Design of the Gradual Patch Spiral Dipole Complementary Gap Composite Ultra Wideband Antenna

Bin Lin¹,a, Yilang Pan¹, Ping Zheng¹, Xinyu Wei¹, Zhijie Hong¹ and Zhenchang Li¹

¹Xiamen University Tan Kah Kee College, 363105 Fujian Zhangzhou, China

a Corresponding author: linbin@xujc.com

Abstract. According to the performance requirements of the multi band compatible antennas for microwave frequency band multi network integration system, the present paper originally combines gradual patch spiral dipole antenna, complementary gap antenna, polyethylene terephthalate film, ceramics thin slice and ferrite coating, designed a gradual patch spiral dipole complementary gap composite ultra wideband antenna. The result of test indicates that this antenna has a better anti-jamming ability. When the antenna is placed near metal objects and various microwave signal sources, the radiation performance of the antenna is almost unaffected and the antenna can work normally. This antenna completely covered all working frequency bands of the second generation to the fifth generation mobile communication, the frequency bands of the radio frequency identification system, the frequency band of the ultra wideband system, and the frequency band of the mobile digital TV system. This antenna has high radiation intensity and large performance redundancy, so it has broad application prospects.

1.Introduction

The important trend in the development of wireless communication technology in the 21st century is to realize the integration of multi-network and multi-band compatibility, and integrate multiple wireless communication terminals with similar working frequency into multi-functional intelligent terminals. The mobile communication system, the radio frequency identification system, the ultra wideband system and the mobile digital TV system are all wireless communication systems working in the microwave band, if they are integrated into microwave band multi network integration system, the terminal of this system will have the functions of receiving and receiving telephone calls, sending and receiving short messages, using mobile Internet, reading and writing RFID cards, ultra-wideband short-range high-speed data transmission, and watching mobile digital TV.

The microwave band multi network integration system requires the terminal antenna to have ultra wide band working performance. In China, what used by the second generation to the fifth generation mobile communication band currently used are 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 [1-3]. The frequency bands of the radio frequency identification system are 0.902-0.928 GHz, 2.400-2.4835 GHz and 5.725-5.875 GHz [4-5]. The frequency band of the ultra wideband system is 3.100-10.600 GHz [6-7]. The frequency band of the mobile digital TV system is 11.700-12.200 GHz [8-9]. The antenna must
cover all the above frequency bands at the same time, and has a large radiation intensity and stable radiation performance. This antenna has a wide working frequency band, and almost all communication base stations and wireless signal sources in the microwave band will interfere with its radiation, which requires that this antenna has a good anti-jamming ability, and can shield the interference of external electromagnetic waves to its normal radiation.

2. Brief introduction of gradual patch spiral dipole antenna
The structure of the gradual patch spiral dipole antenna is shown in Figure 1, which is a superposed broadband dipole antenna consisting of a feed line and a gradual patch spiral radiation area. The gradual patch spiral radiation area contains nine square radiation patches, which are arranged in order from large to small according to the law of fold line spiral. From the feed point to the center of the spiral radiation area, the length of each patches gradually decreasing. The radiation frequencies of the square radiation patches are different because of the different side lengths. The radiation of the nine patches working in different radiation frequency bands can be superimposed to obtain a radiation frequency band with large working bandwidth.

3. Brief introduction of complementary gap antenna
The structure of the complementary gap antenna is shown in Figure 2. In the rectangular conductive region, a gap antenna can be obtained by digging out the conductive region which is exactly the same as the size and shape of the gradual patch spiral dipole antenna. When two antennas are stacked together, they are a complete rectangular radiation patch. Such pair of antennas is complementary antennas, and their radiation performances are similar except for slightly different polarization modes. Complementary gap antenna absorbs part of the radiation energy of the gradual patch spiral dipole antenna and generates secondary radiation. The radiation of a pair of complementary antennas is superimposed in space, which can greatly enhance the radiation intensity of the antenna.

4. Brief introduction of ceramics thin slice-ferrite coating composite structure
The structure of the ceramics thin slice-ferrite coating composite structure is shown in Figure 3. Low loss microwave ceramics have high dielectric constant, adding a ceramics thin slice to the antenna structure can effectively weaken the effect of external electric field on the antenna radiation. Ferrite has high permeability, adding a layer of ferrite coating in the antenna structure can effectively shield the effect of external magnetic field on antenna radiation. The combination of ceramics thin slice and ferrite coating can ensure that the antenna has strong anti-interference performance.
5. Structure design of the gradual patch spiral dipole complementary gap composite ultra wideband antenna

In the design, the polyethylene terephthalate (PET) film is used as the antenna substrate material. The shape of the PET film is rectangular, the size is 40 mm×15 mm, the thickness is 0.5 mm, and the relative dielectric constant is 3.0. The chemical stability of PET film is very good; it can resist corrosion, and can ensure that the antenna has stable physical and chemical properties.

