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Design of Flexible and Dual Band Antenna for Vehicular Communication

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Abstract: The antenna with bowtie and meander lines shaped elements for the vehicular communication in this paper. The dimensions of the proposed antenna are 40.5*91.5*0.1. The substrate used in this antenna is polyamide substrate with a permittivity of 4.3. The implemented antenna is operated at cellular (975MHz) and C-V2X (5.9GHz) band. The efficiency of this proposed antenna is 99.5%. This paper describes the design of antenna with high efficiency vehicular roof mounted for V2V communication system used for ubiquitous intelligent systems. To enhance the connectivity among vehicles by providing seamless communication and to reduce initial access time using high performance antenna systems is the purpose of the ubiquitous intelligent systems. V2V communication efficiency depends on the antenna efficiency used for ubiquitous intelligent systems. We are proposing this antenna to increase the performance of the antenna by enhancing efficiency.

Keywords: Automotive antenna, Cellular frequencies, C-V2X frequencies, HFSS tool.

1. Introduction

Vehicular communication antenna is a type of antenna system used in vehicles for wireless communication. It is designed to transmit and receive signals in a wide frequency range, typically used for radio, cellular, vehicle to vehicle (V2V), vehicle to everything (V2X) and satellite communication. Vehicular communication antenna comes in different shapes and sizes, depending on the type of vehicle and communication requirements [1].

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It can be mounted on the roof, fender, or bumper of the vehicle, and it may include multiple antennas for different frequency bands and communication protocols. The antenna must be designed to withstand the harsh conditions of the automotive environment, including high speeds, vibration, and temperature variations [2-5]. Vehicular communication antennas are essential for the development of intelligent transportation systems, which aim to improve the safety, efficiency, and sustainability of transportation. To improve road efficiency for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, ubiquitous intelligent systems equipped with efficient wireless access vehicular environment (WAVE) antennas can offer alternate routes to vehicles in heavy traffic situations based on collected traffic data.

2. Literature Survey

The existed model antenna i.e., multi-band flexible light weight antenna on LCP for automotive applications had some drawbacks like increased size etc. In order to overcome this the proposed bowtie and meander lines can be a better substitute [6]. The proposed antenna in this paper has reduced its size. The size of this antenna is 40.5*91.5*0.1mm. In the existing model i.e., multi band flexible antenna [1] has maximum value of the realized gain is 4.4 dBi at 5.9

GHz and 0.4 dBi at 800 MHz, as simulated in HFSS, but the gain obtained in antenna designed in this paper has a maximum realized gain is measured to be 1.68 dBi at 800 MHz and 4.6 dBi at 5.9 GHz which is measured in HFSS software [7-8].

The directivity gain of the designed antenna has a maximum gain and minimum gain in dB, this proposed antenna also can resonate at 975 MHZ and 5.9GHZ with improved gain. Radiated power of this antenna is 912.74mW. Radiation efficiency is 99.11%. The antenna designed in this paper is reduced in size and is having higher efficiency and improved gain [9].

3. Antenna Modelling

The antenna is initially designed using Ansys EM (HFSS) software. The dual-band antenna consists of a bow-tie and meander lines with hexagonal shape mounted at the top of meander lines extending the bow-tie along with the slots [10]. It is fed by a slot-line, on which an SMA connector is soldered for measurements. The antenna proposed in this paper is designed with different structures combined together into a single structure [4-6]. This antenna is designed with two layers i.e., the first is substrate layer and then path is placed on it. The dimensions of the antenna are 40.5*91.5*0.1mm. The substrate that we use here is Polyamide which has permittivity of 4.3. The measurements of this substrate are length is 40.5mm and the breadth is 91.5mm and the thickness is 0.1mm.

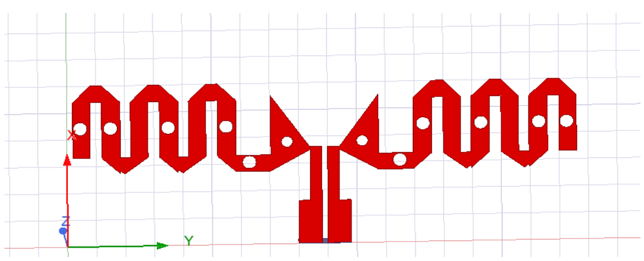

Fig. 1: Proposed Antenna structure

Design Equations

The basic design equation are as follows from equation (1)-(6)

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

$$L_{sub} = 6h+1 \tag{6}$$

$$W_{sub} = 6h+W \tag{7}$$

Where f_r is Frequency of operation, ε_r and h are Dielectric constant and height of substrate, W is the width of the antenna and L is the length of the antenna, f_0 is the resonant frequency of the antenna. ε_{eff} is the effective dielectric constant. The radiation will be done through the air and dielectric substrate so we must calculate the effective dielectric constant. The dielectric constant of the air and substrate are different. L_{eff} is the effective length of the patch. The radiation is done through the width of the patch so we must calculate the width of the patch. L_{sub} is the length of the substrate. W_{sub} is the width of the substrate.

