CSRR Loaded Miniaturized 5G Antenna for Vehicular Communication Appliance

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Abstract*: This paper proposes an Iterated T-shaped antenna for 5G based vehicular communications. To design the proposed antenna, a T-shaped radiating element with coplanar wave guide (CPW) feeding is used and defected ground structure (DGS) were made in the ground. The bandwidth of 5.93GHz and 4.04GHz over the frequency ranging from 26.63-32.56 GHz and 34.11-38.15 GHz respectively are achieved. The designed antenna model covering the required frequencies of 28 and 37 GHz for the future 5G applications in vehicular communications. The proposed antenna attained a peak gain 7.05 dB in the operating band and fabricated with compact dimension of 12 x 12 x 0.8 mm^3 Rogers RT duroid 5880 substrate with dielectric constant (ε_r) of 2.2. The antenna is designed using ANSYS HFSS and the vehicular placement analysis is carried out with the ANSYS Savant tool. The measured outcomes are in good agreement with simulated outcomes.

***Index Terms*: T-patch shape antenna, Defected Ground Structures (DGS), Complementary Split Ring Resonator (CSRR), Vehicular Communications.**

I. INTRODUCTION

From the past few decades, we have gone through four generations of cellular communication. There is a huge bandwidth shortage around the world [1] and the milli-metric wave technology is going to have huge demand and it will be used in wide range of applications, with increase in data rates [2]. There is a huge crowd in the sub-3 GHz spectrum, so spectrum between 3-30 GHz range (SHF)and 30-300 GHz range (EHF) is left unutilized, they are having a wavelength ranging from 1mm-100mm [3]. There are many problems in this milli-metric wave spectrum like fading, attenuations and absorption [4].

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The lower gain and bandwidth are the main reasons to leave patch antennas and which can be achieved by using some special techniques. Defected ground structures are one among them, which can improve the antenna parameters [5]. DGS acts like defects in the ground plane and these defects can affect the current distribution in the ground plane which can change the parameters like capacitance and inductance [6-7]. While designing the antenna to acquire the required results, we can add DGS at different positions in the ground plane to achieve resonant frequency [8]. The microstrip antennas will achieve reconfigurability when use diodes at lower frequencies [9]. The communication bands such as LTE, WLAN, Wi-Fi, and WiMAX are addressed for different vehicular applications and different variations in antennas while using metamaterial inspired structures in the antenna geometry is discussed in [10-21]. This Paper consists of a Different T-patch antenna which is consisting of defected ground structures which are introduced for vehicular applications. The proposed antenna offers a multi bandwidth at milli-metric wave frequencies with good performance. The designed compact antenna which is printed on the Rogers RT duroid material is used to work in the 5G communication bands for vehicular communications. The proposed antenna providing its full resonance at the 28 GHz frequency range, which is best suitable for the 5G vehicular communication applications. The gain of the antenna is stable for the desired applications and antenna is providing an average gain of 5dB. Design and stimulation of propound antenna is carried in ANSYS HFSS and vehicular mounting and its patterns are carried out using ANSYS SAVANT.

II. ANTENNA GEOMETRY AND CONFIGURATION

A. Antenna Design

Single T-shaped antenna is designed with dimensions of 12 × 12 mm^2.The design is having a partial ground structure to achieve the wide band characteristics. The ground has defected ground structures with the split rings in the ground plane, so that it can alter the current distribution along the ground plane. T-shaped patch is placed on the top of the substrate fed with 50Ω matched CPW feed. The substrate of Rogers RT Duroid 5880 having the dielectric constant (ε_r) of 2.2, with a

