

Article

Combined Shark-Fin Rooftop Antenna for LTE, WLAN and BeiDou Applications

Lingrong Shen, Wei Luo, Youming Miao and Gui Liu * 

College of Electrical and Electronic Engineering, Wenzhou University, Wenzhou 325035, China; 21451841021@stu.wzu.edu.cn (L.S.); 22451841025@stu.wzu.edu.cn (W.L.); 22461237086@stu.wzu.edu.cn (Y.M.)

* Correspondence: gliu@wzu.edu.cn

Abstract: This paper presents rooftop automobile antennas designed for Long-Term Evolution (LTE), Wireless Local Area Network (WLAN) and navigation system applications. The proposed antennas are housed within a shark-fin structure on the car's roof, and comprise a main antenna and a diversity antenna. The main antenna and diversity antenna combine for spatial diversity, receiving and processing the same signal to optimize signal quality. To accommodate the limited space within the shark-fin housing, various miniaturization and multiband techniques are utilized. The hexagonal substrate is more closely fitted to the shape of the shark fin, thus making full use of the space of the shark-fin shell. The main antenna and the diversity antenna are perpendicular to each other, which saves the space of the overall antenna and improves the utilization rate of the overall antenna space. The proposed main antenna, compactly sized at 50 mm × 20 mm × 1.59 mm, maintains a VSWR value below 2 across the frequency range of 1.19–2.8 GHz, enabling support for LTE bands 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, as well as WLAN 2400 bands. The diversity antenna maintains a VSWR value below 2 across the frequency range of 1.5–2.6 GHz, which can cover BeiDou B1-1, LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, and 40, and WLAN 2400 bands. The main antenna and the diversity antenna both demonstrate favorable radiation patterns on the azimuth plane. Simulation and measurement results exhibit a high level of agreement.

Keywords: automobile; combination antenna; LTE antenna; BeiDou antenna; shark-fin housing



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1. Introduction

In recent years, there has been significant advancement in vehicle antenna technology to meet the growing demand for signal reception while driving. The evolution of vehicle antennas has transitioned from traditional retractable or whip antennas to the more advanced shark-fin antennas. Shark-fin antennas are aerodynamic structures commonly installed on vehicles to accommodate GPS, cellular communication, and radio reception antennas. Their streamlined design not only improves the vehicle's aesthetic appearance, but also minimizes drag. These antennas operate across multiple frequency bands, effectively dissipate static electricity, and can even serve as functional aerodynamic spoilers. As a result, they provide a multitude of advantages in terms of vehicle communication and overall aesthetic. These onboard antennas effectively cater to the requirements of various communication systems such as LTE, BeiDou (Beidou Navigation Satellite System), and car-to-car (C2C) communication. This technological progression in vehicle antennas ensures reliable and efficient signal reception for a range of applications while maintaining the aesthetic and functionality of the vehicle. The utilization of both a main antenna and diversity antenna effectively boosts the reliability of signal transmission. Diversity technology plays a crucial role in mitigating the negative effects of fading channel loss by leveraging the uncorrelated characteristics found among multiple instances of the same signal in wireless propagation environments. By employing various signal combination techniques, diversity technology effectively amplifies the received signal, minimizing the detrimental impacts caused by

fading phenomena in wireless communication systems. Its implementation significantly enhances signal reliability and overall system performance.

Complexities and material selection must be considered in the mass production of on-board antennas. Antenna shape is also significant: antennas without a base can be divided into three-dimensional model antennas and plane antennas. The work proposed by [1] introduces a three-dimensional compact antenna, incorporating two planar inverted-F antennas (PIFAs) and two modified planar monopoles to cover diverse bands, including 850 MHz, 1570 MHz, 2.4 GHz, and 5.9 GHz. The antenna showcased in [2] features a PIFA with a broad frequency band. The design of the antenna, as presented in [3], is tailored for 5G Sub-6 GHz, LTE, WLAN, and Vehicle-to-Everything (V2X) applications, comprising four dielectric-loaded wideband horns, a common top plate, an annular slot, and four shorting pins. Furthermore, ref. [4] introduces a multi-frequency band antenna PIFA, whereas [5] proposes a multi-wideband monopole antenna for automotive applications in LTE and 5G systems. Additionally, an innovative compact 3D antenna, combining a PIFA and an integrated folded monopole, is designed to operate within the frequency range of 790–2690 MHz, as outlined in [6]. Finally, a single-feed antenna featuring a compact and robust metal structure, capable of operating in a wide frequency band that includes LTE, WiFi/WLAN, and C2C communication services, is introduced in [7]. In reference [8], a helical antenna tailored for Cellular Vehicle-to-Everything (C-V2X) communication is produced and integrated near the car's high mount stop light (CHMSL) area in a Ford SUV. Another antenna, detailed in reference [9], is designed for an unmanned aerial vehicle and features a null-filled axisymmetric secant-square-shaped beam. It consists of four monopoles with sequentially rotated feeds, in addition to a coupling-fed grooved circular patch. Reference [10] presents a 5G-based V2X communication MIMO 10×10 antenna operating below 6 GHz. This antenna incorporates optimally configured cross-polarized antennas and is specifically engineered for mounting on the vehicle roof, operating at a frequency of 4.6 GHz. Meanwhile, the antenna design discussed in reference [11] utilizes short bow tie patches with an air gap. The top-loaded dual monopole along the air gap is placed in a small public biplane, making it suitable for the polarization direction and diversity requirements of mobile radio systems. In response to the challenges posed by the intricate shapes of these 3D structured antennas for mass production, simpler copper-clad antennas have been developed. Notably, two monopoles, namely Shorted Monopole and Drop Monopole, operate at frequencies ranging from 698 MHz to 960 MHz and 1.7 GHz to 2.7 GHz, respectively, as highlighted in [12]. Furthermore, ref. [13] exhibits four DSRC antenna elements integrated into an existing rooftop quad band antenna module. A wide-beam circularly polarized (CP) asymmetric microstrip antenna with four unequal circular patches for GNSS applications is proposed in [14]. In addition, ref. [15] utilizes grounded and parasitic radiating elements, meandered radiating elements, and lumped elements in an integrated shark-fin antenna. An L-sleeve L-monopole (LSLM) antenna for vehicular LTE communication is introduced in [16], and ref. [17] presents a double-sided planar dipole configuration with a single port for GSM, LTE, and Wi-Fi communication systems. Vehicular IEEE 802.11a utilizes an improved Vivaldi antenna with planar directors and transverse slots, as detailed in [18]. Lastly, ref. [19] proposes a multiband polarized antenna based on two half Vivaldi antennas and a slot antenna for V2X communication. Reference [20] presents a novel approach for implementing a filtering series-fed V2X antenna that consists of two radiators connected to a double-sided parallel strip line (DSPSL). The DSPSL functions as the series feed structure and the primary resonator. Additionally, a new design methodology is proposed for a dual-band antenna with polarization and pattern diversity tailored for vehicle communications. This design includes a monopole array, a swastika-shaped patch with gap coupling, and a customized L-shaped driven dipole as essential components [21].

