Design of Multi-band Compatible Trigeminal Monopole Array Antenna for Unmanned Aerial Vehicle

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Abstract—Compared with the performance index of UAV system antenna, a compatible trigeminal monopole array antenna is proposed. This antenna uses photosensitive resin as the substrate material, and can be made with UAV shell using 3D printing technology, realizing the integration of the antenna system and UAV. The antenna uses a trigeminal monopole antenna as the basic radiation unit, which is arranged in accordance with the Sierpinski fractal structure to form fractal radiation array. While enhancing the radiation through the array, it ensures that the antenna has a larger working bandwidth. In radiation performance test, the antenna is operating over a frequency spectrum of 1.038-11.916 GHz, and the minimum S11 is -37.92 dB. The proposed antenna has multi-band compatibility, better radiation performance, and greater performance redundancy.

1. Introduction
UAV is one of the greatest and most practical inventions in the 21st century. It is a revolutionary improvement on manned aircraft. It is the crystallization of a variety of advanced technologies such as aircraft power technology, automatic control technology, wireless transmission technology and so on. It has the characteristics of small size, low cost, vertical or short-range take-off and landing, simple structure, flexible operation, etc, and at the same time has important military and civilian value. Antenna, a communication tool between UAV and its controller, is an important component of UAV. The flight control, wireless data transmission, and function command transmission of UAV all depend on antenna. The performance of antenna directly determines the performance of UAV. Using the UAV shell material as the antenna dielectric plate, and fusing the antenna with the UAV shell, it is possible to design a UAV conformal antenna with excellent performance and good working stability.

At present, the main frequency bands used for UAV communication are the Bluetooth system 2.400~2.4835 GHz[1-4], the second to fifth generation mobile communication frequency bands 0.905-0.960 GHz, 1.710-1.980 GHz, 2.010-2.400 GHz, 2.570-2.620 GHz, 3.300-4.990 GHz[5-7], ultra-wideband system 3.100~10.600 GHz[8-10], GPS system 1.164~1.577 GHz, Beidou system 1.204~1.564 GHz. The UAV antenna must be able to work in the above frequency bands at the same time, have multi-band compatibility, good radiation performance, and greater performance redundancy.

2. Introduction to Trigeminal Monopole Antenna
Figure 1 show the schematic diagram of trigeminal monopole antenna structure. It consists of a feeding area, a monopole radiating arm and two folded monopole radiating arms. The monopole radiating arm mainly covers the frequency bands of Beidou system, Bluetooth system, and the second to fifth
generation mobile communication. The folding monopole radiating arms mainly cover the fifth-generation mobile communication and ultra-wideband system frequency bands. Monopole radiation structure has high antenna gain, which can make the antenna achieve strong radiation intensity. The radiating arms are composed of multiple corner-cut fractal radiation patches, and the self-similarity of the fractal structure can effectively expand the working bandwidth of the antenna.

![Fig.1 Schematic diagram of trigeminal monopole antenna structure](image1)

3. Introduction to Fractal Array Structure

Multiple antennas form an array according to a certain arrangement rule, which can effectively enhance radiation. The Fractal Array Structure is an antenna array method arranged according to the fractal law, which can give full play to the characteristics of the fractal structure in broadband work. The arrangement method ensures that the antenna has a larger working bandwidth while enhancing the radiation through the array. Sierpinski Fractal Structure is a common surface fractal structure, which is widely used in the design of radio frequency antennas. Figure 2 show its iterative process. Arranging the array element antennas according to the Scherpinsk i fractal law can enhance the radiation intensity and ensure the broadband performance.

![Fig.2 Schematic diagram of Sierpinski's fractal iteration process](image2)

4. Antenna Structure Design

The antenna uses photosensitive resin as the substrate material, and its $\varepsilon_r=6.5$. The overall size of the antenna is $30\text{mm} \times 30\text{mm} \times 1\text{mm}$. Figure 3 show the integral structure of the antenna radiator. The radiator is composed of 8 trigeminal monopole antennas according to the first-order Sierpinski fractal structure to form a fractal antenna array. In this way, the antenna radiation intensity can be enhanced while maintaining the broadband performance of the trigeminal monopole antenna to the maximum extent, and the antenna can completely coverage the frequency bands of Beidou system, Bluetooth system, the second to fifth generation mobile communication and ultra-wideband system.
5. Antenna radiation performance test
We have made antenna samples and conducted actual tests on their radiation performance and pattern performance. The results are shown in Figure 4 and Figure 5.

According to the actual test results, the working frequency range of the antenna is 1.038~11.916 GHz and the minimum $S_{11}$ is -37.92dB. The antenna has multi-band compatibility, better radiation performance, greater performance redundancy. It can be seen that the electric and magnetic planes of the antenna pattern cover all radiation angles and have excellent omnidirectional radiation capabilities.

6. Conclusion
In this paper, according to the performance requirements of UAV for antenna system, the photosensitive resin of UAV shell material is selected as the antenna substrate material, and the antenna and UAV shell are fused together. The trigeminal monopole antenna is used as the radiation element antenna, and the antenna array is arranged according to the fractal law. The antenna array is designed with multi-band compatibility, which can cover the Bluetooth system frequency band, the second to fifth generation mobile communication frequency bands, the ultra-wideband system frequency band, the GPS system frequency band, and the Beidou system frequency band. The radiation performance is good, and the multi-band compatibility of trigeminal monopole array antenna with large performance redundancy is achieved. According to the actual test results, the antenna can conform to UAV shell, has excellent multi-band compatibility, strong radiation ability, good omnidirectional working ability, which has broad application prospects in the field of UAV.

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