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Wide Band Flexible Antenna For Future V2X And 5G Automotive Vehicular Imaging And Position Prediction Applications

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Abstract: In this work monopole automotive antenna is designed and analysed using ANSYS HFSS. Polyamide material is take as the substrate material having dielectric constant of 2.9.The antenna is enclosed in an automotive application scenario where the antenna shows its peak performance involving in the occurrence of 3.5GHz(WiMAX) and 5.8(WLAN) and Vehicular communication bands. The proposed antenna works at modern commercial applications and it also verified on virtual automotive scenario. The antenna gets a maximum gain of 4.8dB and average gain of 3.2Db.The proposed antenna exhibits stable type of performance in and out automotive scenario having gain of above 3Db.The antenna is getting radiation efficiency of 90 percent and having front to back ratio of above 75 percent in peak maximum scenario.

Keywords: *Flexible Antenna, Polyamide (P) substrate, Closed Ring Resonators, Circular Patch (CP).*

1. Introduction

Now a days the ultra-wideband technology has been reached heights in the communication scenario and getting attention due to its connectivity and adoptability with the latest applications. Irrespective to different applications such as WiMAX, WIFI and much more wireless communication application covering ultra-wideband scenarios one of its kind of application is vehicular applications which is used as navigation and sensing purposes. The major developments in these kinds of applications are communication modules such as antennas and sensors. Considering the antennas, they should hold good impedance bandwidth and radiation performance to render the services for ultra-wideband applications. The practical scenarios and flexible nature of the antenna plays a vital role for an antenna to work efficient in different applications.

There are few antennas proposed for ultra-wideband antennas and vehicular applications. The modules include shark fin [1-6] and roof top modules, the transparent modules and side mirror embedded conformal and transparent antennas and some on cavity-based antenna which may be embedded in the antenna. Most of the conformal antennas are operating at single/dual band applications because to operate at new services [10-12]. So, of the techniques in recent times also comes with inclusion of pin diode by varying the frequencies and getting wider bandwidth scenarios. In most of the cases the conformal antenna works either in single band or in the dual band scenario. Inflecting factors of planar antenna which is having structural discontinuities which will drag and mounted on non-planar surface while interfacing the vehicle [16-17]

As the research on flexible antennas are limited and study of conformability has various paths, we have chosen is for designing and analyzing conformal antenna for ultra-wideband applications and analyzing it on vehicular applications. A sequential process is carried out for designing antenna iteration wise and analyzing with respect to horizontal and vertical bending. Further the model is placed on vehicular analysis with supporting fabrication results and its far field analysis have been discussed subsequent sections.

2. Automotive Antenna Design

The proposed antenna is designed and analysed using ANSYS HFSS.The dimensions of the proposed antenna are 30 x 26.6 x 0.1 mm^3 and dielectric constant (ε_r) of 2.9. ANSYS EM Desktop is used as simulation software for the proposed work. The top layer of the substrate consists of circular shape and which includes the combination of CRR forming conducting patch with partial ground. The presence of magnetic response is due to the circular radius stubs placed on the patch of the proposed antenna. The circuit extracted using the design and modelling of the patch. As per CRR dimensions and its variations using slots its analysis is carried out.length and breadth of the larger and smaller rings are chosen according to the proposed equations. The equivalent circuit and modelling of the CRR is inspired from [12] and are illustrated in Figure 1. The following equations are used to design the proposed antenna.