In this study, we focus on an integrated shark-fin antenna designed specifically for LTE and BeiDou applications. To address the challenge of limited space within the shark-fin housing, we apply various miniaturization and multiband techniques. These include the strategic use of grounded and parasitic radiating elements, meandered radiating elements,

and lumped elements. Through these technical enhancements, the main antenna is capable of covering LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands, while the diversity antenna is designed to support frequencies within the range of 1.5–2.6 GHz, which can cover BeiDou B1–11560 MHz, LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands with a VSWR value below 2. The integration of both the main antenna and the diversity antenna serves the purpose of achieving spatial diversity. By utilizing two antennas, the system can receive the same signal simultaneously and process them to obtain the optimal signal quality. This combination enhances signal reception capabilities and improves overall performance by mitigating the effects of signal fading and interference.

The second section elucidates the operational status and evolutionary trajectory of both the primary antenna and the diversity antenna. Subsequently, the third segment details the manufacturing process and measurement procedures of the antenna, encompassing various parameters such as directional patterns, gain, and efficiency, among others, with a comprehensive description provided. A comparative analysis is conducted, considering the antenna's performance, size, and other attributes against those of a reference antenna. Finally, the fourth section encapsulates a comprehensive overview of the antenna's overall performance and characteristics.

2. Design of the Combination Antenna

Figure 1 illustrates the overall structure and dimensions of the proposed antenna. The configuration is devised to accommodate both the main antenna and the diversity antenna within the shark-fin housing. The main antenna serves the dual purpose of transmitting and receiving signals, while the diversity antenna is solely responsible for signal reception. Diversity antenna technology is a crucial anti-fading technique that significantly enhances the reliability of transmission in multipath fading channels. Diversity reception involves two essential elements: effectively isolating received multipath signals to ensure their lack of correlation and appropriately combining these isolated signals to maximize the signal-to-noise ratio. The combination of the main antenna and diversity antenna provides spatial diversity, as both antennas receive the same signal for processing in order to obtain optimal signal quality. When the uplink signal from the mobile station (MS) is transmitted to the antenna, both the main and diversity antennas can receive the signal simultaneously. As a result, two signals are available, and the base station employs a discriminator to select the optimal signal for further processing and mediation.

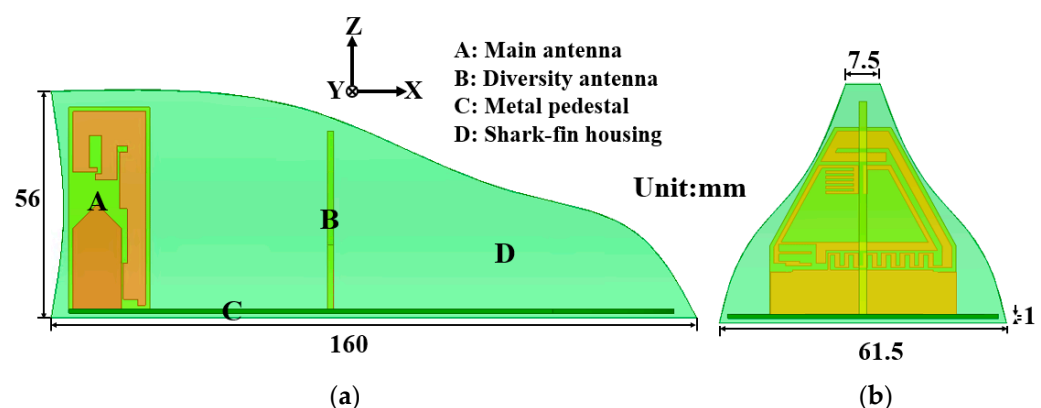


Figure 1. Overall structure and dimensions of the proposed antenna. (a) Side view, (b) front view.

The main antenna and the diversity antenna are denoted as A and B, respectively. The copper-clad ground plane and the shell of the shark-fin housing are denoted as C and D, respectively. Both antennas are printed on FR-4 substrates with a thickness of 1.59 mm, featuring a dielectric constant (ϵ_r) of 4.4 and a loss tangent ($\tan\delta$) of 0.02. To optimize space utilization and enhance isolation between the antennas, the main antenna and diversity antenna are mounted perpendicular to each other. The hexagonal substrate

A. Main Antenna

The figure illustrates the geometry of the test specimen, which has a total width of 20 mm and a total height of 50 mm. The specimen contains a central orange-colored notch and several yellow-colored regions labeled A through G. Key dimensions include:

- Overall Dimensions:** Width = 20 mm, Height = 50 mm.
- Notch Dimensions:** The notch at the bottom has a depth of 20 mm from the base. Its top width is 12 mm, and its bottom width is 3.5 mm. The notch is centered horizontally.
- Yellow Regions (A-G):** These regions are defined by various internal dimensions:
 - A:** Bottom right corner, 9 mm wide and 2 mm high.
 - B:** Top right corner, 8.5 mm wide and 2.5 mm high.
 - C:** Top left corner, 6 mm wide and 3 mm high.
 - D:** Middle right section, 11 mm wide and 1.5 mm high.
 - E:** Middle left section, 9 mm wide and 2 mm high.
 - F:** Bottom left section, 20 mm wide and 6 mm high.
 - G:** Central notch area, 14 mm wide and 2 mm high.
- Coordinate System:** A Cartesian coordinate system is shown to the right of the specimen, with the X-axis pointing right, the Y-axis pointing down (indicated by a circle with a cross), and the Z-axis pointing up.

