, gain, E-Field, Current distribution and radiation patterns have been analysed using HFSS in this article.

Keywords: Stepped rectangular patch, PIN diode, Parasitic element, DGS.

I. INTRODUCTION

Antenna are essential component in any wireless communication system. Future intelligent transport systems where Vehicular communication plays an important role which covers important aspects such as traffic safety and traffic efficiency. A reconfigurable antenna is an antenna capable of modifying its frequency and radiation properties dynamically, in a controlled and reversible manner [1]. Reconfigurable Antenna has various advantages such as reduction of number of antennas used. Reconfigurable antenna changes the characteristics of the original antenna through mechanical, electrical or other means. For the implementation of the reconfigurable antennas, several antenna structures are used, among them microstrip patch antennas are very attractive structures for reconfigurability of many types.

Compact Linearly Polarized (LP) or dual band antenna is a need-of the-hour for vehicle-to-vehicle (V2V) and wireless local area network (WLAN) communications. The antenna should be mountable into a telemetric platform to provide with real-time information to the base station or to the driver to avoid traffic accidents. Vehicular networking includes V2V and vehicle-to-infrastructure communications, among other potential applications . For V2V applications low profile antennas have been reported in Refs. 2-4 with narrow operating bandwidths, though these antennas are easy to implement. Frequency reconfiguration is extensively used in multimode applications such as cognitive radio, software defined radio [2]. It has the ability to change the flow of current on an antenna using switches, attenuators etc. Vehicular communication covers a frequency range of 2.5GHz-5.9GHz . UWB covers a frequency range of 3.1GHz-10.3GHz. Reconfiguration can be attained by using switching mechanism or changing the geometry of an antenna. It can also be achieved by the changing the antenna loading externally. In [7], rectangular patch antenna with slots etched in the patch in order to reduce its size and increase the tuning range. Three PIN diodes were used for reconfiguration. It produces less efficiency and also has significant power consumption.

In this article a three-stepped rectangular patch antenna on a FR4 epoxy substrate is designed with a defective ground connected to a parasitic element which is on the either side of a substrate with a diode. The antenna is analysed in PIN diode on and off cases. The antenna is analysed using HFSS.

II. ANTENNA DESIGN

In high-performance aircraft and vehicular applications, where size, weight, cost, performance and ease of installation are constraints. So, there is a need for low profile antennas. Microstrip patch is generally preferred for designing reconfigurable antenna because of its low-profile characteristics. Among various shapes of microstrip patch, rectangle, circular, square and triangular patch are the most popular because of better radiation characteristics. Various steps are involved in the design of proposed work. The design steps are as follows:

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a) Design of rectangular patch
b) Design of stepped rectangular patch
c) Design of PIN diode
d) Design of DGS(defected ground structure) and parasitic element on the substrate.

The stepped rectangular patch is implemented on FR4 epoxy dielectric substrate (Ɛr= 4.4) with a length (Ls) of 65 mm, width (Ws) of 50 mm and thickness of 1.6 mm. Here the rectangular patch is designed with side length (Lp) of 34.7 mm and width(Wp) of 33.2mm and made step like structure below with a rectangular patch with width of 2mm and length of 29.2mm,23.2mm,and 10.8mm .This stepped rectangular patch is excited through a microstrip feed having a length (Lf) of 20 mm and a width (Wf) of 3 mm. The impedance matching is achieved between lumped port and antenna (load)In this design a Defected Ground Structure (DGS) implemented with length (Lg) and width (Wg) of 19.9mm and 50 mm, respectively. A microstrip fed of patch with DGS ground structure and RF-PIN diodes is shown in fig. 1.In this proposed microstrip patch antenna design one MPP4203 PIN diodes are placed between DGS based ground plane and parasitic feed structure to achieve frequency reconfigurability for X and S band .