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(Geometrical parameter: Ls=26.6, W_s=30, $R1$=7.5, $R2$=6.5, $R3$=5.5, $R4$=4.5, $R5$=3.5, $R6$=8,Rs=3 WF=2, L_{G1}=6, L_{G2}=12, L_F=6, G=0.5, (All dimensions are in mm)]

Below Equations are used to construct the proposed antenna

(A) The operating wavelength $\lambda_0 = c / f_r$

(1)

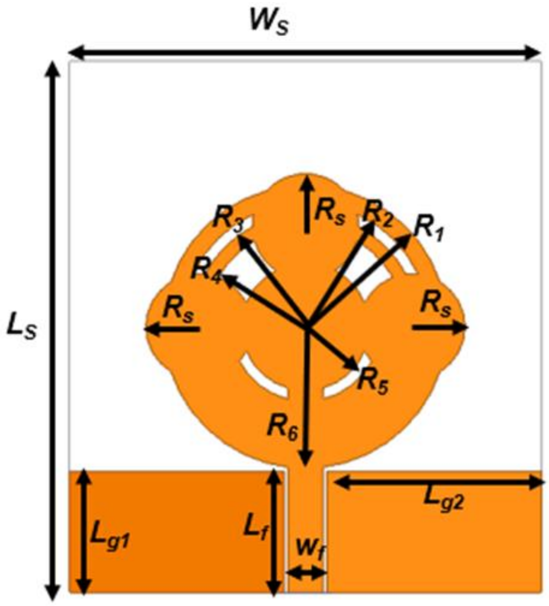


Fig.1. Structure of the proposed Antenna

Where speed of light c and ' f_r ' is the resonant frequency

(B) $\lambda_g = \lambda_0 / \sqrt{\varepsilon_r}$ (2)

Dielectric constant = ε_r

(C) Substrate thickness

$$h_s \le \frac{0.3*c}{2\pi f_r \sqrt{\varepsilon_r + 1}} \quad (3)$$

(D) Strip width

$$w_s = \frac{c}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (4)$$

(E)

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + \frac{12 h_s}{w_s}\right)^{-\frac{1}{2}} + 0.04\left(1 - \frac{w_s}{h_s}\right)^2\right] \quad (5)$$

(F) Effective length

$$\Delta L = 0.412 * h_s \left\{\frac{\varepsilon_r + 0.3}{\varepsilon_r - 0.258}\right\}\left\{\frac{\frac{w_s}{h_s} + 0.264}{\frac{w_s}{h_s} + 0.813}\right\} \quad (6)$$

(G)Length of the patch

$$L_d = \left\{\frac{c}{2 f_r \sqrt{\varepsilon_{reff}}}\right\} - 2\Delta L \quad (7)$$

(H)Flexible antenna width

$$W = \frac{1}{2 f_r \sqrt{\epsilon_0 \mu_0}}\sqrt{\frac{2}{\epsilon_r + 1}}$$

(8)

The total current concentrate at the wide band antenna at different radius creats half wave resonator antenna. In this aspect the following equation provides the calculation of resonance.

$$\left. \begin{array}{l} f_{ri} = c / 2 L_{ri}\sqrt{\epsilon_{re}} \\ i = 1, 2, 3, 4 \end{array} \right\} \quad (9)$$

