Car Windscreen FM Antenna Design

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Abstract
Today, windscreen antennas are used by every automobile manufacturer in the globe. Windscreens are used in cars, motorcycles, and aeroplanes to shield the drivers and passengers from scorching wind and flying debris. They also serve as a safety feature. A type of FM antenna known as a windscreen antenna is built of laminated glass with an EVA and PVB (Polyvinyl Butyral) interlayer. that can play FM radio and receive FM radio signals, and is intended for use in vehicles. Windscreen FM antennas are mounted internally and use the metal frame of the windscreen as a ground plane, as opposed to exterior antennas, which are mounted externally. This enables the use of a smaller, more discrete antenna that is simple to attach using adhesive or suction cups. In this paper, the performance of a windscreen FM antenna is examined for various laminated glass thicknesses. It is measured how well an antenna performs in terms of things like Reflection Coefficient, VSWR, Gain, Directivity, and Impedance.

***Equipment**: Glass antennas, gain-enhancing devices, parasitic elements, and reflector antennas.*

Introduction

An example of a front-facing window in a car is the windscreen. Due to this design, the windscreen is able to withstand impact without breaking because the PVB layer maintains the glass together.

The windshield's main function is to shield the car's occupants from the wind, rain, dust and other roadside debris. Additionally, it acts as a partition between the passengers and the outside world, enabling climate control inside the car. Additionally, the windscreen gives the car structural support, assisting in keeping the roof's integrity in the event of a rollover accident.

Due to its clear perspective of the road in front of the driver, the windscreen also contributes s ignificantly to driver visibility.
Windscreens can be coated to decrease glare and resist water to further improve vision, allow ing drivers to see better in inclement weather.
Overall, a car's windscreen is an essential part because it offers security, structural support, and sight when driving,

A. Material Requirements

Parameters	Values	Parameters	Values
l1	25 mm	w5	2 mm
l2	2 mm	g1	0.13 mm
l3	1.4 mm	g2	0.13 mm
l4	2.03 mm	g3	0.5 mm
w1	25 mm	g4	0.5 mm
w2	9.62 mm	t	3.2 mm
w3	0.8 mm	M	4
w4	0.5 mm	N	6

III PLACEMENT OF ANTENNA OVER CAR

The CPW feeding structure, the monopole radiator with parasitic elements, and the lattice-structure reflector make up the proposed antenna. The CPW has grounds (length l2 width w2) and an inner conductor (l2 w4). The distance g1 exists between the inner conductor and grounds. The CPW is printed with dimensions of w1 l1 t (width length thickness) on top of the thick car window glass substrate (r = 6.9, tan = 0.017 at 28 GHz). It should be noted that unlike other transmission lines (such as strip line, microstrip, and CPW with a ground) that cause greater electromagnetic fields inside the substrate, the guided fields from the CPW line are less impacted by substrate thickness. The K-type (2.92 mm) connector feeds this CPW line [21], and as shown in Figure 2, we modelled the actual geometry to take the connector's effects into account. In the simulation environment, the K-type connector is activated by feeding the CPW through a waveguide port that is directly connected to the coaxial cable at the starting positions of the inner and outer conductors. The monopole radiator, which has a length of l4 and a width of w4 for resonance at 28 GHz, is directly connected to the CPW inner conductor. In general, this monopole is used extensively for 5G vehicular communications because it has the LP characteristic, which might be advantageous for the design and construction of an antenna [22,23,24,25]. The parasitic elements have four rectangular patches (l3 w3) that are positioned at, respectively, g1 and g2 distances from the CPW ground and the monopole radiator. By indirect coupling with the monopole radiator when their dimensions are changed, the parasitic elements act as a radiator. Additionally, the electromagnetic waves emitted by each parasitic component can be coupled with the electromagnetic waves emitted by the monopole radiator to increase the bore-sight gain. On the opposite side of the monopole radiator is printed the lattice-structure reflector.The reflector is made up of numerous square patches, each measuring w5, with g3 separating the next patches. M N represents the total number of reflector patches along the x- and y-axes, respectively, and represents the number of reflector elements. The distortion of the radiation pattern caused by the thick car window glass at 28 GHz can be efficiently reduced by adjusting the reflector's specifications. The following design objectives were set for this work: a glass substrate thickness of 3.2 mm, a glass operating centre frequency of 28 GHz, a bandwidth of more than 850 MHz, a reflection coefficient of less than 10 dB, a bore-sight gain of more than 0 dBi, and LP.The proposed antenna was modelled and optimised using the CST Studio Suite full EM simulator to meet the objectives. Table 1 lists the optimised design parameters.