4. Results and Analysis

A vehicle's roof has been used to replicate the planned antenna. If the suggested antenna is to attain optimal efficiency, its E and H plane patterns must track in phase and amplitude throughout the necessary FOV [11]. The simulation results are calculated using the High Frequency Structure simulator (HFSS). The suggested antenna's simulated return loss is shown in Figure 3. The frequencies that our antenna will emit at may be determined from the return loss graphic. Fig. 2 shows the simulation design, Fig. 3 shows the simulation results on return loss, Fig. 4 depicts the radiation pattern at 975MHz, Fig. 5 presents the radiation pattern at 5.9 GHz.

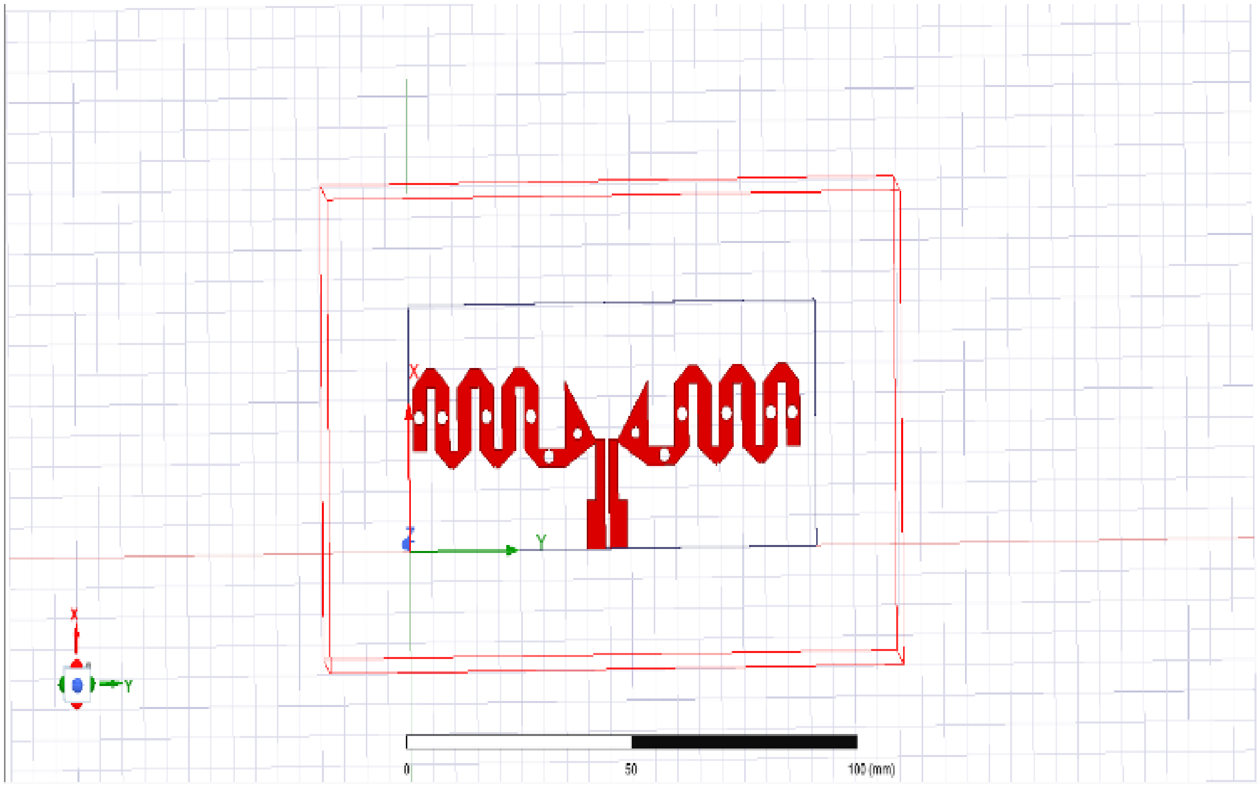

Fig. 2: Simulation design

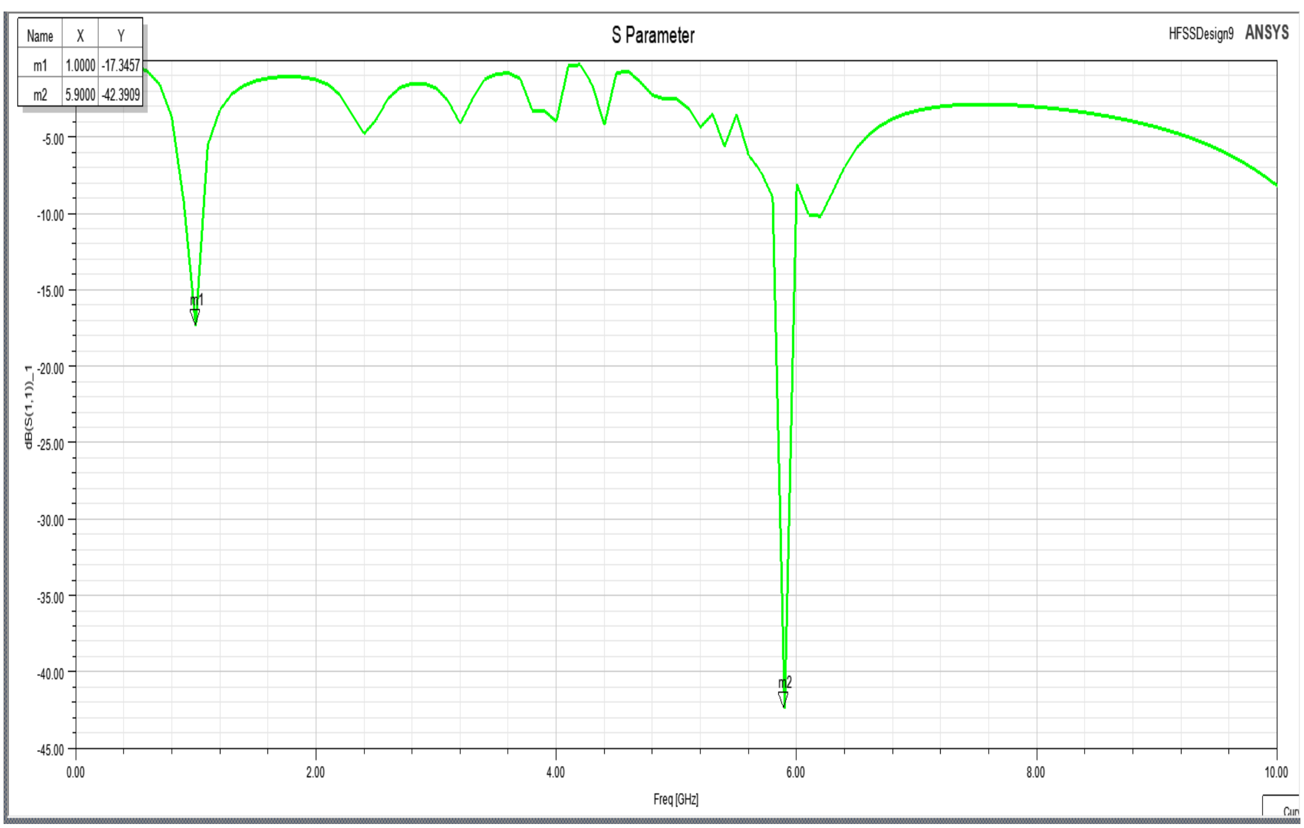