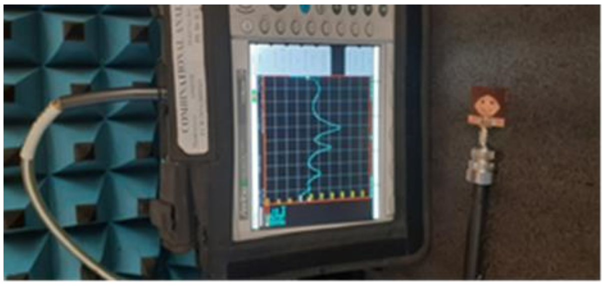


Fig.2. Measurement View proposed Antenna

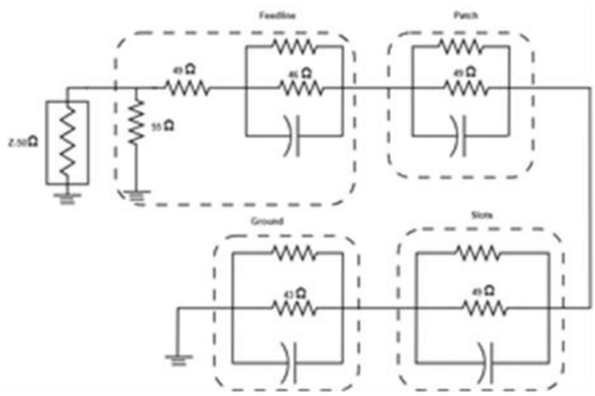
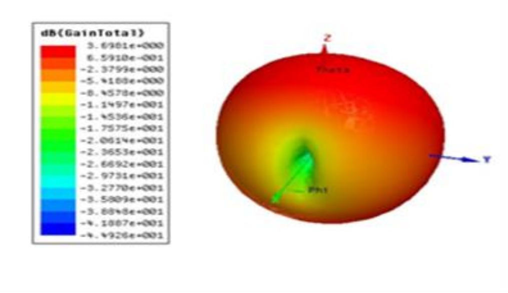
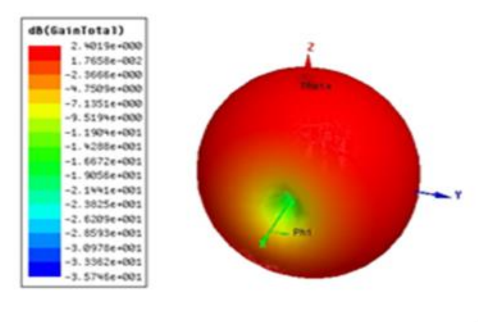


Fig 3-Equivalent Circuit Diagram of Proposed Antenna

The radiation patterns and gain give orientation of the direction of the antenna at lower bands and higher bands. At lower bands, almost 2.5dB of gain is observed whereas in higher bands 7 dB of gain is observed. The radiation patterns are almost Omni and quasi Omni directional patterns as seen from figure4 and figure 5. The E-plane patterns are dipole type orientation and H-plane patterns are Omni directional patterns.

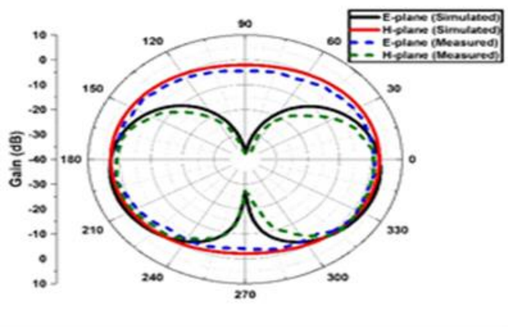


a)

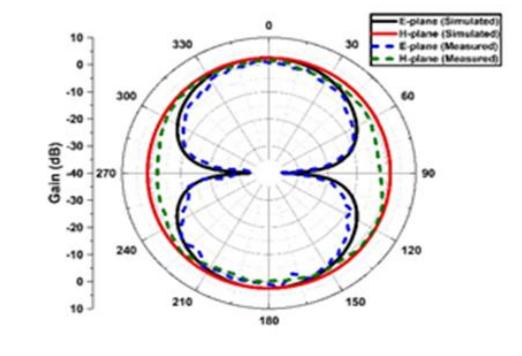


b)

Fig 4-Gain of Proposed Antenna at (a) 3.5GHz (b) 5.8GHz



a)



b)

Fig 5-Simulated and measured radiation Pattern of Proposed antenna at(a) 3.5GHz (b) 5.8GHz