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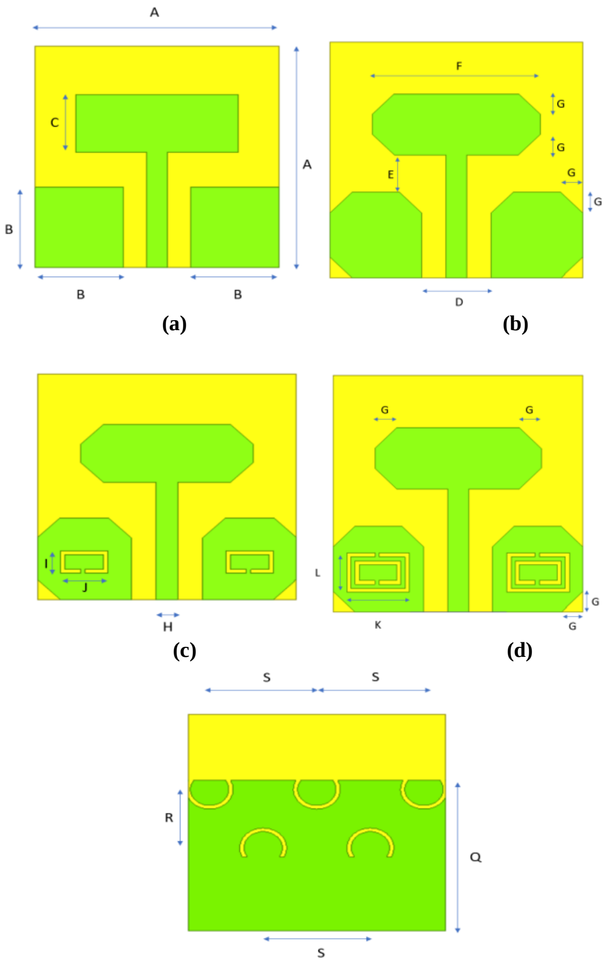
height of 0.8 mm is placed on the partial ground plane. Designing, simulation and analysis is carried out in the HFSS software. Split rings having width of 0.2mm on the ground plane. There are totally two iterations for five rings, 3 rings at the top and 2 rings in the middle of the ground, which covered up to 25% approximately. In the first iteration, one slot is placed at the ground, which couples both patch and feed line. Two slots are placed at the terminating edges of the ground at 3mm. These slots, which radiate can create resonance at this state. Here, ground plane is consistent throughout the iterations and patch is changed. To improve resonant response, two symmetric slotted split ring slots are established at a distance so that the symmetry can be conserved and provides multiple resonant frequencies.

B. Iterations



(e)

Fig.1 Iterations of antenna
(a) First iteration, **(b)** Second iteration, **(c)** Third iteration, **(d)** fourth iteration, **(e)** ground.

Table 1:- Dimensions

Variables	Dimension (mm)	Variables	Dimension (mm)
A	12	I	2.2
B	4.35	J	1.2
C	3.1	K	3
D	3.3	L	2
E	1.9	Q	8.35
F	8	R	3.25
G	1.05	S	5
H	1	Radius of outer slot	1.1
Radius of inner slot	0.9		

III. Results

A. Impedance Bandwidth

Fig. 2 shows the simulated return loss of antenna iterations 1, 2, 3 and 4. Antenna1 which is a simple t-patch antenna achieved good return loss from 26.7 – 27.92 GHz and 29.43 – 31.8 GHz. Antenna 2 which is a chamfered model of antenna 1, as the edges are removed, a wide bandwidth and a resonant peak at higher frequencies are achieved. The bandwidths achieved are 5.48 GHz and 4.16GHz. An SRR is employed on the chamfered model, due to this employment the antenna return loss achieved multiband with bandwidths of 1.72GHz, 3.13GHz and 4.04 GHz and achieved resonance peaks. The CSRR is introduced in the fourth iteration model which achieved bandwidth of 5.93 GHz and 4.04GHz, achieved the resonance peak at 28 GHz.

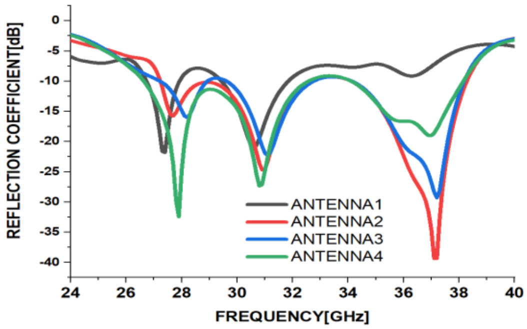


Fig.2 Reflection coefficient of all the iterations.

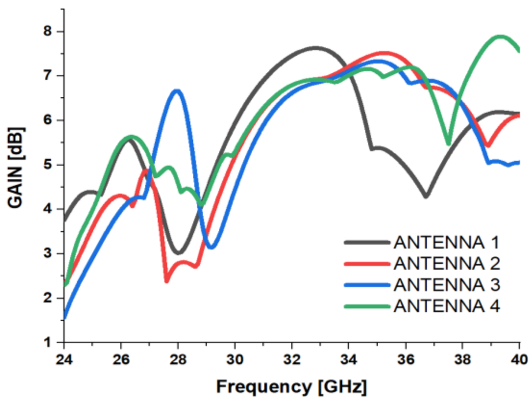


Fig.3 peak gain of all the antenna iterations.