Unit: mm

The evolution of the proposed antenna is depicted in Figure 3, showcasing the design process for the main antenna in case 1, case 2, and case 3. Simulated S_{11} values for the three cases are presented in Figure 4. In case 1, the antenna consists of an inverted Γ -shaped strip that resonates at 1.1 GHz. Introducing a grounded plane enhances bandwidth, leading to resonances at 1.1 GHz, 2.4 GHz, and 3 GHz in case 2, achieving three broad frequency bands. To further extend the operational bands and optimize impedance matching, additional components such as an L-shaped strip, an inverted L-shaped strip, and two rectangular strips are incorporated into the radiator design. Case 3 demonstrates the culmination of these enhancements, enabling the proposed antenna to cover an ultra-wideband spectrum from 1.19 to 2.8 GHz.

Figure 5 showcases the simulated current distributions at three resonance points, namely 1.45 GHz, 1.8 GHz, and 2.57 GHz. The results indicate that the longer feeding strip (section AB) is excited at its fundamental mode at 1.45 GHz. At 2 GHz, the feeding strip (sections ABCD and ABCE) is also excited at its fundamental mode, confirming that the first mode of the middle frequency band is predominantly contributed by the driven feeding strip. Notably, the ABC region of the antenna plays a crucial role in achieving impedance matching from 1.8 GHz to 2.4 GHz, as currents mainly flow in this area during these frequencies. At 2.57 GHz, a robust surface current is observed on both the longer feeding strip (section AB) and the grounded strip (section FG). This analytical process further validates the operational principle and the accuracy of the antenna design.

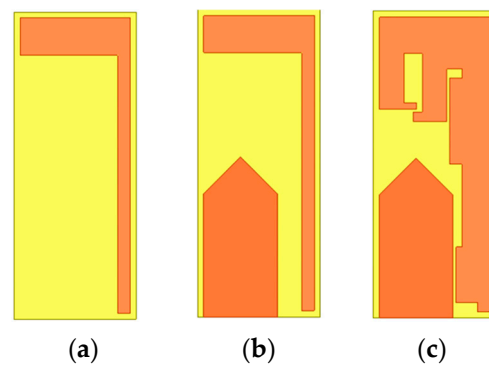


Figure 3. Evolution of the proposed antenna in (a) case 1, (b) case 2, and (c) case 3 (proposed).

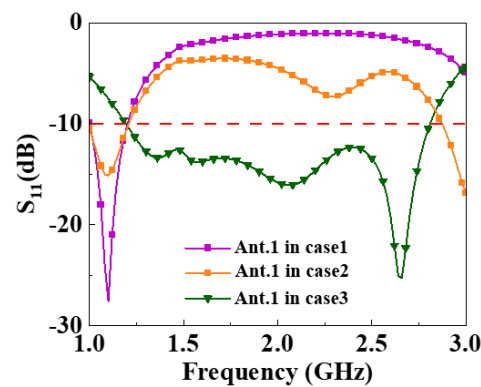


Figure 4. Simulated S_{11} values for the main antenna.

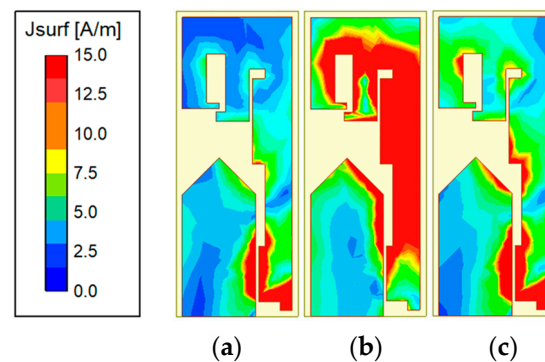


Figure 5. Current distribution of the proposed main antenna at (a) 1.45 GHz, (b) 1.8 GHz, and (c) 2.57 GHz.

Figure 6 illustrates the Voltage Standing Wave Ratio (VSWR) of the main antenna, which quantifies the effectiveness of RF power transmission from the power supply through the transmission line to the load. The VSWR values depicted in the figure indicate that within the frequency range of 1.19–2.8 GHz, the VSWR remains below 2. Typically, for antennas, a VSWR ranging between 1 and 2 is considered reasonable under normal operating conditions. Thus, the VSWR performance of the antenna aligns with the established standard criteria.

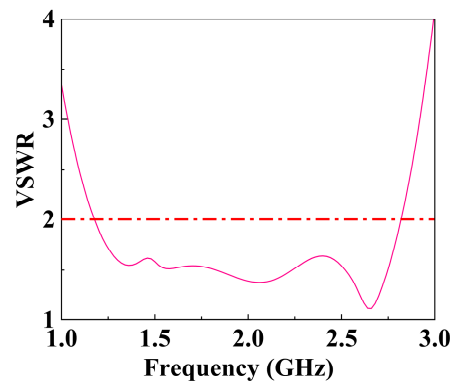


Figure 6. VSWR of the main antenna.

B. Diversity antenna

The configuration and dimensions of the proposed diversity antenna are presented in Figure 7. The antenna is fabricated on an FR-4 substrate with a thickness of 1.59 mm, featuring a unique shape that combines a cuboid overlay with an isosceles trapezoid body. The diversity antenna consists of three main components: a feeding strip, a grounded strip, and a feeding point. In Figure 7, the feeding point is denoted as A and is connected to a 50 Ω SMA connector. The feeding strip extends along the shape of the substrate and is labeled as AB/AC/AD. The grounded strip is represented as EF. On top of the rectangular shape, the frame of the grounded strip is folded. All dimensions are clearly marked in the figure, while any unmarked dimension can be assumed to be 1 mm.