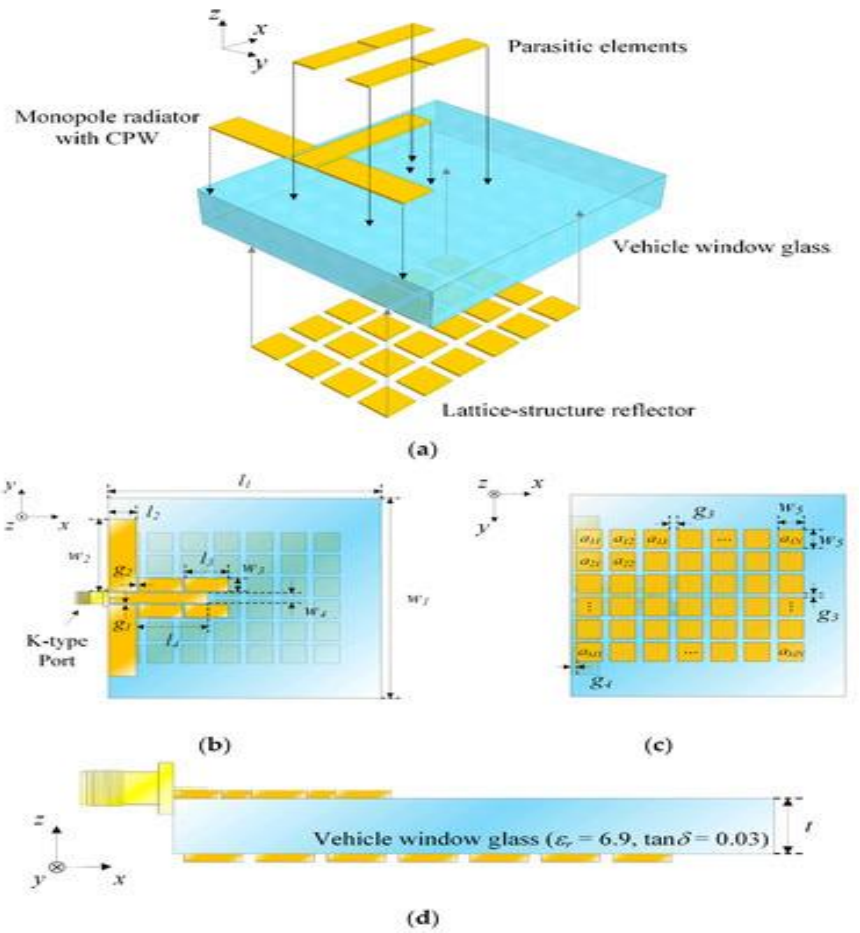

Figure 1 shows the proposed printed antenna's geometry in isometric, top, bottom, and side views.