B. Peak Gain

Fig. 3 shows the simulations results of gain characteristics for antenna iterations 1, 2, 3 and 4. The gain outcomes of the iterations are good, but the antenna4 which is having a peak resonance at 28GHz is the main requirement for propound application has achieved a gain of 4.45dB, at 28 GHz frequency.

C. Current Distributions

Fig.4 & Fig.5 explains about the distribution of currents in the antenna at 28GHz and 37 GHz frequencies respectively. The antenna achieved resonance at 28GHz, So These distributions are done to check the radiating nature of the antenna at 28GHz. High coupling effect of slots with the feedline is determined by the high current density at the slot edges of the ground. High current density is accountable for added resonances.

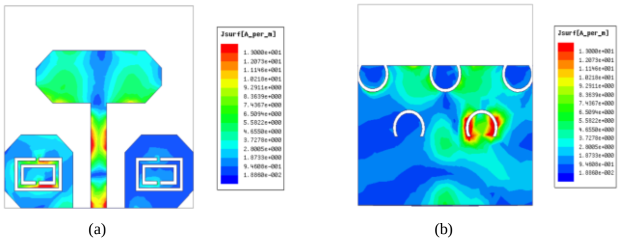


Fig.4 Current distribution at 28 GHz
(a) Patch, (b)ground

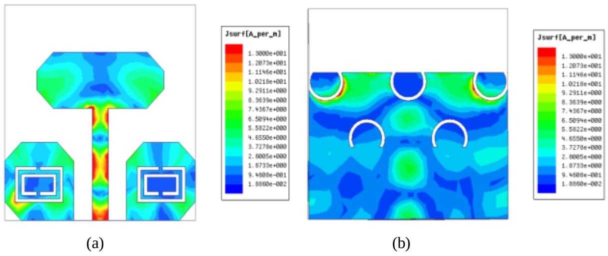
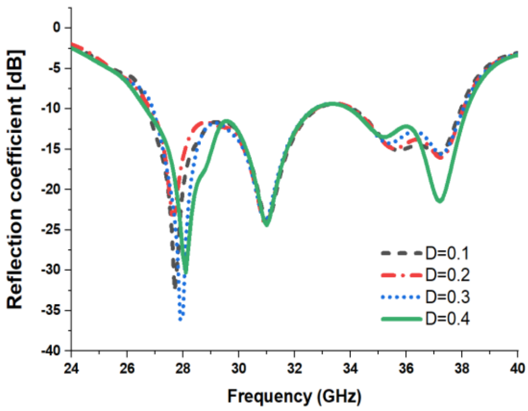
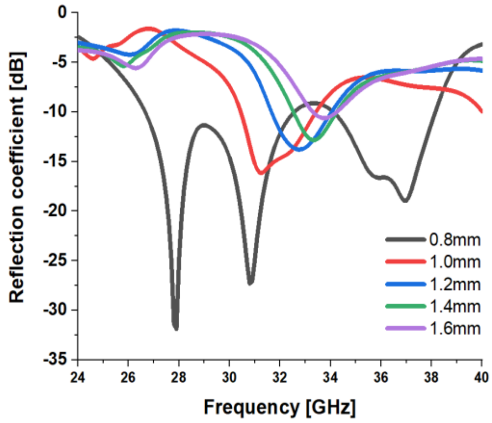


Fig.5 Current distribution at 37 GHz
(a) Patch, (b)ground

D. Parametric Analysis



(a)