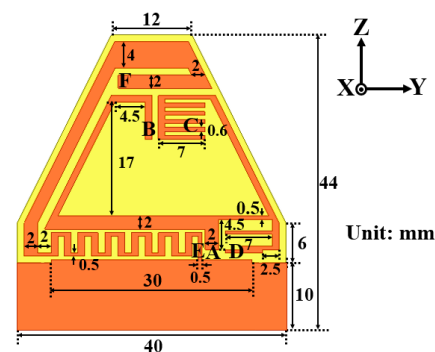


Figure 7. Geometry and dimensions of the proposed diversity antenna.

Figure 8 presents the evolutionary process of the proposed diversity antenna. It showcases the design progression through case 1, case 2, and case 3, while Figure 9 provides a comparison of the S-parameters for the different antennas proposed in Figure 8. In case 1, the initial design comprises a simple feeding strip and a rectangular ground plane. This configuration enables the antenna to operate at a frequency of 2.5 GHz, with a bandwidth of 0.3 GHz. Moving on to case 2, two additional feeding strips are introduced to the antenna design. The result shows that the antenna now exhibits two distinct frequency bands, operating at 2.25 GHz and 2.7 GHz, respectively. To further enhance the bandwidth and improve impedance matching, a long grounding strip with a folded structure is applied. This extended grounding strip is inserted near the feed of the antenna, resulting in an optimized response. The proposed diversity antenna provides coverage across a wide frequency band from 1.51 GHz to 2.6 GHz. Notably, the center frequency of 1.56 GHz corresponds to the BeiDou B1-1 band.

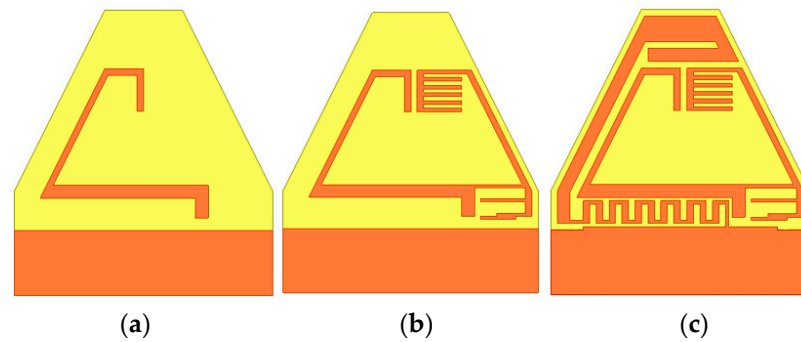


Figure 8. Evolution of the proposed diversity antenna in (a) case 1, (b) case 2, and (c) case 3 (proposed).

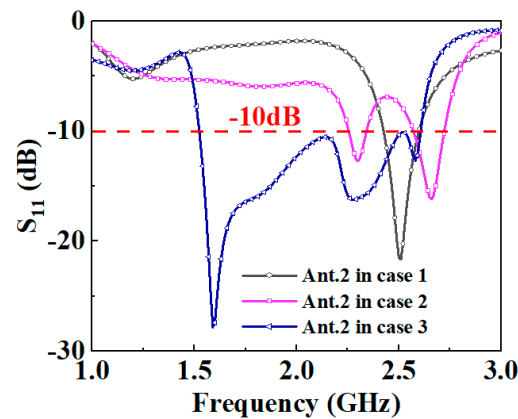


Figure 9. Simulated S-parameters for the three different cases of the diversity antenna.

Figure 10 showcases the current distribution at different frequency bands. In Figure 10a, the folded section of the grounded strip primarily functions at 1.56 GHz. Moving to Figure 10b, the interaction between the folded portion of the grounded strip and the adjacent feeding strip harmonizes at 1.8 GHz. Finally, Figure 10c highlights the feeding strip section as the main contributor, operating effectively at 2.57 GHz.

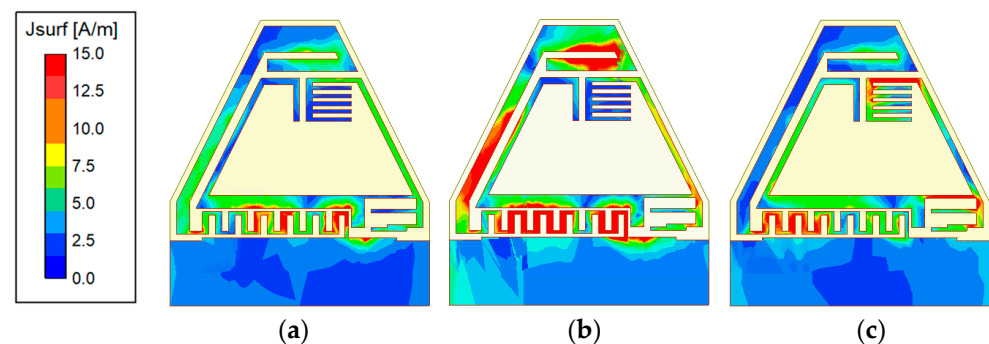


Figure 10. Current distribution of the proposed diversity antenna at (a) 1.56 GHz, (b) 1.8 GHz, and (c) 2.57 GHz.

Figure 11 depicts the Voltage Standing Wave Ratio (VSWR) performance of the diversity antenna. The VSWR values illustrated in the figure indicate that within the frequency range of 1.15–2.6 GHz, the VSWR remains below 2, aligning with the standard criteria for antenna performance.

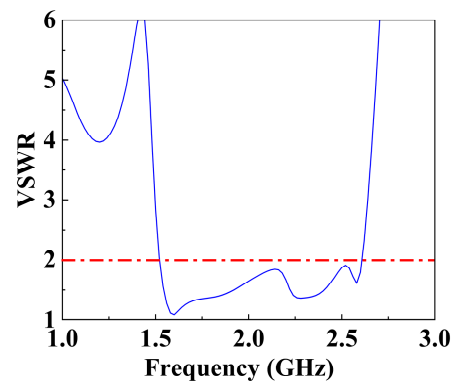


Figure 11. VSWR of the diversity antenna.

3. Fabrication and Measurement

To validate the performance of the proposed design, a prototype was fabricated, as depicted in Figure 12a. The S-parameters of the antenna were measured using a Keysight Vector Network Analyzer (VNA) with model number N5224A. Additionally, the far-field radiation parameters, including pattern, gain, and efficiency, were tested within an anechoic chamber, as shown in Figure 12b.