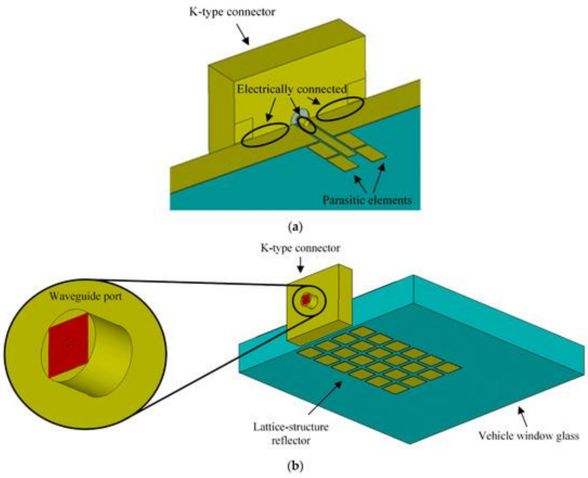

Figure 2. The real connector model in the CST EM modelling software with a waveguide port: (2) a waveguide port excitation portion, (3) a feeding connection component.
Table 1 lists the proposed antenna's optimal design parameters.
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Measurement and Production:

Photos of the constructed 5G monopole antenna with parasitic components and a lattice-structure reflector mounted on a car window are shown in Figure 3. The fabrication or printing of glass antennas on vehicle glass often involves the use of an epoxy resin glue or the silk-screening technique [17]. However, these techniques have poor manufacturing accuracy, poor conductivity in the electrical connection, and poor thermal endurance in the production of the glass antenna. The proposed antenna is made by etching the copper layer and using a thermosetting glue to firmly adhere the copper patterns to the glass of a vehicle window in order to address these issues. The inner and outer wires of the feeder are soldered to CPW, and the suggested antenna is directly fed by the K-type (2.92 mm) connector. Note that in the simulation settings, the CPW is fed at the starting positions of the inner and outer wires to model and excite the actual K-type connector. The lattice-structure reflector patches are printed on the bottom of the car window glass, which is electrically insulated from the antenna feeder. The manufactured antenna is measured in a fully anechoic laboratory to determine its parameters, such as gains, reflection coefficients, and radiation patterns, in order to ensure its viability.The suggested antenna is supported in the anechoic chamber's air using a jig with a low dielectric constant, and the cable is linked to the K-type connection using the jig to reduce the impacts of the cable. Additionally, as shown in Figure 4, the thick car window glass substrate is measured to acquire the specific EM characteristics in accordance with the measurement setup's frequency. At 28 GHz, the measured values for the loss tangent (tan) and dielectric constant (r) are 6.9 and 0.017, respectively. The measured values are then used as input parameters in a simulation of the suggested antenna.The suggested antenna's measured and modelled reflection coefficients are shown in Figure 5 as solid and dotted lines, respectively. The values at 28 GHz are 20 dB and 15.6 dB, respectively, and the measured and simulated reflection coefficients accord well.The suggested antenna's bore-sight gain is shown in Figure 6 both with and without parasitic components. The simulation result of the vehicle window glass antenna without the parasitic elements is 0.3 dBi, in contrast to the measured and simulated bore-sight gains of 2 dBi and 1.6 dBi at 28 GHz for the suggested antenna. In addition, depending on the presence or absence of the proposed parasitic elements, the gain bandwidth over 0 dBi increases from 1.7 GHz to 3 GHz.Due to the substantial dielectric loss of the thick vehicle glass, the gain of the suggested antenna appears to be a little lower than that of typical monopole antennas. It produces a radiation efficiency of 33.68% at 28 GHz, although this radiation efficiency can be raised when the antenna substrate's dielectric loss is reduced.In Figure 7, the solid line and dashed line represent the observed and simulated results, respectively, for the radiation patterns in the zx- and zy-planes at 28 GHz and 29 GHz.At 28 GHz, the zx- and zy-plane observed half power beam widths are 42° and 64°. At angles of 25° and 1° in the zx- and zy-planes at 28 GHz, the greatest gains measured are 2.3 dBi and 2.1 dBi, respectively. The calculated radiation patterns at 29 GHz and the measured radiation patterns correlate fairly well.Figure 8 shows the proposed antenna's 3D radiation patterns for each frequency to observe the highest gains.At 26 GHz, 28 GHz, and 30 GHz, the suggested antenna's maximum gains are 0.3 dBi, 3.2 dBi, and 3.4 dBi, respectively. As shown in Table 2, the suggested antenna's parameters, including its operating frequency band, maximum gain, dimensions, and substrate material, are contrasted with those of prior studies to determine its viability.

