Design of Fractal Array Bionic Ultra Wideband Antenna

Bin Lin\textsuperscript{1,a}, Peitao Zhang\textsuperscript{1}, Yuankun Cai\textsuperscript{1}, Guangya Ye\textsuperscript{1}, Qisheng Yang\textsuperscript{1}, Zetai Liu\textsuperscript{1} and Ying Zhang\textsuperscript{1}

\textsuperscript{1}Xiamen University Tan Kah Kee College, Fujian Zhangzhou 363105, China

\textsuperscript{a}email: linbin@xujc.com

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Abstract. According to the requirements of the second generation, the third generation, the fourth generation and the fifth generation mobile communication system, radio frequency identification system and ultra wideband communication system to the antenna's performance, the present paper originally combines bat wing bionic antenna and cross fractal array, designed a fractal array bionic ultra wideband antenna, fabricated the antenna sample and tested the radiation characteristics of the antenna. The result of test indicate that the antenna's working frequency range is 0.728-12.739 GHz, the antenna's working bandwidth is 12.011 GHz, the bandwidth octave is 17.49, the antenna return loss is less than -10 dB in the whole operating frequency band, the minimum value of return loss is -23.18 dB. This antenna completely covered the second generation mobile communication standard GSM frequency band, the third generation mobile communication standard TD-SCDMA frequency band, the third generation mobile communication standard WCDMA frequency band, the fourth generation mobile communication standard TD-LTE frequency band, the three candidate frequency bands of the fifth generation mobile communication, the three common frequency bands of the radio frequency identification system, and working band of ultra wideband communication system. This antenna can meet the requirements of small size, low thickness, low return loss and wide working bandwidth at the same time, it has a broad application prospect.

1. Introduction

Mobile communication is one of the most important applications of wireless technology, the mobile communication technology that can support multi band, multi standard and multi-mode is the key technology for future wireless communication applications. At present, the second generation mobile communication is still widely used, the third generation mobile communication is in the ascendant, the fourth generation mobile communication have begun to spread, the fifth generation mobile communication system under development will meet the growth needs of mobile internet traffic in the next 10 years, and will be put into commercial operation around 2020. Mobile radio signals of different frequencies and different formats will coexist for a long time in space, which requires mobile communication antenna to have multi band compatible functions and can covered GSM 0.905-0.915 GHz, 0.950-0.960 GHz, 1.710-1.785 GHz, 1.805-1.880 GHz frequency band, TD-SCDMA 1.880-1.920 GHz, 2.010-2.025 GHz, 2.300-2.400 GHz frequency band, WCDMA 1.920-1.980 GHz, 2.110-2.170 GHz frequency band, TD-LTE 2.570-2.620 GHz frequency band, and the three candidate frequency bands of the fifth generation mobile communication: 3.300-3.400 GHz, 4.400-4.500 GHz, 4.800-4.990 GHz. Mobile communication antenna also meet the requirements of mobile communication systems for small size, low thickness, low return loss and wide working bandwidth [1-2].

Radio frequency identification technology is a non-contact automatic identification technology based on wireless communication, the radio frequency signal automatic target recognition and access to relevant data, identify work without manual intervention, it can work in various hostile
environments. Radio frequency identification technology has gained a series of achievements in recent years. It has been widely used in warehousing, logistics, commercial automation, transportation control, security, books, aviation and other fields [3-5]. At present, the most promising frequency bands of radio frequency identification technology are 0.902-0.928 GHz, 2.400-2.4835 GHz and 5.725-5.875 GHz.

Ultra wideband (UWB) communication technology is one of the hotspots in the field of electronic communication research. New communication technologies begin to apply UWB technology to civil high-speed and near distance wireless communications, and have achieved rapid development. With the advantages of high speed, low power consumption and low cost, the UWB short distance communication technology standard has begun to challenge the traditional field of bluetooth. In addition to the existing characteristics of Bluetooth technology, UWB technology has the advantages of high speed, low power consumption and lower cost, it will be one of the main means of short distance wireless interconnection, and has a wide range of applications and market prospects. The frequency band of ultra wideband communication prescribed by the Federal Communications Commission (FCC) is 3.100-10.600 GHz, and this standard has now become an international standard for ultra wideband communication system. UWB communication system antenna need to meet the requirements of small size, low thickness, low return loss and wide working bandwidth, antenna need large performance redundancy, and can guarantee the quality of wireless communication signals under various unpredictable bad electromagnetic environments [6-7].