Fig. 3: Simulation results on return loss

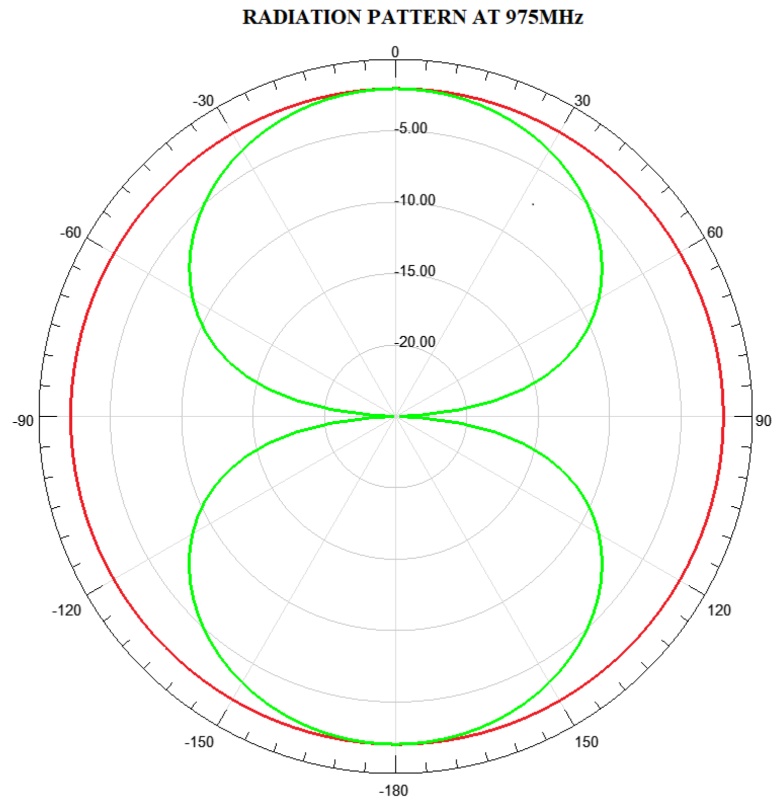

Fig. 4: Radiation pattern at 975MHz

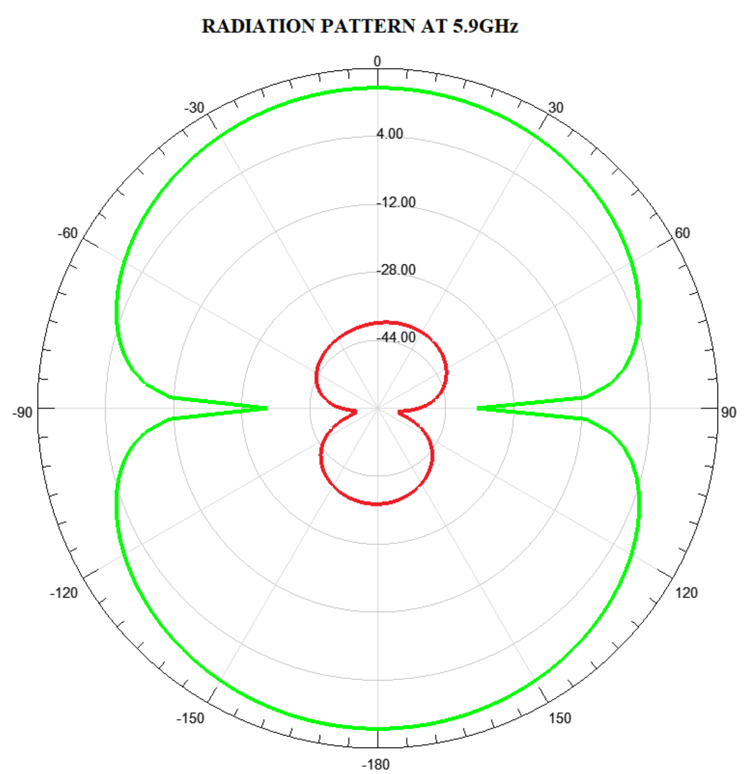

Fig. 5: Radiation pattern at 5.9GHz

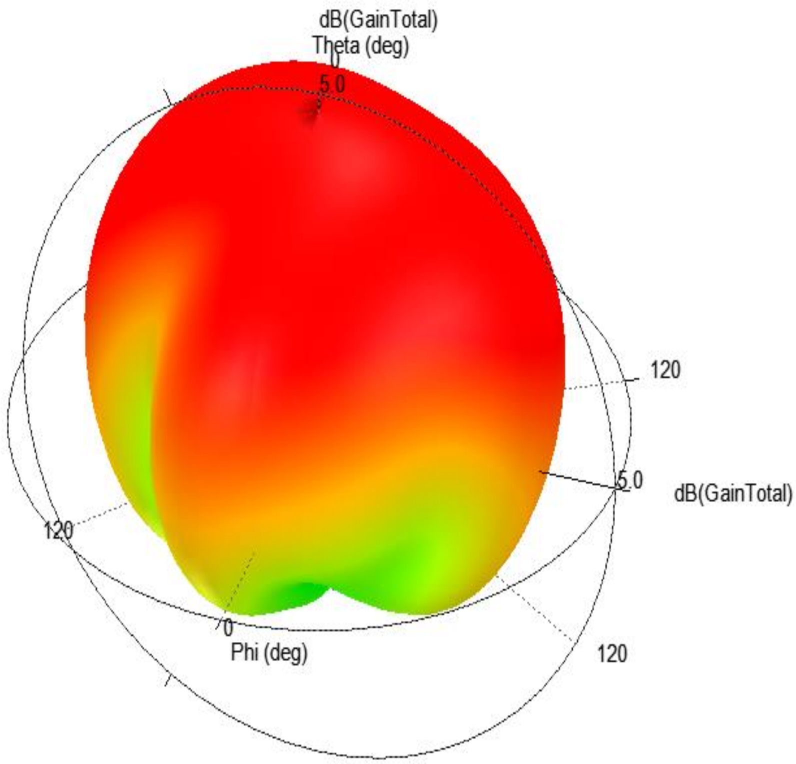

Fig. 6: Simulation result of gain pattern