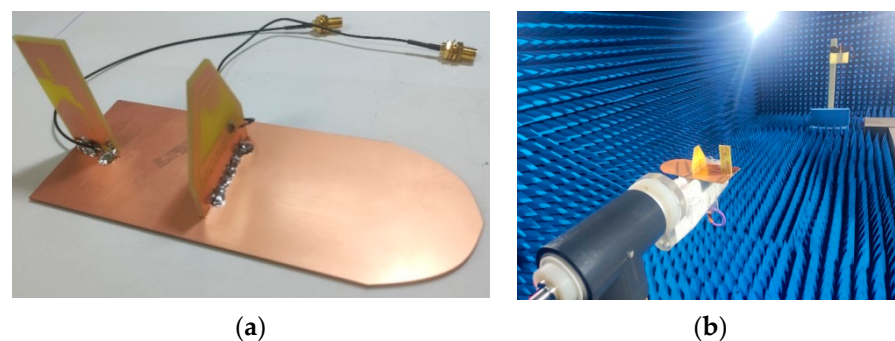


Figure 12. Photographs of the experimental setup. (a) Fabricated prototype. (b) Anechoic chamber.

It is essential to highlight that the S-parameters and far-field radiation parameters were obtained by connecting both antennas and conducting individual measurements while terminating the other antenna with a $50\ \Omega$ load. This method ensured the precise characterization of the antennas' performance under realistic operating conditions, facilitating a comprehensive evaluation of their behavior in a connected configuration. This configuration allows for the accurate characterization of the antennas' performance.

Figure 13 presents the simulated and measured reflection coefficients of the main antenna and diversity antenna. In Figure 13a, it is evident that the main antenna offers a -10 dB impedance bandwidth ranging from 1.19 to 2.8 GHz, effectively covering LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands. On the other hand, the diversity antenna exhibits a -10 dB impedance bandwidth spanning 1.51–2.6 GHz, which can cover BeiDou B1-11560 MHz band, LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands. The general trends observed in the simulation and measurement results are consistent. Discrepancies between the measurements and simulations are attributed to the high loss tangent of the low-cost FR-4 substrate and fabrication tolerances. Furthermore, as depicted in Figure 13c, the mutual coupling between the LTE antennas exceeds 15 dB across the entire operating frequency bands. Additionally, the isolation between the two antennas can be further improved by increasing their separation distance. In MIMO applications, the envelope correlation coefficient (ECC) is commonly employed to assess channel capacity and cross-correlation performance. As depicted in Figure 13d, the simulated ECC of the proposed MIMO antennas remains below 0.2 across the entire LTE band. This level of ECC

for MIMO antenna diversity is considered acceptable in practical terms [16]. The ECC value can be calculated using the following formula:

$$ECC = \frac{|S_{ii}^* S_{ij} + S_{ji}^* S_{jj}|^2}{(1 - |S_{ii}|^2 - |S_{ji}|^2)(1 - |S_{jj}|^2 - |S_{ij}|^2)} \quad (1)$$

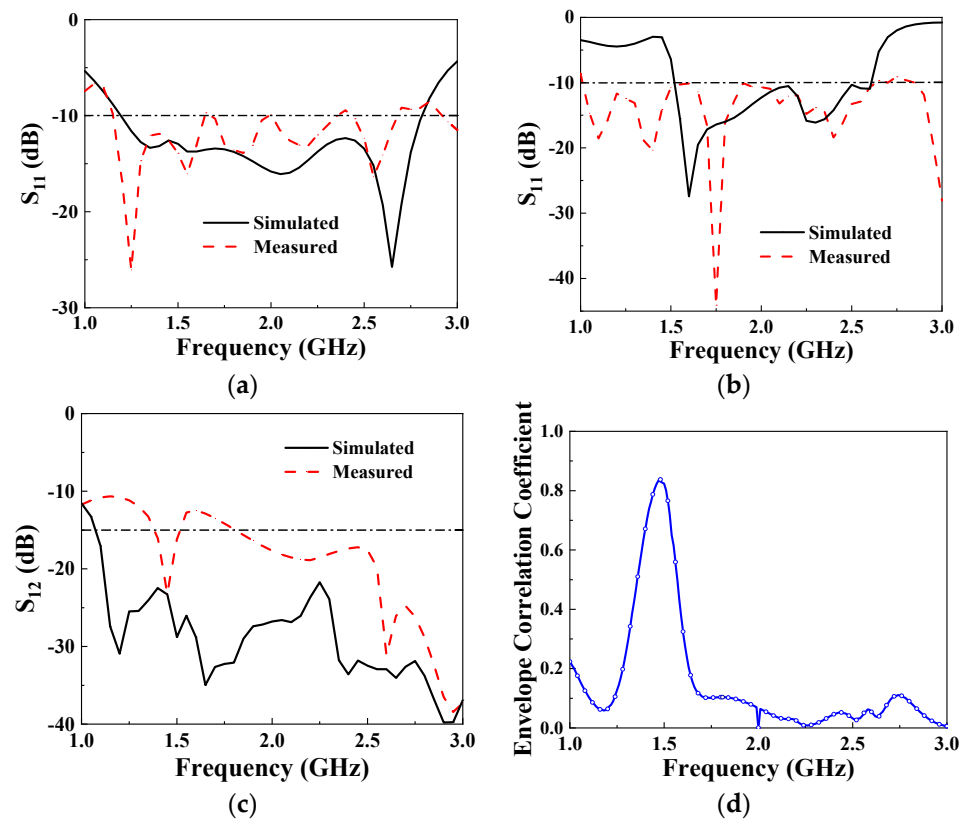


Figure 13. Simulated and measured S-parameters and simulated ECC of the proposed antennas. (a) Main antenna. (b) Diversity antenna. (c) Mutual coupling (S_{12} parameter). (d) ECC of the proposed antennas.