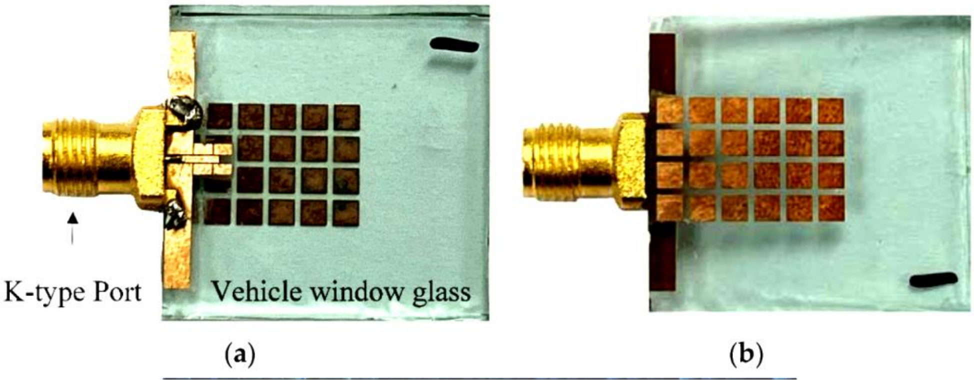

Figure 3 shows images of the suggested measurement and antenna arrangement. top view, bottom view, and measurement setup, in that order.

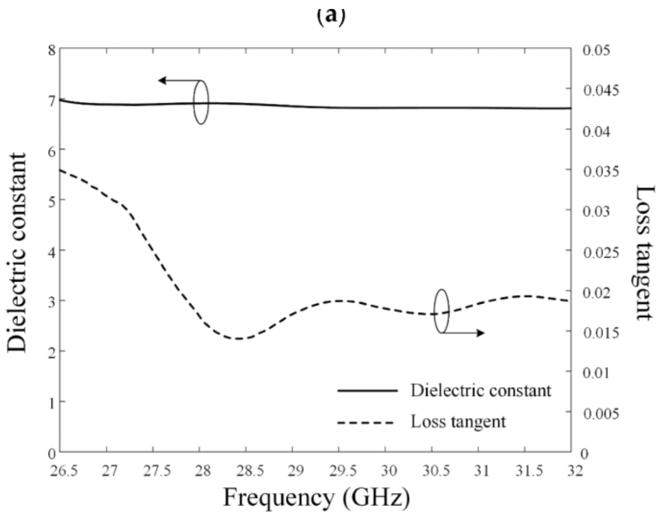

Figure 4 shows the thick car window glass substrate's measured EM properties, including (a) loss tangent and dielectric constant.

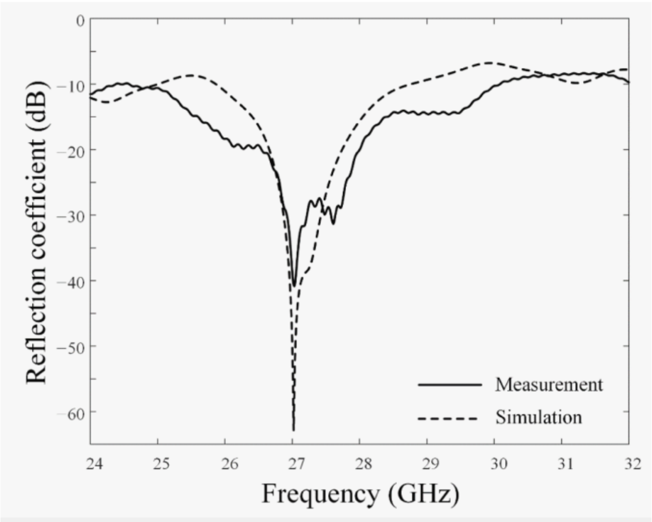

Figure 5 shows the proposed antenna's reflection coefficient.