With the continuous development of wireless communication technology, a variety of wireless communication frequency band models with different standards, different frequencies, different formats will coexist for a long time. As an indispensable device for wireless communication, antenna must be compatible with the development of communication standards and have multi band compatible functions. The second generation, the third generation, the fourth generation and the fifth generation mobile communication system, the radio frequency identification system and the ultra wideband communication system work at close frequencies, and both require mobile terminals. If we can design an antenna, while covering the second generation mobile communication standard GSM frequency band, the third generation mobile communication standard TD-SCDMA frequency band, the third generation mobile communication standard WCDMA frequency band, the fourth generation mobile communication standard TD-LTE frequency band, the three candidate frequency bands of the fifth generation mobile communication, the three common frequency bands of the radio frequency identification system, the working frequency band of ultra wideband communication system, and can meet the requirements of small size, low thickness, low return loss and wide working bandwidth at the same time, it can realize the compatibility of the second generation, the third generation, the fourth generation and the fifth generation mobile communication system, the radio frequency identification system and the ultra wideband communication system. After use this antenna, the smart phone can be combined with radio frequency identification read-write device and ultra wideband communication terminal device, and the integration of a plurality of wireless communication terminals can be realized.

2. Brief introduction of bat wing bionic antenna

Bionics is the science of studying the structure and properties of biological systems, and it can provide new design ideas and working principles for engineering. Bionics studies the structure, function, and working principle of organisms, transplanting these principles into engineering technology, inventing superior instruments, devices and machines, and creating new technologies. Now, in the field of Biological Sciences, researchers have made significant progress in the study of sonar systems for many living creatures, such as bats and dolphins. In the field of engineering technology, many applied and developing technologies have promoted the development of bionic sonar technology. The propagation of ultrasonic wave and electromagnetic wave follows the same physical law. The design
method of bionic sonar is applied to microwave band, which can help human beings improve the
performance of antenna and design a bionic antenna with higher performance.

The structure of the bat wing bionic antenna is shown in Figure 1, which consists of a microstrip
open route symmetrical oscillator and a microstrip short line. From the two sides to the middle,
microstrip open route dipole arm length gradually reduced, the capacitive reactance is gradually
increasing; and the corresponding microstrip shortest route length gradually increased, the inductive
reactance is gradually increasing, the inductive reactance and capacitive reactance mutual
compensation. Each dipole has a similar input impedance and radiation impedance, it ensure that each
dipole has a similar excitation and radiation, the resonant frequency of each dipole is close, and the
operating frequency band is superimposed, thus forming the broadband radiation of the antenna.

![Figure 1. Schematic diagram of bat wing bionic antenna.](image)

3. **Brief introduction of photonic crystal structure**

Photonic crystal is a periodic structure consisting of a medium arranged periodically in another
medium. Photonic band gaps produced by photonic crystals can all or partially impede the
propagation of electromagnetic waves. When using photonic crystal structure in antenna design,
through strict design, can make the photonic band gap frequency and antenna working center
frequency consistent, the photonic band gap will partially block the energy radiation of the antenna at
the original working center frequency, so that the energy will diffuse to the nearby frequency radiation,
thus increasing the frequency range of the antenna radiation energy, and increasing the working
bandwidth of the antenna.

4. **Brief introduction of cross fractal array**

The fractal structure is a self similar geometric structure generated by iteration, it has self similarity
between the whole and the local and between the local and the local. The fractal array is a constitute
array method for arranging a plurality of array antennas in accordance with the fractal iterative law, it
can give full play to the advantages of self similarity of the fractal structure, and ensure the antenna
array has a large operating bandwidth while enhancing the radiation intensity of the antenna through
constitute array.

The cross fractal structure is a common surface fractal structure, and its iterative process is shown
in Figure 2. The original structure of the cross fractal structure is square, divided square into 3 rows, 3
columns, 9 small squares, remove four small squares at four corners, leave 5 small square areas,
obtained 1st-order cross fractal structure. Made the cross fractal iteration to the 5 square regions of the
1st-order cross fractal structure, can obtained the 2nd-order cross fractal structure. Followed this iteration, can get high-order cross fractal structure [8-9].