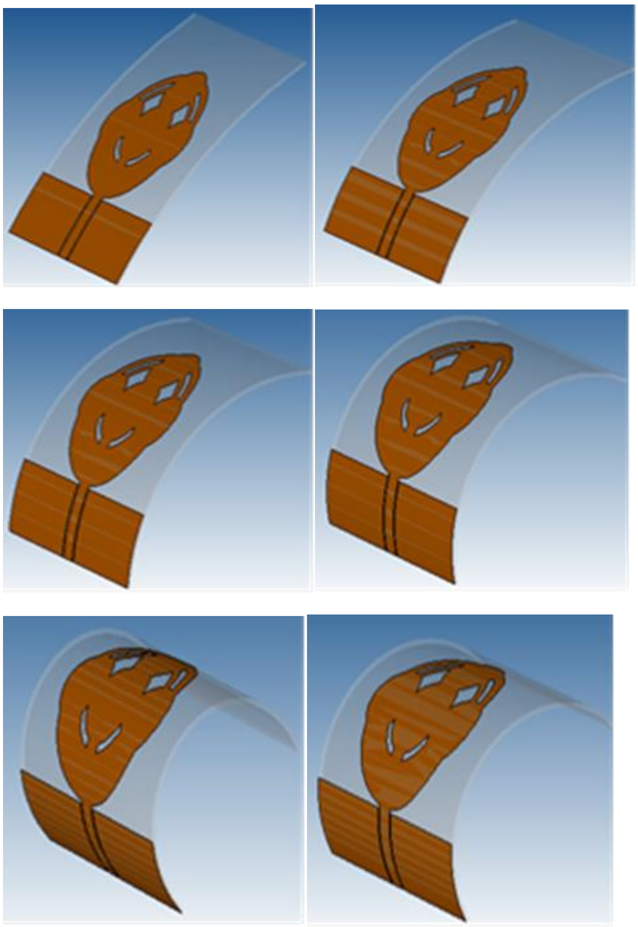
Bending analysis of proposed antenna

The different bending angles can be seen from the following figures .We have bending through x bending and y bending respectively as shown in Figure 3.

Feed length is calculated by

$$f_b = L_s - \frac{2b_r}{\left(360/\pi\theta\right)} \tag{10}$$

After analysing the proposed antenna which is designed using polyamide substrate at different bending angles shown in figure 6,The antenna provides similar kind of results when the bending is done on x-direction and y-direction. And it is evident that the antenna is more effectively depends upon the patch which is CRR (closed ring resonator).It is observed that more than feedline the patch plays a vital role in changing the reflection coefficient at different bending angles as shown in figure7 and figure 8.The patch which acts as half wave resonator contributes the band pass characteristics of the wideband antenna.



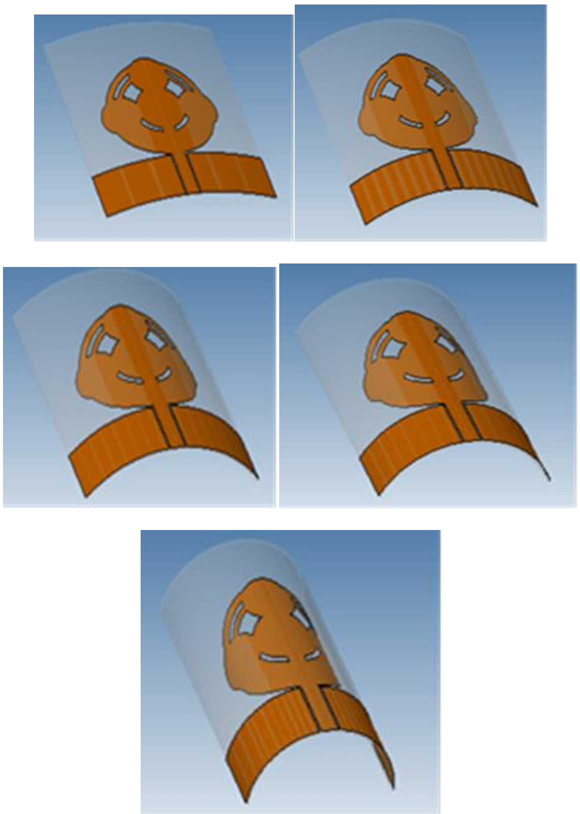


Fig.6. Different bending (both X and Y bending) angles of Proposed Antenna.