A parasitic element is an element, which depends on other's feed. It does not have its own feed. which help in increasing the radiation indirectly. These parasitic elements are not directly connected to the feed. DGS is used to achieve high gain and wider bandwidth. The equation for finding the parameters of the patch which is used to design the rectangular patch is as follows:

1) Calculation of Width (W)

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r+1}}$$

2) Calculation of the effective length

$$L_{eff} = \frac{c}{2fr\sqrt{\varepsilon reff}}$$

3) Calculation of length extension

$$\Delta L = 0.412h\frac{(\varepsilon reff+0.3)(\frac{w}{h+}+0.264)}{(\varepsilon reff-0.258)(\frac{w}{h}+0.8)}$$

4) Actual length of the patch (L)

$$L = L_{eff} - 2\Delta L$$

Where the dielectric constant ε_r of the substrate is, f_r is the resonant frequency and h is the height of the substrate.

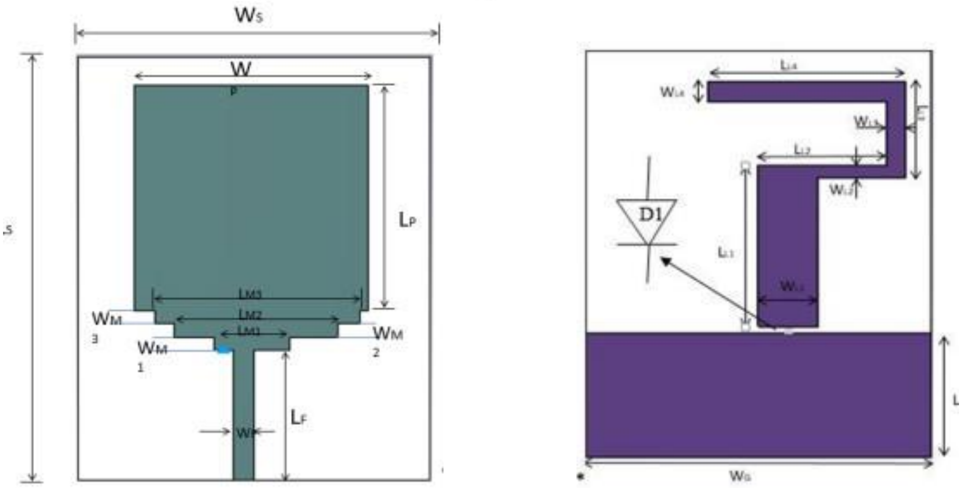

Fig 1 : SHOWS THE FRONT AND BACK VIEW OF THE ANTENNA

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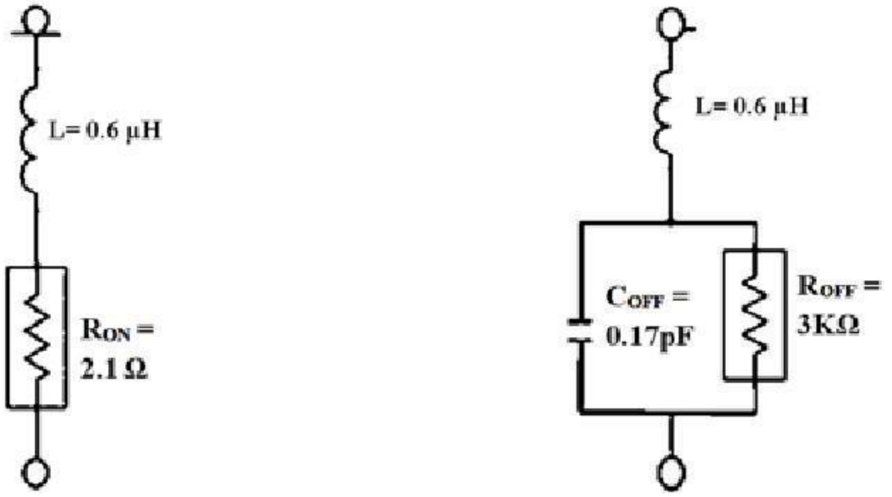
Table 1: Dimensions in mm of the antenna.