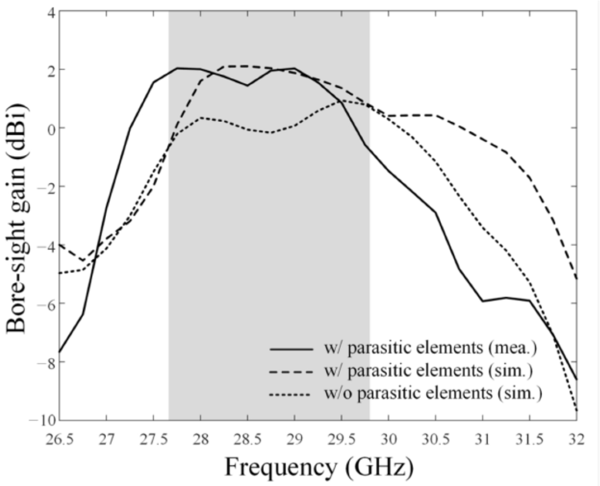

Figure 6 shows the proposed antenna's measured and simulated bore-sight gains with and without parasitic elements.

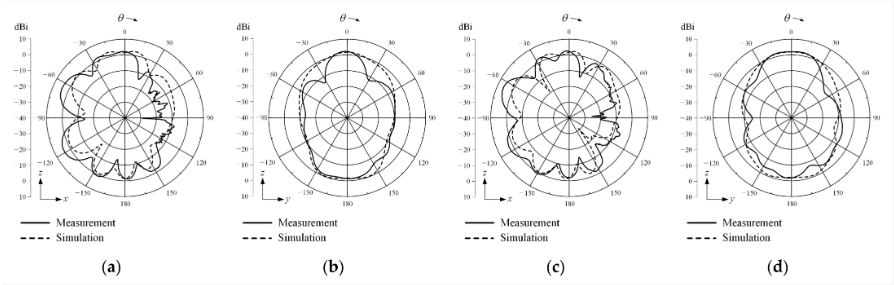

Figure 7 shows the proposed antenna's measured and simulated radiation patterns. (A) zy-plane at 28 GHz; (B) zx-plane at 29 GHz; (C) zx-plane at 29 GHz.

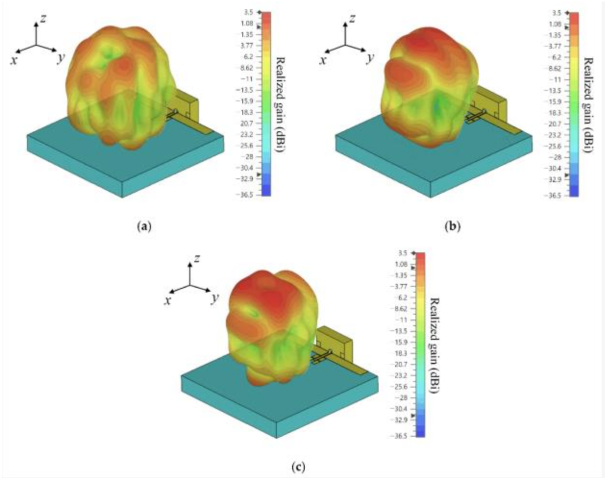

Figure 8 displays three-dimensional patterns at 26 GHz, 28 GHz, and 30 GHz.