The antennas' far-field radiation patterns for LTE communication at various frequencies are illustrated in the following figures. Figures 14 and 15 display the simulated and measured far-field radiation patterns of the main antenna at four specific frequencies (1.45, 1.8, 2.4, and 2.57 GHz) in the H-plane and E-plane, respectively. The frequencies can support LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands. The radiation pattern observed in the H-plane exhibits omnidirectional characteristics, while the pattern in the E-plane demonstrates an acceptable performance. Similarly, Figures 16 and 17 present the simulated and measured far-field radiation patterns of the diversity antenna at four different frequencies (1.56, 1.8, 2.4, and 2.57 GHz) in the H-plane and E-plane, respectively. The diversity antenna is designed to support frequencies within the range of 1.5–2.6 GHz, which can cover BeiDou B1-11560 MHz, LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands. The radiation pattern in the H-plane indicates omnidirectional behavior, while the pattern in the E-plane shows satisfactory performance. Notably, as the main antenna, the proposed diversity antenna achieves excellent omnidirectionality on the horizontal plane.

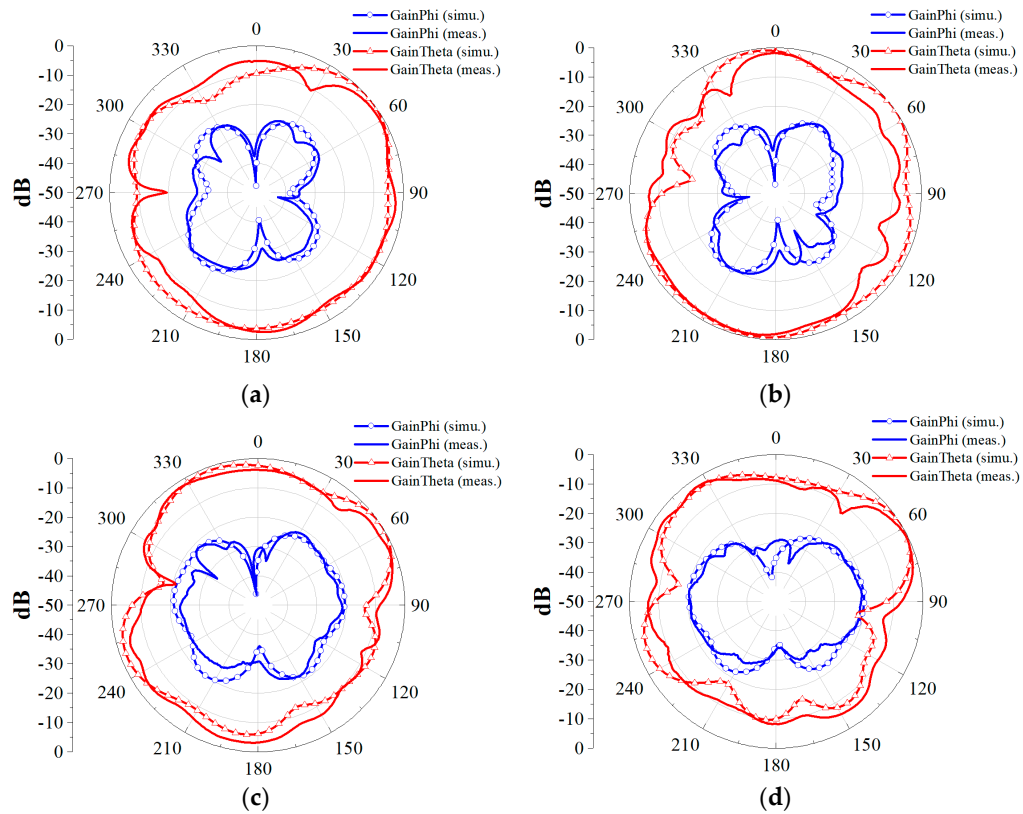


Figure 14. Simulated and measured radiation patterns of the proposed main antenna at H-plane: (a) 1.45 GHz, (b) 1.8 GHz, (c) 2.4 GHz, (d) 2.57 GHz.

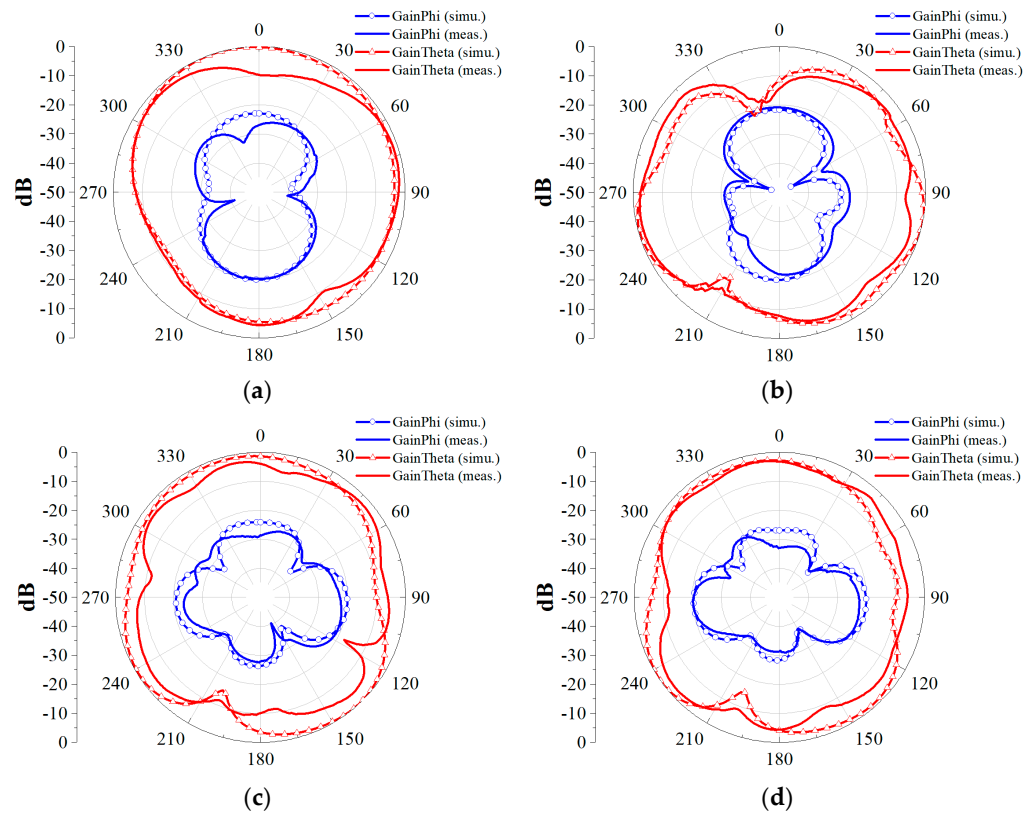


Figure 15. Simulated and measured radiation patterns of the proposed main antenna at E-plane: (a) 1.45 GHz, (b) 1.8 GHz, (c) 2.4 GHz, (d) 2.57 GHz.

