Simulation Design of Wi-fi/5G Dual-Frequency Vehicle Antenna Based on Computer Aided Technology

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Abstract. In recent years, the automobile and train industry in our country has made amazing progress both in quantity and in industry technology and technology, thus giving birth to the tireless pursuit of on-board antenna. As the Wi-Fi/5G network becomes more popular, we enjoy a wider coverage, faster speed, more smooth experience of the network, car-mounted antennas can also be changed to bring new surprises. In this paper, the dual-frequency vehicle antenna is designed from the perspective of appearance, shape, size and simulation by using computer technology, and the feasibility conclusion is drawn.

Keywords: Bual-band, On-board Antenna, Design, Computer Aided Technology

1. Introduction

With the continuous development of science and technology, modern communication technology is also constantly improving. For electronic communication equipment, miniaturization has become its continuous pursuit. The ability to deal with information is also increasingly intelligent, broadband. Antenna, as one of the essential equipment of various civil and military radio systems, such as radio communication, broadcasting, navigation, radar, measurement and control, microwave remote sensing, radio astronomy and electronic confrontation, is playing an increasingly important role. The main function of the antenna is to complete the conversion between the electromagnetic wave and the guided traveling wave in the receiving system or to make the opposite transformation in the transmitting system[1]. Micro-strip antenna has the advantages of light weight, small volume, thin section and small scattering section, which is very common, but the narrow frequency band has always been a defect.

A normal micro-strip patch antenna has a relative bandwidth of 0.5~3%, thus limiting the practical application of antennas in engineering[2]. A novel broadband dual-band antenna is designed and simulated in order to extend the antenna bandwidth and reduce the size of the antenna, and considering
that in many applications, it is hoped that the antenna can work in two or more discrete frequency bands at any interval to achieve more functions. The antenna is printed on 1.6 mm thick glass fiber epoxy substrate and fed by coaxial line.

2. Design concept of different type of car-mounted antenna

2.1. Automobile category

With the development of automobile industry, the safety, comfort and functional requirements of automobile are improved. A wide variety of broadcasting, wireless communications, satellite and radar systems are used on automobiles, accompanied by the widespread use of large numbers of antennas in automobiles. The design of the new car-mounted antenna and the electromagnetic compatibility between the car-mounted antenna and the car-body are the key links in the current car design. The numerical simulation technology can be calculated repeatedly because of its fast calculation, low cost and convenient parameter change. The high prediction success rate is more and more applied to the research of related problems. The highly realistic car-body model is of great significance for the electromagnetic numerical simulation calculation process and results of vehicle-mounted antenna. The model can reduce the excessive demands on computer resources. Reduce the calculation time, and can get close to the actual exact results. At present, the electromagnetic simulation model of automobile can be produced by two ways. One is imported into the simulation platform by external stem type. This approach can perfectly reproduce the geometry dimensions of the car, including very small parts dimensions, but too much model detail increases simulation time, reduces computational efficiency, and sometimes even fails to calculate. Another method is to use the modeling tool of numerical simulation platform to directly establish the model that can be used for electromagnetic simulation calculation, which can not only improve the calculation efficiency, but also the size of the module, and the simulation parameters can be easily modified\[3\].

A method of establishing realistic vehicle model by using CST microwave working propaganda is discussed in this paper. Aiming at the disadvantages of the aerodynamic model of automobile, a vehicle-mounted antenna with a low profile PIFA car-body is designed.

2.2. Trains

China's rapid development of railway industry, especially fixing high-speed train operation speed has reached 350 km/h, which also prompted the progress of wireless communication technology in the railway field. This paper focuses on the design of wireless communication antenna inside the high-speed train carriage\[4\]. Therefore, the Wi-Fi frequency band of 2.4 GHz and 5 indoor communication frequency bands of 3.4 GHz will become the preferred frequency band of indoor and in-vehicle high-speed wireless communication technology, which has the characteristics of high transmission rate, long transmission distance and flexible arrangement. Wi-Fi/5G dual-band network requires the design of the corresponding antenna, patch antenna structure is simple, low cost, easy to integrate, easy to obtain line polarization and circular polarization. Slot antenna or butterfly antenna is widely used in the design of dual-band antenna, but its resonant frequency is generally low, which cannot cover Wi-Fi/5G two commonly used mobile communication bands. As patch antenna, the resonant frequency of a novel printed antenna is lower and the difference between high and low frequency is smaller. The dual-band antenna is realized by ring structure, but its low-band bandwidth is too narrow. Through the reference of literature, it can be seen that the circular structure is an
effective structure to realize the characteristics of double frequency band. And the two-band patch antennas covering 2.4/3.4 GHz are rare. Hence, this paper proposes a new design method for Wi-Fi/5G dual-band antenna. Through processing and testing, it can be seen that the measured results are very similar to the simulation results using software. The antenna has the characteristics of dual-band.