Return loss Characteristics of bending antenna

The bending return loss graphs are used to know the proportions of the antenna when it is placed in real time scenario. In an automotive scenario the antenna will be tested at different bending angles to know its reliability. From below graphs it is evident that when the antenna bends in both direction its patch is mainly responsible for occurrence of the wideband or stop band characteristics of the antenna.

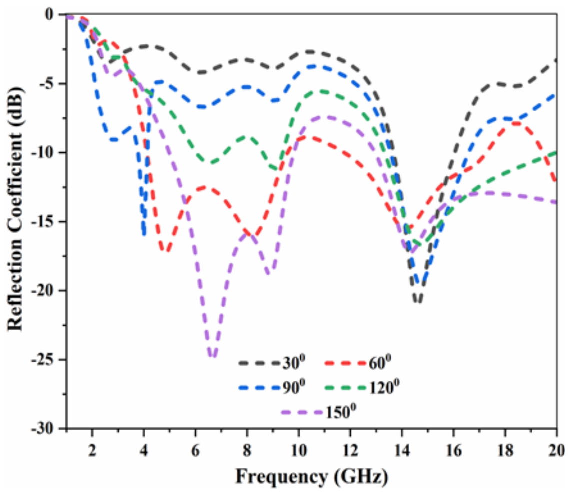


Fig.7. measured Reflection coefficient characteristics of X bending

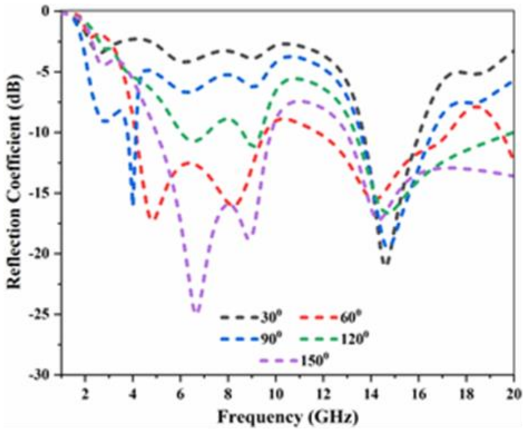


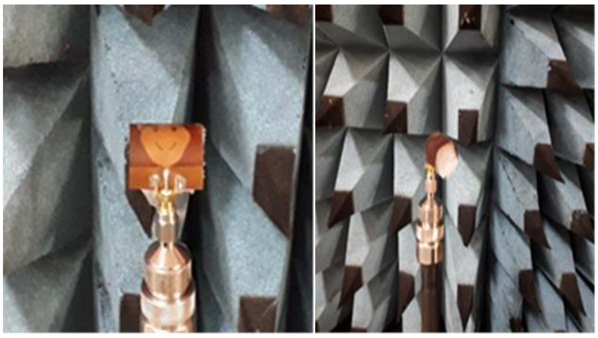
Fig.8. Mmeasured Reflection coefficient of Y bending

The reflection coefficient graphs for different bending angles indicated the effect of patch in antenna geometry which is influential factor for obtaining the band characterises in desired band. The patch acts as a half wave resonator in which varying its length may differ the variations in band coverage.

Figure 7 and figure 8 shows, the variation of reflection coefficient with the bending angles. When the antenna is horizontally bent, the majority of the bending angles works at ultra-wide band frequencies due to heavy concentration of closed ring resonator the antenna is operating. The antenna is bent on the side of patch concentration, with respect to that the results of antenna at those particular bending angles are not working at ultra-wideband frequencies. Same as in the vertical bending the ground radiating area places a vital role. So that antenna gets operated at 3.1-10.6 GHz..The antenna gets its peak performance when it bends at 30 and 60 degrees

Fabricated Model:

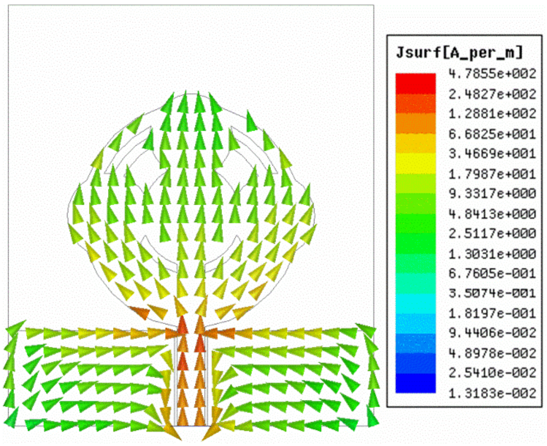
The fabrication model has been developed using chemical etching process after fabrication a good agreement can be seen in simulation and measurement values which further boots the antenna a complete candidate for proposed bands.



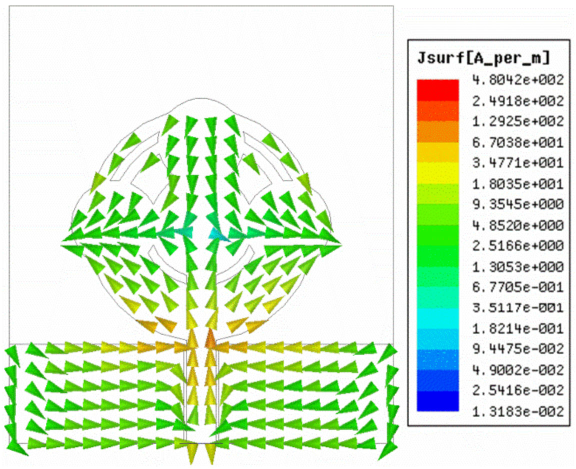
a) b)

Fig.9. Fabricated view of proposed bending antenna.

Current Distributions Of Proposed Antenna.



a)



b)

Fig.10. current distribution of proposed antenna at (a) 3.5GHz (b) 5.8GHz

The patch alone contributes more amount of dense current vectors. It is clear represents that the distributed current for different branches gives clear evidence that feedline and source currents are moving in a proper direction to obtain targeted bands. The antenna also gets the benefited for ground CPW feeding and also high currents accumulate to add wideband characteristics.it is further clear that the feedline ground and also the patch combinations shows good impedance matching.

Vehicular Placement Analysis.

One of the prominent characteristics of the proposed antenna it is designed for automotive applications. The proposed antenna is roof toped on a car and its gain and other parameters are analysed. The antenna is enclosed on a back shark fin antenna. The antenna is projected on a stable platform in the simulation environment and measured at open area test site for real time validation the measured and simulated radiation patterns shows good agreement for validation of the proposed antenna.