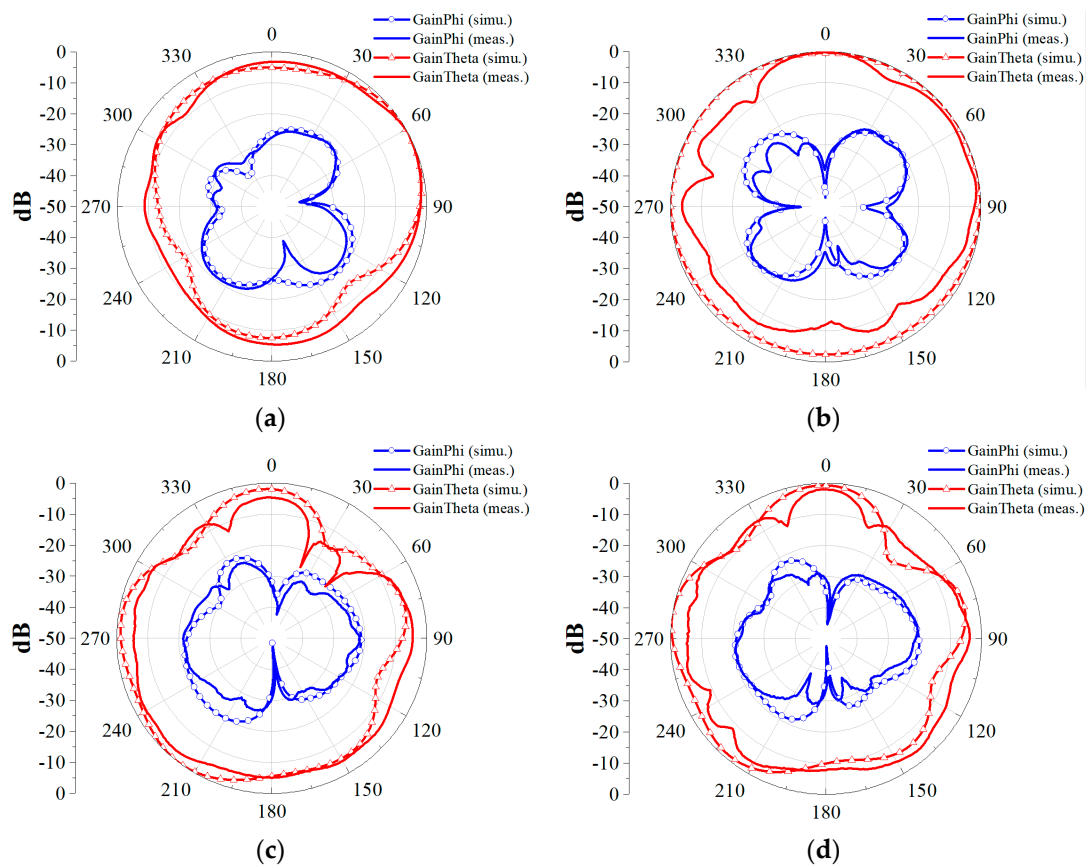


Figure 16. Simulated and measured radiation patterns of the proposed diversity antenna at H-plane: (a) 1.56 GHz, (b) 1.8 GHz, (c) 2.4 GHz, (d) 2.57 GHz.

Figure 18 showcases the simulated and measured efficiency and gain of both the main antenna and diversity antenna. The main antenna exhibits an efficiency range from 65% to 99% across the entire frequency band (1.19–2.8 GHz), with corresponding gains varying from 0.1 to 4.5 dBi for the same frequency range. Similarly, the diversity antenna displays an efficiency range from 65% to 99% over the whole frequency band (1.5–2.6 GHz), with corresponding gains varying from 0.1 to 4.6 dBi. Given the compact size of the antenna and the finite effective radiated area, the demonstrated efficiencies and gains of the system are deemed acceptable.

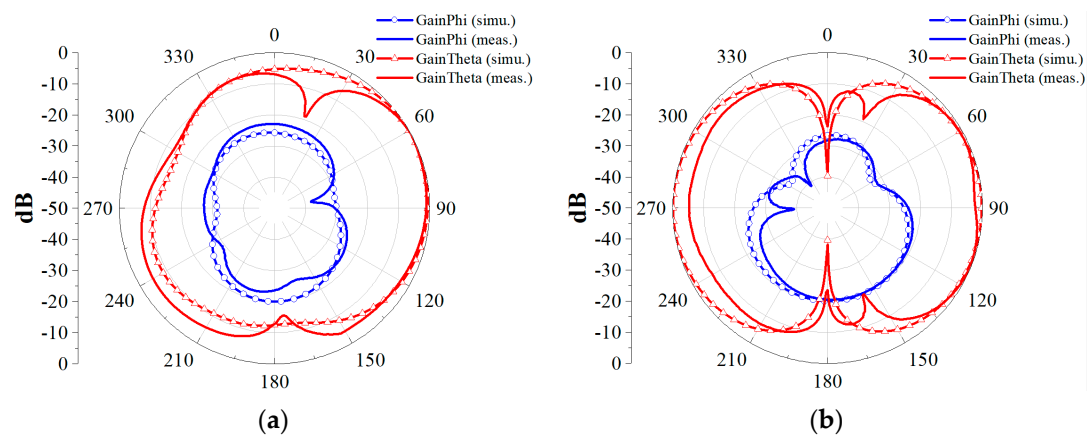


Figure 17. Cont.