3. Design and analysis of communication antenna in Wi-Fi/5G dual-band train

3.1. Form
A single-feed point circularly polarized antenna for circularly polarized radiation does not require additional phase-shift networks or power divider circuits\(^5\). It is based on cavity model theory and operates using two degenerate modes with orthogonal polarization, equal radiation and 90° phase difference. The TM01 of the antenna and the radiation field of the TM10 mode in the direction of the Z axis are two orthogonal components. Adjusting the side length of the rectangle and the position of the feed point can make the two orthogonal modes differ 90° in time, thus realizing circular polarization. In a single feed point circularly polarized patch antenna, there are many options for the position of the feed point. Either way, however, perturbation \(\Delta S\) is needed to achieve the conditions required for circularly polarized radiation. \(\Delta S\) also known as "degenerate separators ". The influence can be better analyzed by using variable method. When using such antennas to generate a wide beam pattern, the location of the feed point and the degenerate separation must be cleverly arranged. For the on-board antenna, the antenna size should be minimized. In order to reduce the size, the higher the dielectric constant is required; in order to ensure the working bandwidth, the lower the dielectric constant of the plate is required, the better the thickness is, in order to ensure the radiation efficiency, the lower the dielectric constant of the plate is required, the better the thickness is. According to the above conclusion, the design of patch antenna must be considered by compromise. The shape of patch antenna is varied, but through literature review, this paper designs a new type of dual-circle antenna, which can effectively and quickly realize the dual-band characteristics of antenna, and has better antenna performance\(^6\).

3.2. Size
Assuming that the relative dielectric constant of the dielectric is \(\varepsilon_r\), the waveguide wavelength can be expressed by a formula for antenna operating at a frequency.

\[
\lambda_e = \frac{c}{f\sqrt{\varepsilon_r}}
\]

A new dual-band antenna with two full-wavelength annular antennas is designed. The radius of the full-wavelength ring antenna is \(r\) as follows:

\[
r = \frac{\lambda_e}{2\pi}
\]

3.3. Model
During the process of establishing the antenna model of Wi-Fi/5G dual-band train vehicle, the patch radiation unit is located in the upper layer of the dielectric plate, which mainly consists of two rectangular patches and two concentric circular rings. A genetic algorithm is chosen to calculate the antenna size in the Wi-Fi/5G dual-band in-vehicle communication antenna model. The length of
Wi-Fi/5G antenna in x and y direction is 40 and the height of antenna is 1.6 mm. Of the two rectangular patches that form the radiating element of the patch, the length of the rectangle is 11.7 mm, while the width of the rectangle connecting the two concentric circles is 1.6 mm. Based on the further clarification of the inner diameter and width of the two concentric circular ring patches, a Wi-Fi/5G dual-band communication antenna structure model is constructed.

3.4. Simulation test

Both inner and outer rings based on the communication antenna are responsible for the radiation element of patch antenna in this Wi-Fi/5G. and it also shows that in the Wi-Fi/5G dual-band train in-vehicle communication antenna designed in this paper, the specific performance of the communication antenna depends directly on the inner diameter of the inner and outer circular rings based on the communication antenna. For effectively improving the efficiency of communication antenna simulation experiment and ensuring the authenticity and validity of simulation results, this paper chooses to use professional HFSS simulation software directly in this process[7].

In the optimization stage, without changing other parameters, the inner diameter parameters of inner ring and outer ring are scanned and analyzed respectively. And when the radius of the inner ring increases, the frequency points in the high frequency segment of the antenna will gradually move towards the lower frequency band. However, when the radius of inner ring increases continuously, it has no substantial effect on the bandwidth of high frequency band.

According to the final simulation results, the optimal resonant effect can be obtained when the inner circle radius is 7.5 mm. If the radius of the inner ring is 6.5 mm, the center frequency of the two rings is close to the specified value. However, no matter how the radius of the inner ring changes, the bandwidth of the low frequency band and the frequency point remain basically unchanged. In addition, the antenna return loss will increase with the increasing radius of the inner circle, which will affect the performance of the antenna at low frequency. This is mainly because of the energy provided by the coupling feeder on the outer ring at a center frequency of 2.4 GHz, at which time there is a large spacing between the inner ring and the outer ring, which increases the coupling of the outer ring to a certain extent. In the simulation analysis of the radius of the outer ring, the resonant frequency of the center of the low frequency band is obviously shifted to the low frequency, the bandwidth is obviously reduced, and the antenna return loss is also reduced. At this time, the communication antenna in low frequency train has relatively high communication performance. The high frequency band and frequency point of antenna are hardly affected by the radius of outer ring. According to the simulation results, the antenna can obtain the optimal performance in high frequency band when the outer ring radius is 11 mm. Therefore, by integrating all the simulation results, we can see that in the Wi-Fi/5G dual-band train communication antenna designed in this paper, the inner diameter of the two ring patches is 7.3 mm and the width of 11.7 mm, is 2.2 mm and 2 mm, respectively. Figure 1 shows the simulated radiation schematic of the dual-band on-board antenna at 2.4 GHZ and 3.44 GHZ.
Figures 1. Aimulated radiation patterns of dual-band vehicle antennas at 2.4 GHZ and 3.44 GHZ

4. Conclusion

For Wi-Fi/5G high-speed network environment, the antenna is required to have wider beam and wider bandwidth in vehicle navigation system applications. The antenna designed in this paper is a wide-beam on-board Beidou navigation antenna to facilitate more comprehensive acceptance and collection of information to meet the requirements of system applications. Therefore, impedance bandwidth and axial ratio bandwidth is the key to the antenna design. Moreover, because this antenna is on-board antenna, so the antenna should have the characteristics of light and low profile. The combination of antenna and spiral antenna is used to transmit and receive navigation information, and a circularly polarized on-board antenna is designed.

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