L_S	W_S	L_P	W_P	L_F	W_F	L_G	W_G	L_{M1}	W_{M1}	L_{M2}	W_{M2}
65	50	34.7	33.2	20	3	19.9	50	10.8	2	23.2	2
L_{M3}	W_{M3}	L_{L1}	W_{L1}	L_{L2}	W_{L2}	L_{L3}	W_{L3}	L_{L4}	W_{L4}	P_F	d
29.2	2	25.8	8.7	18.6	2	12.2	2.6	28.6	3.2	0.96	1



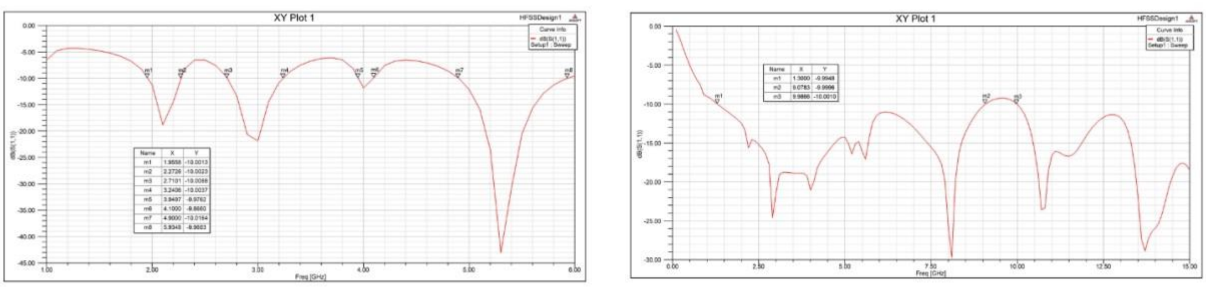
(a) FORWARD BIAS(ON CONDITION) (b)REVERSE BIAS(OFF CONDITION)

Fig 2: SHOWS PIN DIODE EQUIVALENT CIRCUIT

The electrical equivalent circuits of MPP4203 pin diode in forward bias and reverse bias configuration are depicted in Fig.2 (a) and (b) respectively. In forward bias configuration, the pin diode is represented as a series configuration of inductance (LS) and a resistance (RS). While in reverse bias configuration, the pin diode exhibits a parallel circuit of resistance (RP) and capacitance (CP) with an inductance (LS) in series configuration .

III. RESULTS AND DISCUSSION

Here we have analysed the stepped rectangular patch and DGS with Single pin diodes by using the Ansoft HFSS simulation solver. When the Pin diode at on state works in vehicular applications. When the Pin diode at OFF state works in UWB applications. In this topic we discussed and analysed about return loss, VSWR, gain, radiation pattern , electrical distribution.



(a)PIN DIODE IN ON CONDITION (b)PIN DIODE IN OFF CONDITION

Fig 3: SHOWS THE RETURN LOSS

In figure 3(a) shows the PIN diode works in on condition where the antenna cover ranges between 1.95GHz2.27GHz,2.71GHz-3.2GHz,3.9GHz-4.1GHz,4.9-5.9GHz which has high return loss of -43dB at 5.3GHz . In