Research	**Frequency Band**	**Maximum Gain**	**Antenna Dimensions (Width × Length × Thickness)**	**Substrate Material**
[17]	108–130 MHz	−7.47 dBi	850 × 480 × 3 mm3	Glass
[18]	112.5–130 MHz	−7.58 dBi	1.2 × 0.42 m2 (width × length)	Glass
[26]	88–106 MHz	-	52.6 cm (width)	Glass
[27]	4.66–11.84 GHz	−0.15 dBi	50 × 17 × 1 mm3	Glass

Research	Frequency Band	Maximum Gain	Antenna Dimensions (Width × Length × Thickness)	Substrate Material
[28]	24–30.6 GHz	>5 dBi	40 × 24 × 1.6 mm3	FR-4
[29]	25–30 GHz	>8 dBi	20 × 16 × 0.508 mm3	Nelco NY9220
Proposed antenna	24.6–30 GHz	2 dBi	25 × 25 × 3.2 mm3	Glass

Analysis and verification (2.3)

Figure 9 displays the results of the bore-sight gain based on the quantity of reflector patches. To observe the gain characteristics of the suggested antenna, the M and N values were changed from 3 to 9. When the patches of the lattice-structure reflector are placed in a 4 6 (M N) planar array, the maximum bore-sight gain of 1.6 dBi is observed. To achieve the best bore-sight gain, we further investigate the gain characteristics by adjusting various reflector patch parameters.The bore-sight gain according to the distance between and breadth of the reflector patches is shown in Figure 10a. The bore-sight gain is seen to be in the ranges of 1.5 mm w5 2.5 mm and 0.1 mm g3 0.9 mm in the fixed 4 6 (M N) setup. The bore-sight gain is often improved by increasing the reflector patch width whereas the bore-sight gain is typically decreased by increasing the gap. As shown in Figure 10b, these parameters can also be used to modify the reflection coefficients for impedance matching properties. Impedance matching for the suggested antenna is improved when w5 is less than 2 mm and g3 is greater than 0.5 mm.The results show that 2 and 0.5 millimetres are the best values for the lattice-structure reflector's parameters w5 and g3, respectively. A patch width of w5 can also increase bore-sight gain by reducing pattern distortion, and w3 is another important design parameter that can change the proposed antenna's impedance matching properties. In order to observe the effects of the vehicle platform, we also simulate the suggested antenna mounted on an actual car model.According of the limited computational resources, the partial vehicle model, where the dimensions were over 20 wavelengths at 28 GHz, is utilised to analyse the radiation characteristics of the suggested antenna.Figure 11a shows the calculated 3D radiation patterns for the proposed antenna mounted on the front, back, left, and right windows of the vehicle. The suggested antenna's radiation patterns are comparable to those of a stand-alone antenna, however as can be seen in Figure 11b, there are minor oscillations brought on by the ground effect.The outcomes show that the parasitic elements and the lattice-structure reflector can be optimised to achieve high gain performance for the proposed antenna for 5G communication in vehicle applications.

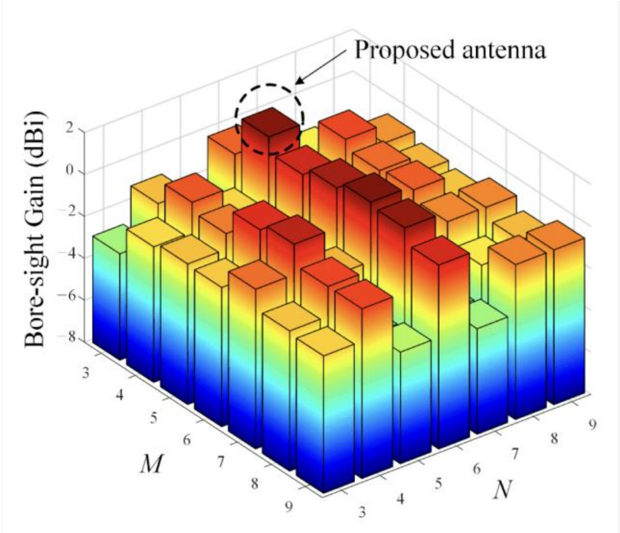

Figure 9 shows differences in bore-sight gain according on reflector count.