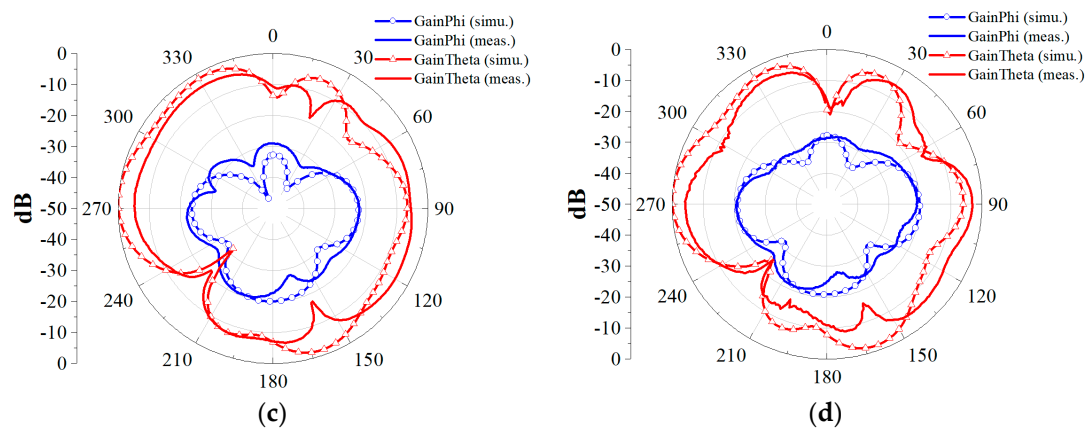


Figure 17. Simulated and measured radiation patterns of the proposed diversity antenna at E-plane: (a) 1.56 GHz, (b) 1.8 GHz, (c) 2.4 GHz, (d) 2.57 GHz.

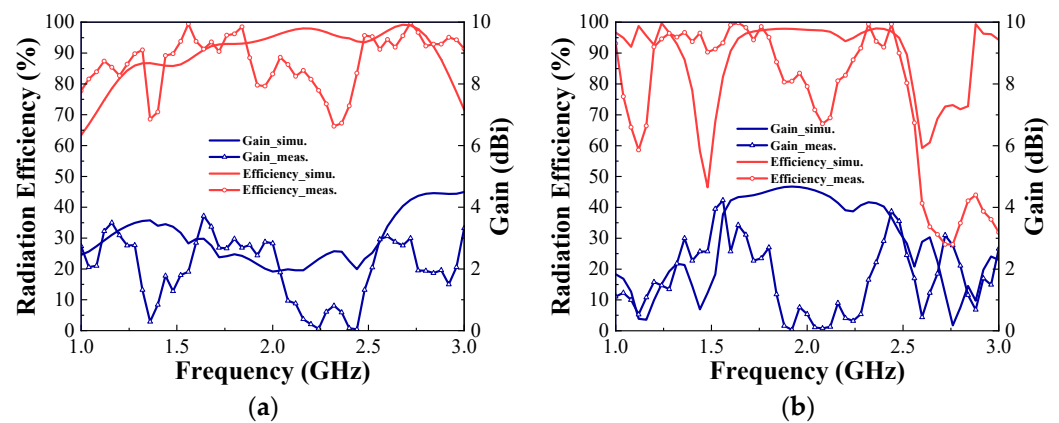


Figure 18. Simulated and measured efficiency and gain of the proposed antennas. (a) Main antenna. (b) Diversity antenna.

Table 1 provides a comparison of the antenna parameters between the proposed antennas and previous studies. It is apparent that the proposed antennas offer a more compact size than other antennas. Furthermore, when compared to the antennas discussed in references [15,16], the proposed antennas demonstrate superior performance, as indicated by a return loss parameter of -10 dB. Additionally, they exhibit a broader operating frequency band compared to the antenna referenced in [17]. Moreover, the isolation of the proposed antennas is relatively strong, achieving -15 dB. In summary, the overall performance of the proposed antennas is significantly superior to previous designs.

Table 1. Performance comparison with recently published work.

Reference	Operating Frequency (GHz)	Minimum Isolation (dB)	Gain (dBi)	Size (mm ³)
[15]	1.71–2.69 (-6 dB)	>11	5	$55 \times 25 \times 2$
[16]	0.698–2.7 (-6 dB)	>20	5.8	$66 \times 52 \times 0.8$
[17]	1.7–2.7 (-10 dB)	>13	4.27	$100 \times 37 \times 1.6$
This work	1.19–2.8 (-10 dB)	>15	4.6	$50 \times 20 \times 1.59$

4. Conclusions

This research paper presents a novel roof-mounted automobile antenna specifically designed for LTE and navigation system applications. The antenna is housed within a sleek

shark-fin structure positioned on the car's roof, and it comprises a primary antenna for communication and a diversity antenna. To address the space limitations within the shark-fin housing, various miniaturization and multiband techniques are employed in the antenna design. These techniques include the use of grounded and parasitic radiating elements, meandered radiating elements, and lumped elements. One notable achievement of this study is the development of a compact main antenna measuring only 50 mm × 20 mm × 1.59 mm, which provides coverage across a wide frequency range from 1.19 GHz to 2.8 GHz, covering LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands. The diversity antenna can cover 1.5–2.6 GHz within the range of 1.5–2.6 GHz, which can cover BeiDou B1–11560 MHz, LTE 1, 2, 3, 4, 7, 11, 15, 16, 34, 39, 40, and 41, and WLAN 2400 bands. The main and diversity antennas both exhibit desirable radiation patterns on the azimuth plane. A significant advantage of these antenna designs is their seamless integration into the printed circuit board, utilizing planar-printed antennas. This integration not only enhances the performance and efficiency of the antenna system but also results in a substantial reduction in manufacturing costs. Simulation and measurement results demonstrate a high degree of agreement, effectively validating the proposed design. Overall, this research contributes to the advancement of LTE and navigation system technologies in automobiles by presenting an innovative and efficient roof-mounted antenna solution.

Author Contributions: Conceptualization, L.S. and W.L.; methodology, W.L.; data curation, L.S. and Y.M.; investigation, Y.M.; measurement, L.S. and W.L.; writing—original draft preparation, L.S.; writing—review and editing, G.L.; supervision and funding acquisition, G.L. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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