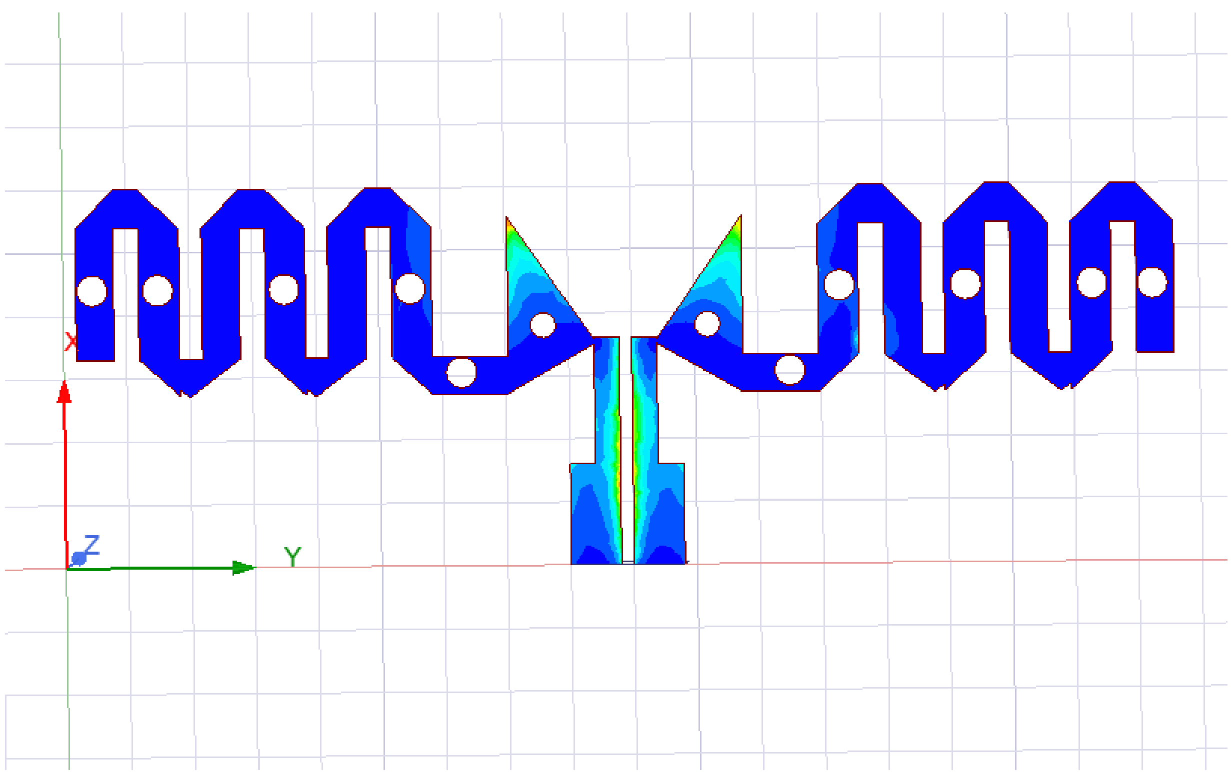

Fig. 7: E Field of designed antenna

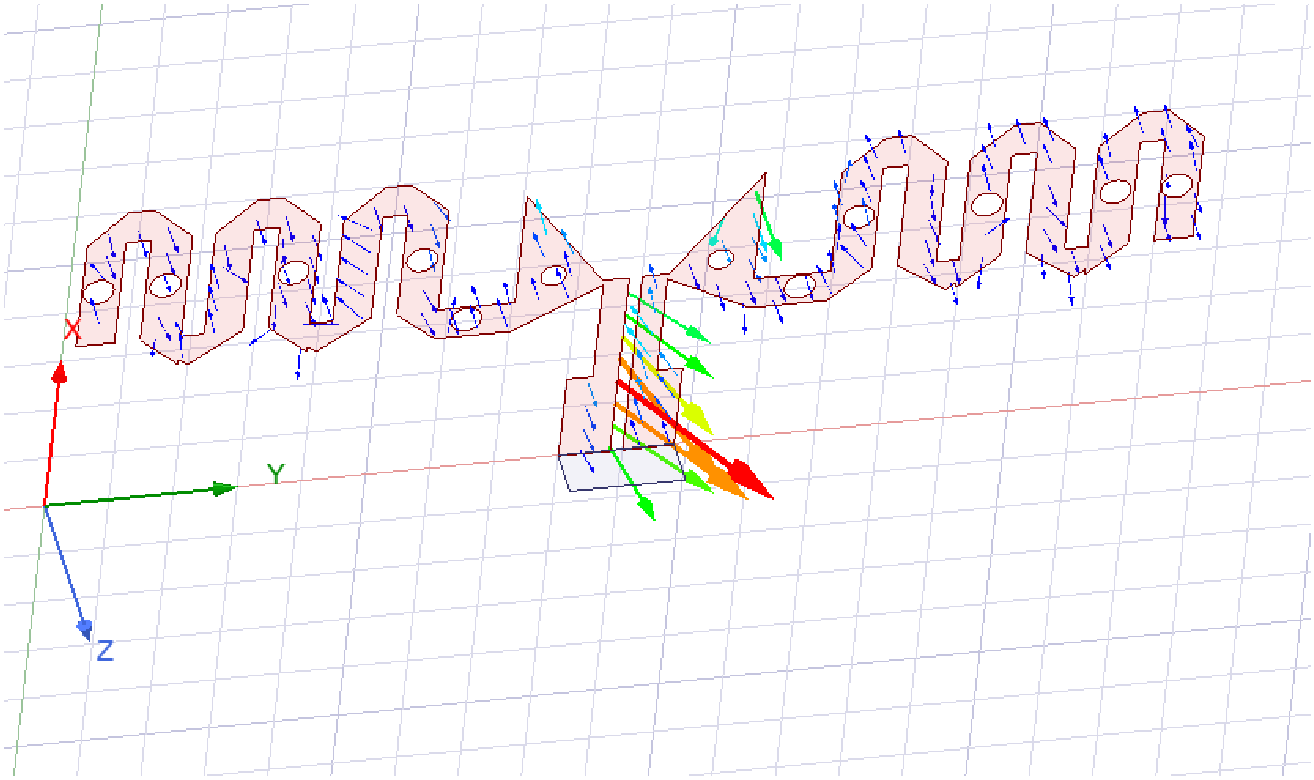

Fig. 8: E Field direction

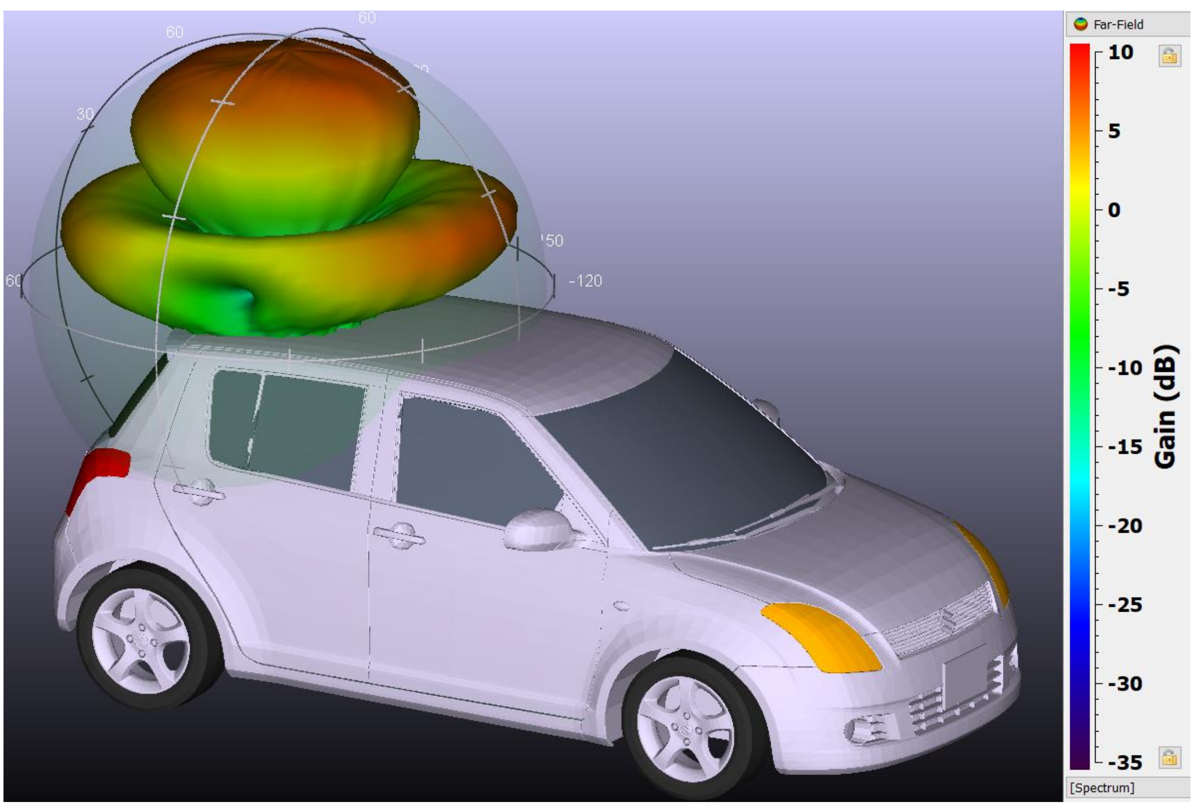

Fig. 9: Radiation of antenna when placed on the car.