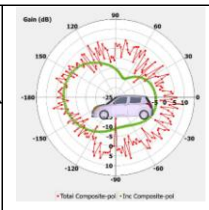
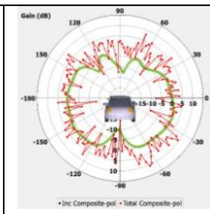
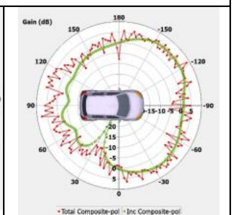
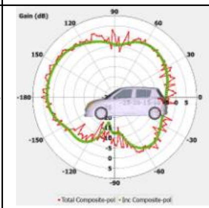
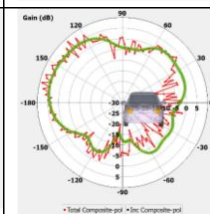
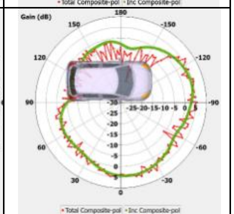
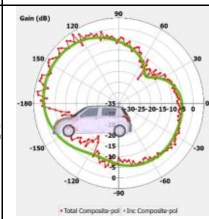
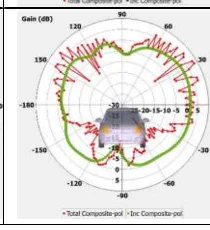
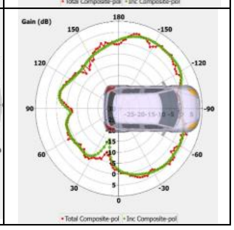


(b)

Fig.6 (a)Parametric analysis by varying feedline width.
(b) Parametric analysis by varying substrate thickness.

Fig.6(a) and Fig.6(b) shows the variations of reflection coefficient when varying the feedline width and substrate thickness of the antenna. The antenna with 0.4mm feedline width variation is having a better bandwidth and resonance peaks. The antenna with 0.8mm substrate width is having good reflection coefficient.

Table 2 Vehicular mounting of the proposed antenna at different positions on Car

	XZ-plane	YZ-plane	XY-Plane
	At 28GHz		
A			
B			
C			

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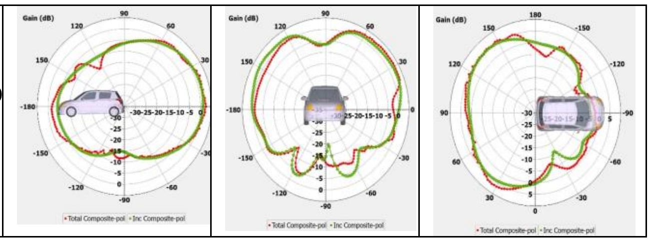
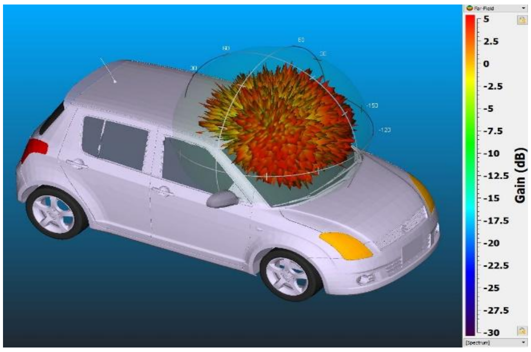
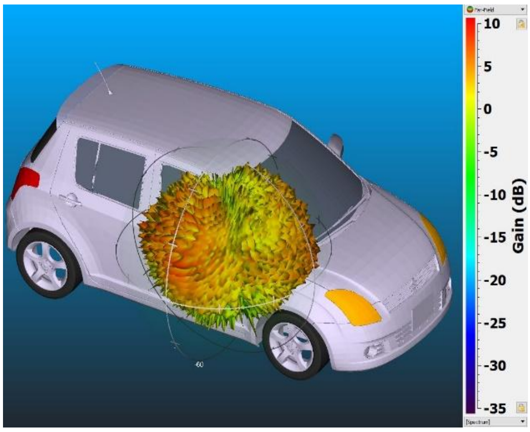
D	

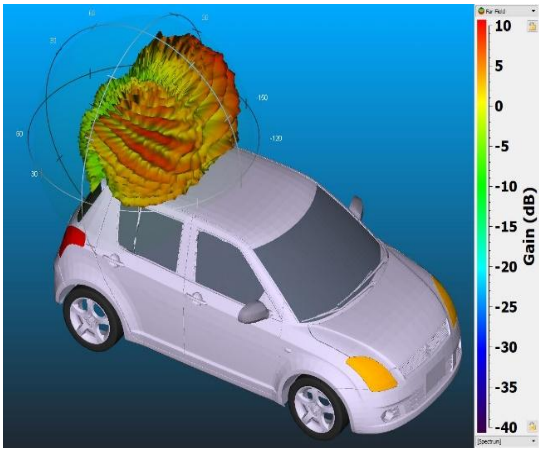
Table 2. represents the antenna placed on the different position of the car at the 5G communication band i.e., at 28GHz. The observation of the radiation in the vehicular region mainly depends on the placement of the antenna in vehicular area. The radiation stableness in the car is almost same with variance of the position.