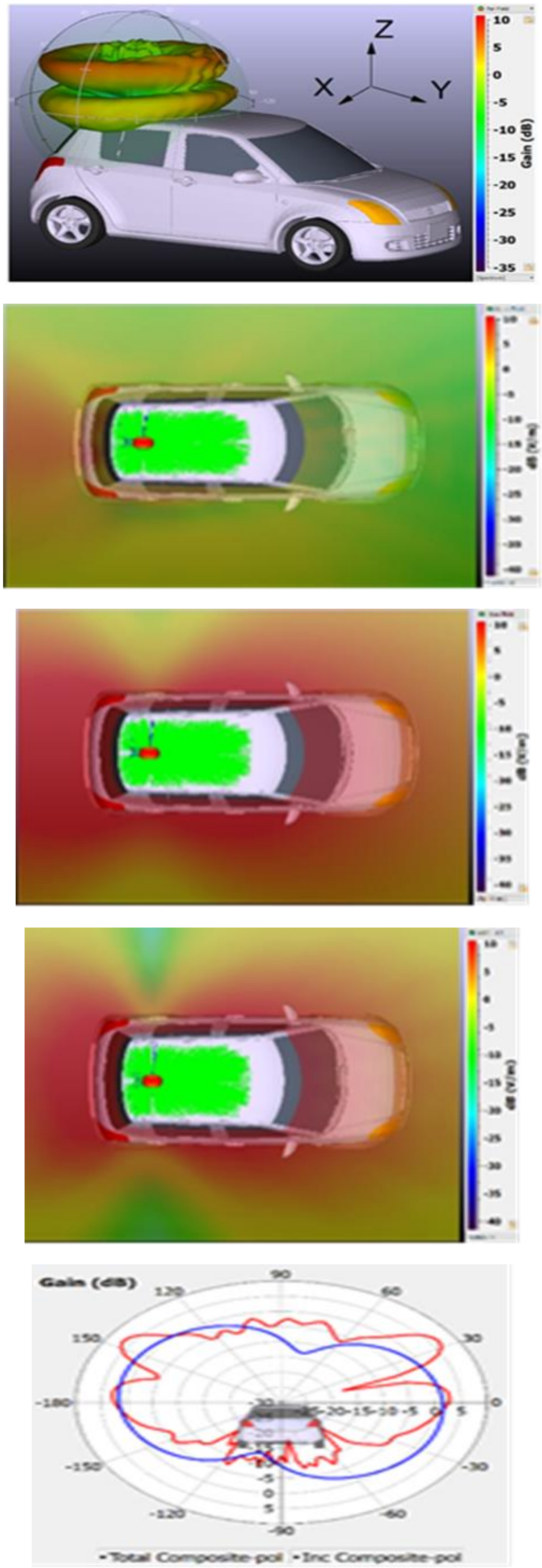


Fig.11. Proposed vehicular platform analysis at 3.5GHz and 5.8GHz

Characteristic	[3]	[4]	[5]	[6]	[7]	Proposed Modal
Antenna Size L x W x h (mm^3)	2.58λ_0 x 2.83λ_0	13.8λ_0 x11.5λ_0	3.68λ_0 x2.8λ_0	3.33λ_0 x0.61λ_0	9.88λ_0 x6.33λ_0	0.44λ_0 x0.37λ_0
Thickness	0.1	4	0.25	1	0.13	0.1
Band/f_0	Dual/2.5, 5.2GHz	Dual/ 2,2.3GHz	Single/ 2.4GHz	Single/ 1.85GHz	Single/7.6 GHz	Dual/3.5, 5.9GHz
Substrate	Polyimide ϵ_r =3.4	Felt Fabric ϵ_r =1.5	Paper ϵ_r =3.4	PDMS ϵ_r =2.67	PEN Film ϵ_r =3.2	Polyamide ϵ_r =2.9
Dielectric Loss	0.002	0.002	0.065	0.37	0.015	0.025
Tensile- Strength	High [165MPA]	Low [30MPA]	Low [30MPA]	Low [30MPA]	High [74 M P A]	High [74 M P A]
Strength of flexurality	High [50,000 P.S.I]	High [50,000 P.S.I]	High [50,000 P.S.I]	High [50,000 P.S.I]	High [50,000 P.S.I]	High [13,640 P.S.I]
Deformability	Low	High	High	High	Low	Low
Stability (Thermal)	High	Low	Low	Low	High	High
Fabrication Complexity	Simple/ Printable	Complex/ Non-Printable	Simple/ Printable	Complex/ Non-Printable	Simple/ Printable	Simple/ Printable

Table 2 Comparison table

Conclusion.

The antenna has mostly satisfied required bands which used for automotive applications. The antenna covers modern bands of 5g (3.5GHz) and 5.2ghz WLAN bands. The antenna virtual placement analysis also indicates good agreement that the proposed antenna can be used for automotive applications. Proposed antenna compactness and easy to fabricate proposed and its reliability at different bending angles makes proposed antenna suitable for mentioned applications.

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