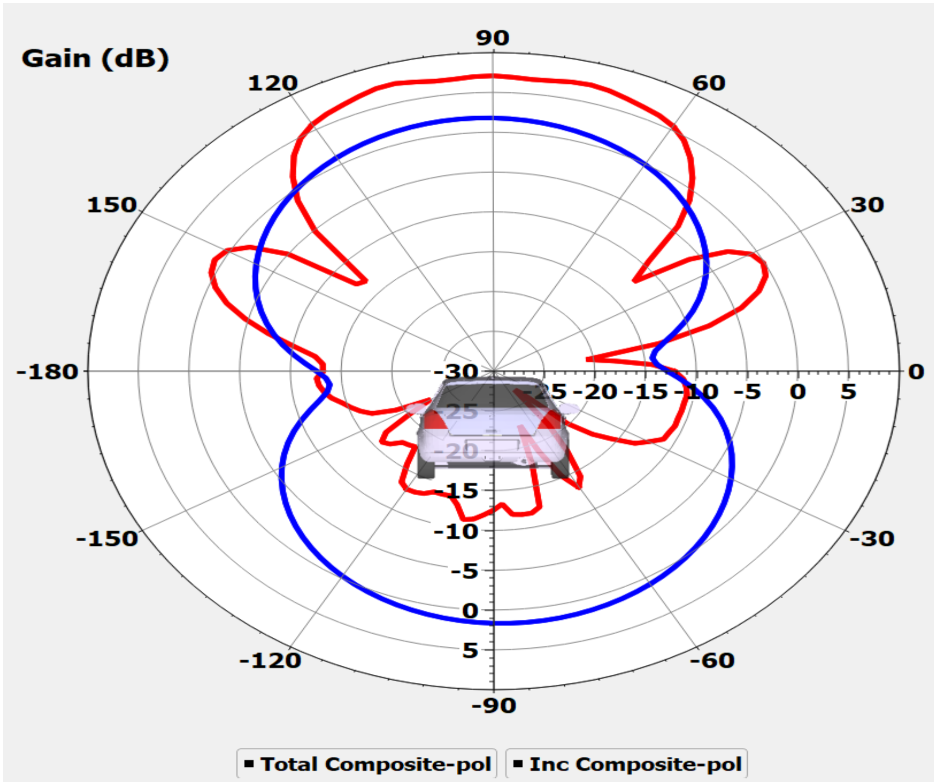

Fig. 10: Back view of car

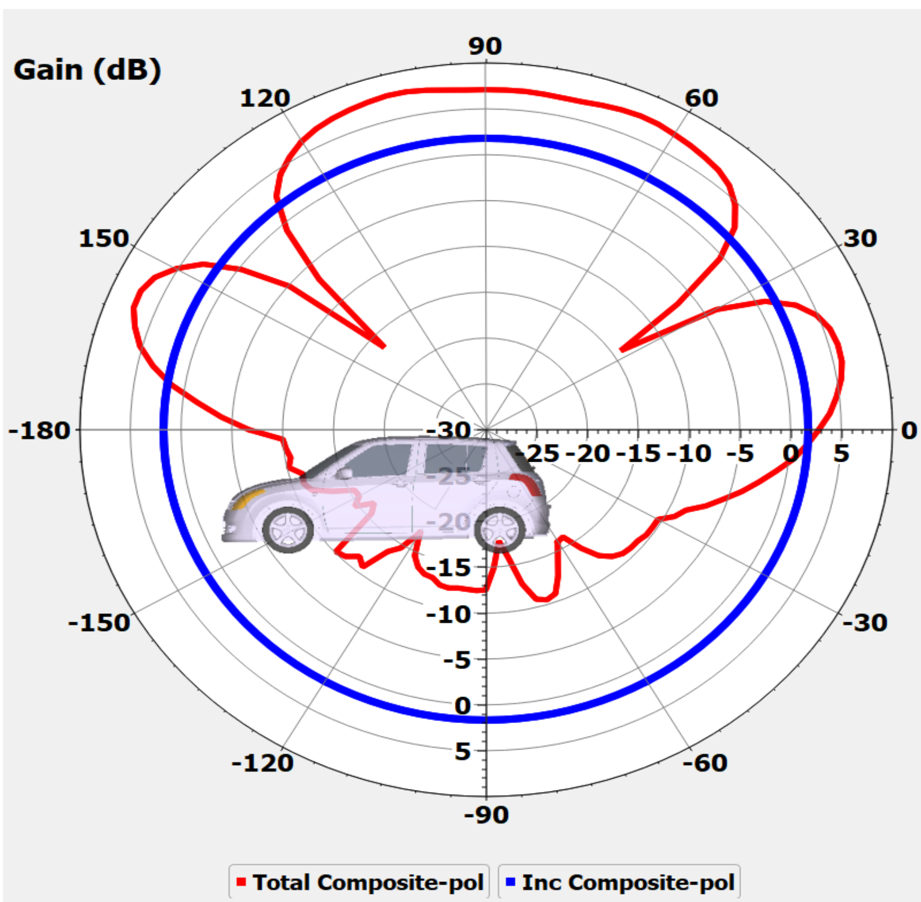

Fig. 11: Side view

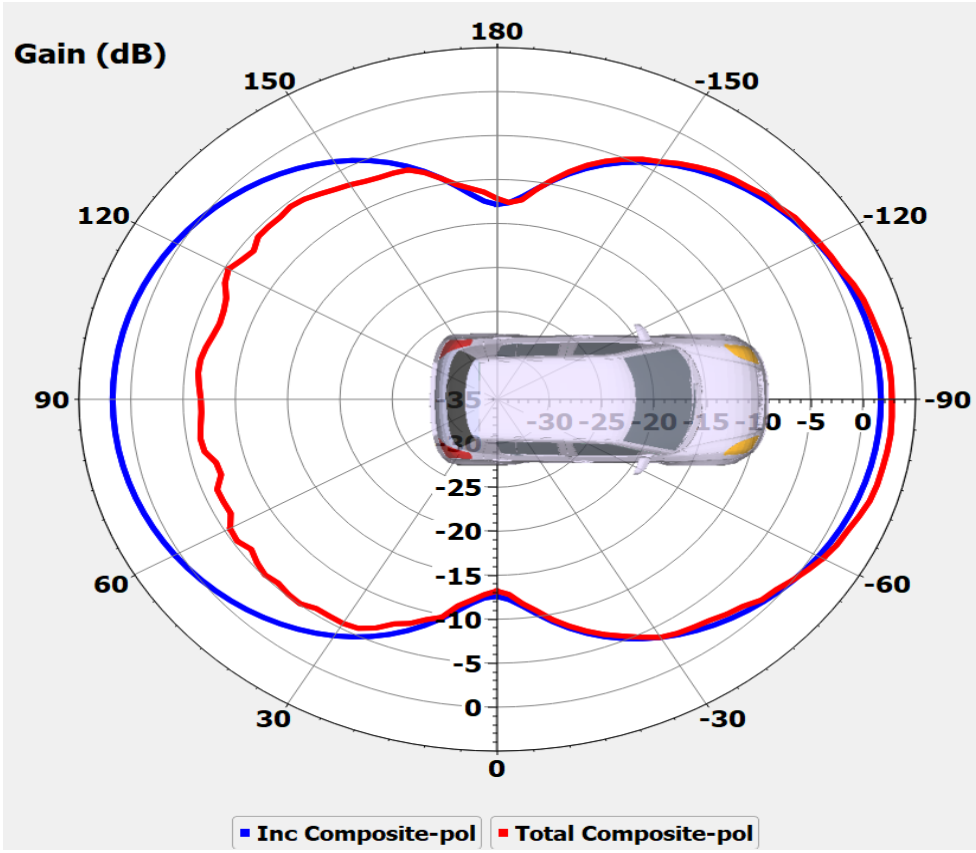

Fig. 12: Top view

Fig. 6 shows the simulation result of gain pattern and Fig. 7 shows the E Field of designed antenna. Fig. 8 shows the direction of E Field flowing in the antenna in sinusoidal manner. Fig. 9 represents the radiation of antenna when it is placed on car by savant analysis. Fig. 10 represents the back view of the car when the antenna is placed on the top of the car and it represents the radiation of antenna from 0^0 to 180^0 with both negative and positive degrees of directions. Fig. 11 represents the side view of the car when the antenna is placed on the top of the car and it represents the radiation of antenna from 0^0 to 180^0 with both negative and positive degrees of directions. In the plot we can see the frequencies which are less than -10db are the desired ones which are bandwidth of the antenna with the resonating frequencies 972MHz and 5.9GHz. Fig 6 shows the gain of the antenna when it is located on the roof of a vehicle. The proposed array antenna exhibits a gain of upto 5dB. Fig. 12 represents the top view of the car when the antenna is placed on the top of the car and it represents the radiation of antenna from 0^0 to 180^0 with both negative and positive degrees of directions.

5. Applications

This proposed antenna is being operated at two different frequencies that are 975 MHz and 5.9 GHz. So this antenna can be applicable in vehicular communications.

6. Conclusion

This designed antenna can be preferred because of its high performance. This proposed antenna is operated at 975MHz and 5.9GHz frequencies. The maximum gain of this antenna is 5db and the minimum gain of the antenna is. The maximum gain of this proposed antenna is 5 dB. The minimum gain is -2.4 compared to the antennas that for automotive applications this proposed antenna in this paper achieves high gain and higher data rates. So this proposed antenna is compatible with vehicular communication. This proposed antenna can be used for the topless cars and this can be placed on the side mirror of the car and truck lid of the car which can be used for the advance and future applications.

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