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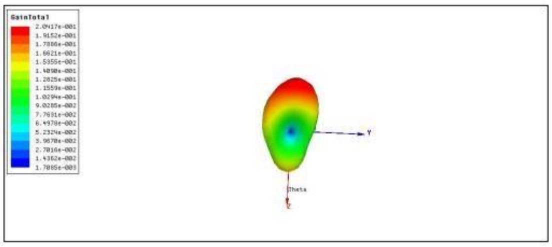
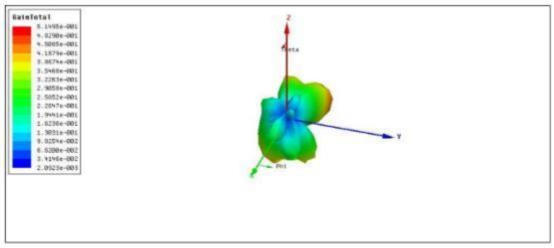
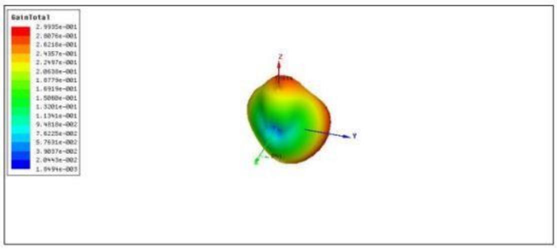
figure 3(b) shows the PIN diode works in OFF condition where the antenna cover ranges between 1.3GHz-9.07GHz which has high return loss of -30dB at 8GHz. For both condition we achieved VSWR <2 .

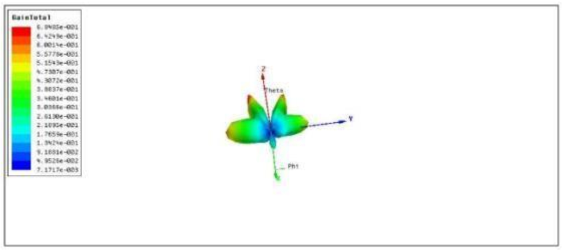




(a) shows the gain at 3.4 GHz in ON condition at maximum gain of 2dB

(b) shows the gain at 9GHz of ON condition at maximum gain of 5dB



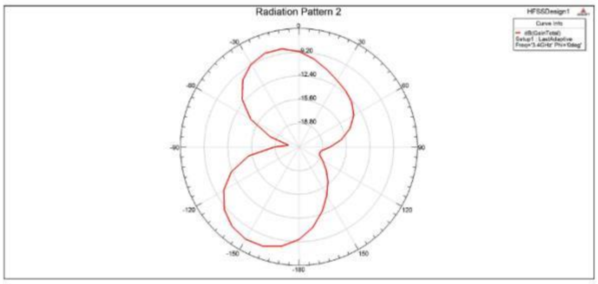


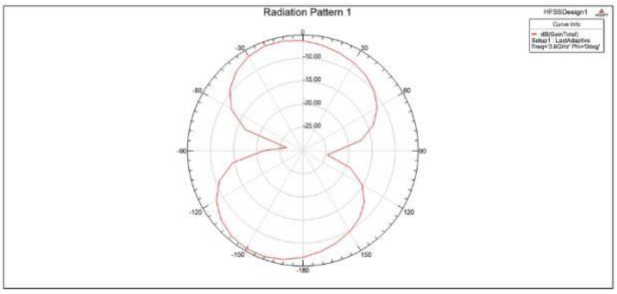
(c) shows the gain at 3.4GHz of off condition at maximum gain of 2.9dB

(d) shows the gain at 9GHz of off condition at maximum gain of 6.8dB

Fig 4:3D POLAR PLOT(ANTENNA GAIN)

In the figure 4 we show the 3D polar plot(Antenna gain) which tells about " ability of the antenna to radiate more or less in any direction compared" for both condition on and off.





(a) shows radiation pattern of ON condition

(b) shows radiation pattern of OFF condition

Fig 5:RADIATION PATTERN

Figure 5 shows the radiation pattern of both condition at 3.4GHz which tells about a mathematical function or a graphical representation of the far field.