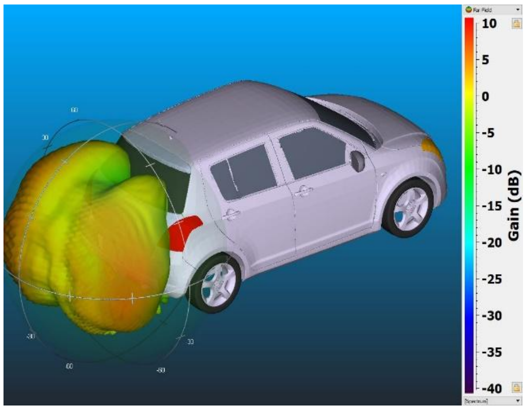
(A)



(B)



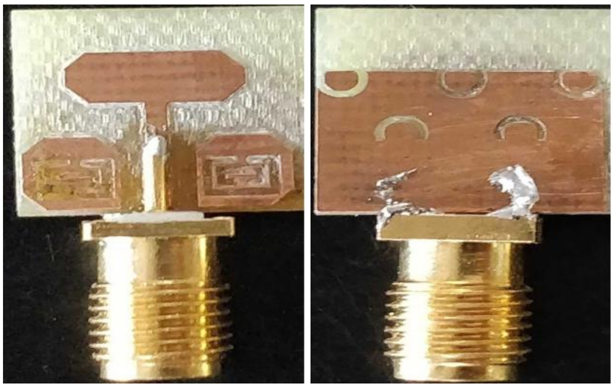
(C)



(D)

Fig.7 3D gain when mounted on different positions of the car, A- antenna placed on the glass, B-antenna placed on the side mirror the car, C-antenna placed on the top of the car, D-antenna placed on the back of the car

E. Fabricated Antenna



(a) **(b)**

Fig.8 Fabricated Prototype, **(a)** Front Side, **(b)** Back Side

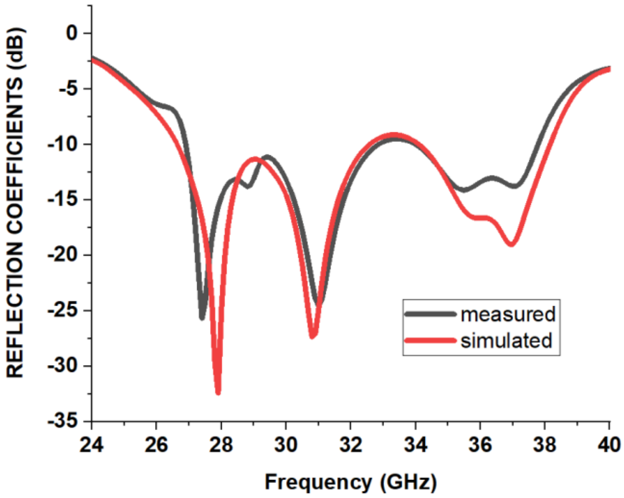


Fig.9 simulated and measured results of antenna

Table 3 Comparison table

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Ref No	Dimensions (in mm)	Working band (GHz)	Bandwidth of the antenna (GHz)	Peak gain (dB)
17	5x10x0.8	21-23.5	2.5	5.9
18	11x12x0.254	27-29.1	2.1	6.17
19	14x18x0.254	20-26	6	2.6
20	16x20x0.254	26.5-38.2	11.7	6.12
Proposed Work	12x12x0.8	26-38	12	7.05

IV. CONCLUSION

A miniaturized defected ground antenna is presented in this article for 5G mobile applications in the vehicular communication. The proposed antenna characterized using Ansys HFSS and later vehicular mounting is done with the help of Ansys savant. The proposed antenna works at 28 GHz frequency range which is most suitable for the IEEE-5G based vehicular communication applications. The antenna propound is fabricated. Parameters of antenna are measured. The measured outcomes are in good agreement with the simulated outcomes.

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