(a) 0-order  (b) 1st-order  (c) 2nd-order

Figure 2. The iteration process of cross fractal structure.

5. Structure design of fractal array bionic ultra wideband antenna

The antenna substrate used in the design is a low loss microwave ceramic substrate with a relative dielectric constant of 70. The shape of the antenna substrate is rectangular, the size is 18 mm×18 mm, and the thickness is 0.5 mm. The ceramic material is made from ceramic powder, dispersing agent and carrageenan as raw materials, through a plurality of processes, it overcome the problem of high loss for high frequency signals of the traditional high dielectric constant material, in the range of dielectric constant 10~100, the loss tangent of the microwave signal is less than 0.002, which is suitable as the base material of the antenna.

The structure of the fractal array bionic ultra wideband antenna is shown in Figure 3. In the design, a 2nd-order cross fractal structure with a size of 18 mm×18 mm is used as the basic array arrangement structure, it has 25 small square areas inside, placed a photonic crystal bat wing bionic small antenna in each small square area, forming a fractal array bionic radiation patche.

Each photonic crystal bat wing bionic small antenna has a size of 2 mm×2 mm, it consists of 9 pairs of parallel symmetrical dipoles, each pair of parallel symmetric dipole has lengths of 0.85 mm, 0.70 mm, 0.55 mm, 0.40 mm, 0.25 mm, 0.40 mm, 0.55 mm, 0.70 mm, 0.85 mm. In the photonic crystal bat wing bionic small antenna symmetrical dipole arm, each square metal regions with a size of 0.05 mm×0.05 mm, all used photonic crystal structure. This photonic crystal structure consists 4 square holes in a square metal region, each square hole has a size of 0.01 mm×0.01 mm.

Figure 3. Schematic diagram of the structure of fractal array bionic ultra wideband antenna.

6. Fabrication and test of antenna sample

According to the design scheme mentioned above, a fractal array bionic ultra wideband antenna sample is fabricated by magnetron sputtering, as shown in Figure 4. We have tested the radiation characteristics of the antenna sample, and the result is shown in Figure 5.
The tested results show that the antenna's working frequency range is 0.728-12.739 GHz, the antenna's working bandwidth is 12.011 GHz, the bandwidth octave is 17.49, the antenna return loss is less than -10 dB in the whole operating frequency band, the minimum value of return loss is -23.18 dB. This antenna completely covered GSM 0.905-0.915 GHz, 0.950-0.960 GHz, 1.710-1.785 GHz, 1.805-1.880 GHz frequency band, TD-SCDMA 1.880-1.920 GHz, 2.010-2.025 GHz, 2.300-2.400 GHz frequency band, WCDMA 1.920-1.980 GHz, 2.110-2.170 GHz frequency band, TD-LTE 2.570-2.620 GHz frequency band, and the three candidate frequency bands of the fifth generation mobile communication: 3.300-3.400 GHz, 4.400-4.500 GHz, 4.800-4.990 GHz, the three common frequency bands of the radio frequency identification system: 0.902-0.928 GHz, 2.400-2.4835 GHz and 5.725-5.875 GHz, the working frequency band of ultra wideband communication system: 3.100-10.600 GHz.

7. Conclusions

According to the requirements of the second generation, the third generation, the fourth generation and the fifth generation mobile communication system, radio frequency identification system and ultra wideband communication system to the antenna's performance, this paper use the low loss microwave ceramic materials with proprietary intellectual property rights as the antenna substrate, combines bat wing bionic radiation structure, photonic crystal structure and cross fractal array, designed a fractal array bionic ultra wideband antenna, fabricated the antenna sample and tested the radiation characteristics of the antenna. This antenna size is only 18 mm×18 mm, has unique advantages in miniaturization. This antenna uses a wide operating frequency band, complete covered the operating frequency band of the second generation to the fifth generation mobile communication system, the radio frequency identification system, and the ultra wideband communication system, the performance of this antenna is much better than the conventional ultra wideband antenna. The low frequency radiation performance of this antenna is better, and the problem that the conventional ultra wideband antenna is difficult to work under the frequency range of 2 GHz is solved. This antenna can meet the requirements of small size, low thickness, low return loss and wide working bandwidth at the same time, it has a broad application prospect.

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