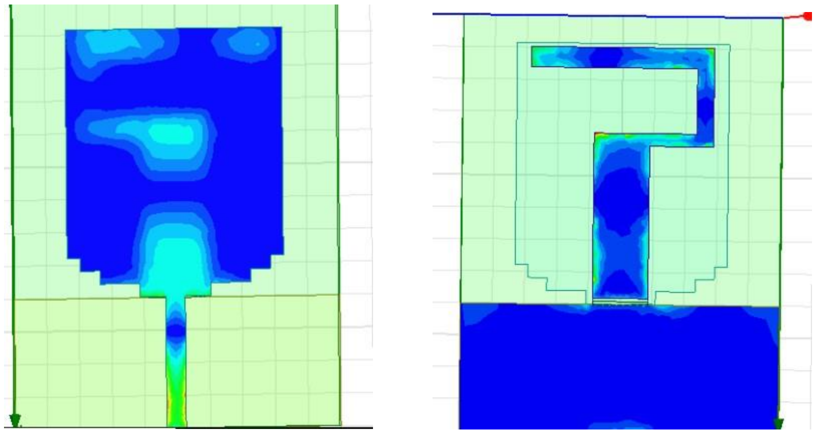


Figure 6(a) :SHOW THE ELECTRIC DISTRIBUTION FOR BOTH SIDE OF ANTENNA AT 3.4GHZ

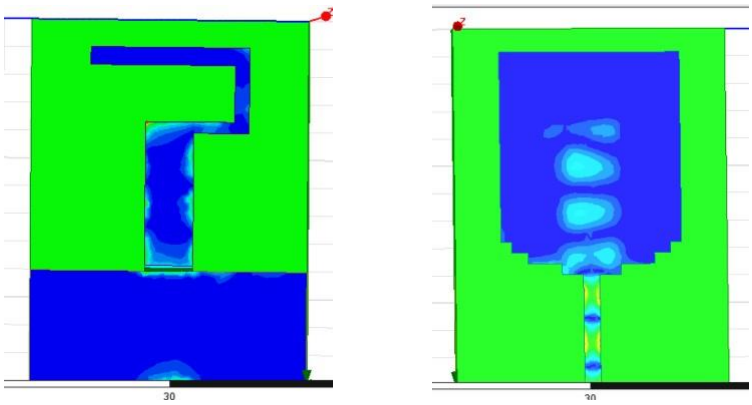
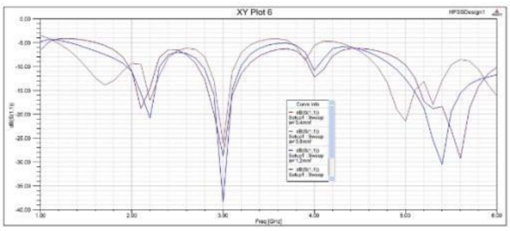
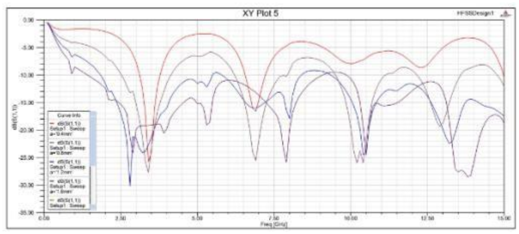


Figure 6(b): SHOW THE ELECTRIC DISTRIBUTION FOR BOTH SIDE OF ANTENNA AT 9 GHZ
Figure 6 shows the electrical distribution on surface of the patch, ground plane and parasitic element.



(a)shows by varying the height of substrate for 0.8mm,1.2mm and 1.6mm for on condition



(b) shows by varying the height of substrate for 0.8mm,1.2mm and 1.6mm for off condition

By considering both graphs we chosen the substrate height has 1.6GHz because it has High return loss and wider bandwidth for the both ON and OFF condition.

IV. CONCLUSION

A stepped reconfigurable antenna is analysed and discussed in this article. HFSS 13.0 Version is used to analyse and characterize the results of the proposed antenna. Two cases that is ON and OFF cases have been studied and characteristics has been discussed. The proposed antenna when stimulated in OFF cases works at ultrawideband region where as in ON case three rejections have been occurred. The propose antenna gain plots, radiation pattern and efficiency of the antenna have been analysed in this article.

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