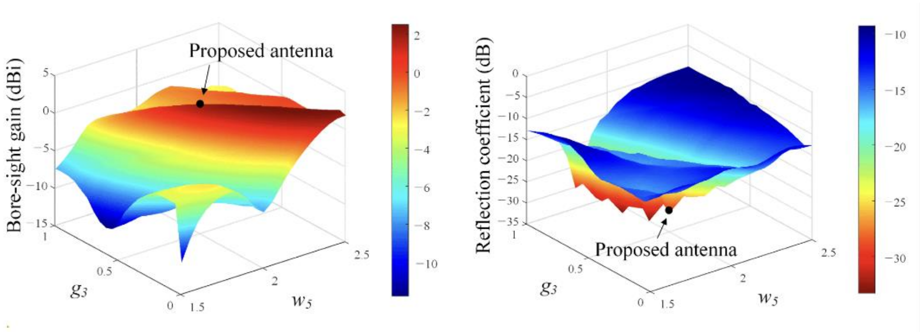

Figure 10 shows the fluctuation of the parameters w5 and g3 in relation to the bore-sight gain and reflection coefficient: (A) the gain in boresight; (B) the reflection coefficient.

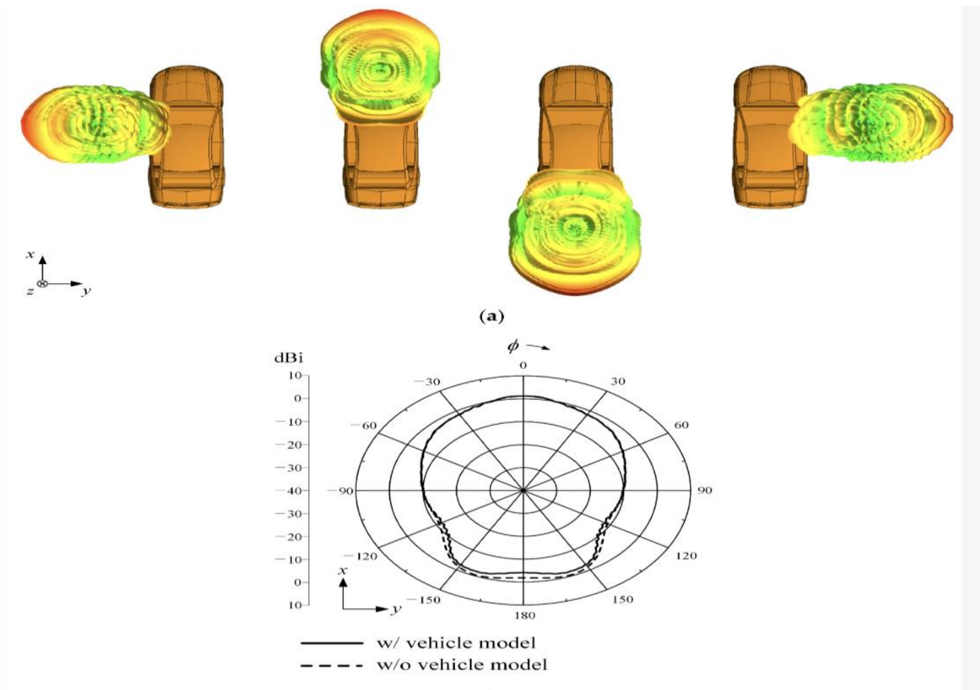

Figure. Simulated radiation patterns of the suggested antenna taking into account the impacts of the vehicle platform: (a) 2D radiation patterns with and without the vehicle mode, as well as 3D patterns based on the mount location.

CONCLUSIVE

This research analyses windscreen FM radio antennas over laminated glass materials of various thicknesses.

For Frequency Modulation (FM) radio communication in vehicles and other moving objects, a windscreen FM antenna is useful. The ferrite substrate reduced the antenna's resonance frequency by 80%.This research analyses windscreen FM radio antennas over laminated glass materials of various thicknesses.According to the findings, Material-1, which has a lower thickness, outperforms Materials with higher thicknesses. -2 Laminated glass composition.

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