Integral layered cross section structure of antenna is shown in Figure 4. The gradual patch spiral dipole radiation patch consists of two symmetrical radiating arms which include patch radiation area and feeder line that length of 5.5 mm. The size of the patch radiation area is 15 mm×15 mm, divided into 3 rows, 3 columns, 9 square areas. In the patch radiation area of the left radiation arm, a square radiation patch is placed at the center of each square area. Starting from the square area of the upper right corner, the edge length of each patch decreases gradually according to the counter-clockwise spiral order. The edge lengths of the nine patches are 4.5 mm, 4.0 mm, 3.5 mm, 3.0 mm, 2.5 mm, 2.0 mm, 1.5 mm, 1 mm, 0.5 mm, respectively. Each patch is connected by a connecting line. The patch radiation area of the right arm is mirror symmetrical to the patch radiation area of the left arm. Complementary gap induction radiation patch is obtained by digging out the conductive region in the rectangular conductive region, which is identical to the gradual patch spiral dipole radiation patch in size and shape, and forming a complementary gap.

Low loss microwave ceramics are used in the ceramics thin slice. The shape of the ceramics thin slice is rectangular, the size is 40 mm×15 mm, the thickness is 0.5 mm, and the relative dielectric constant is 55. The size of the ferrite coating is the same as that of the ceramics thin slice, and the ferrite used is soft magnetic ferrite, it is made of iron oxide, nickel oxide, zinc oxide, manganese oxide, magnesium oxide, barium oxide, strontium oxide and other metal oxides.

The radiation patch of antenna is made of graphene conductive ink. Graphene has a high electron mobility and can accommodate a high intensity of radio-frequency current. Using graphene conductive ink watermark to make antenna radiation patch can enhance the radio-frequency current intensity inside the antenna, and improve the radiation intensity of the antenna.
6. Fabrication and test of the gradual patch spiral dipole complementary gap composite ultra wideband antenna sample

According to the above design, the gradual patch spiral dipole complementary gap composite ultra wideband antenna sample is fabricated, and its radiation performance is tested, the result is shown in Figure 5 and Figure 6.

As can be seen from Figure 5, the tested results show that the antenna's working frequency range is 0.393-15.475 GHz, the operating bandwidth is 15.082 GHz, and the octave bandwidth is 39.38. The return loss of the antenna is lower than -10 dB in the whole working frequency band, and the minimum value of the return loss is -52.92 dB. This antenna completely covered the working frequency bands of several microwave systems, such as 0.902-0.928 GHz, 0.905-0.915 GHz, 0.950-0.960 GHz, 1.710-1.785 GHz, 1.805-1.880 GHz, 1.880-1.920 GHz, 1.920-1.980 GHz, 2.010-2.025 GHz, 2.110-2.170 GHz, 2.300-2.400 GHz, 2.400-2.4835 GHz, 2.570-2.620 GHz, 3.300-3.400 GHz, 4.400-4.500 GHz, 4.800-4.990 GHz, 5.725-5.875 GHz, 3.100-10.600 GHz, 11.700-12.200 GHz. This antenna completely covered all working frequency bands of the second generation to the fifth generation mobile communication, the frequency bands of the radio frequency identification system, the frequency band of the ultra wideband system, and the frequency band of the mobile digital TV system.

As can be seen from Figure 6, the radiation pattern test results of the antenna indicate that this antenna has good omnidirectional working ability.

Compared with the conventional microwave multi band compatible antenna, this antenna has great performance advantages. The tested results show that this antenna has excellent ultra wideband performance, operating bandwidth exceeds 15 GHz, octave bandwidth is close to 40, far beyond the existing antenna bandwidth performance limit. This antenna has stable and reliable radiation performance, it uses a wide operating frequency band, complete covered the working frequency bands of multiple microwave communication systems. In most working frequency bands, the antenna return loss values are lower than -50 dB. This antenna can resist the interference of external electromagnetic waves, even when placed near metal objects and microwave signal sources, it can work normally.

![Figure 5. The return loss performance test results of the gradual patch spiral dipole complementary gap composite ultra wideband antenna.](image-url)
Figure 6. The radiation pattern test results of the gradual patch spiral dipole complementary gap composite ultra wideband antenna.

7. Conclusion
According to the performance requirements of the multi band compatible antennas for microwave frequency band multi network integration system, the present paper designed a gradual patch spiral dipole complementary gap composite ultra wideband antenna. This antenna uses nine square radiated patches that are gradual reduced in size, forming a dipole antenna radiation arm. The radiation superposition of nine radiation patches working at different frequency band, ensure that this antenna has good broadband operation characteristics. The dipole radiation patch and the complementary gap radiation patch below constitute a pair of complementary antennas, their radiation is superimposed in space, which can effectively enhance the radiation intensity of the antenna. Using PET film as the antenna substrate material, can ensure that the antenna has good temperature adaptability, corrosion resistance and stable physical and chemical characteristics. Using ceramics thin slice and ferrite coating in antenna structure can effectively reduce the interference of external electromagnetic field to antenna radiation. Using graphite conductive ink to print antenna radiation patch, further enhance the radiation performance of the antenna. The tested results show that this antenna has excellent ultra wideband performance, can use a radiation stable ultra wide working frequency band, completely covered all working frequency bands of the second generation to the fifth generation mobile communication, the frequency bands of the radio frequency identification system, the frequency band of the ultra wideband system, and the frequency band of the mobile digital TV system. This antenna has great radiation intensity, good anti-interference ability and good application prospect.

Author information
Bin Lin, born in 1984, male, associate professor of the Xiamen University Tan Kah Kee College, his main research direction is microwave antenna design.
Yilang Pan, Ping Zheng, Xinyu Wei, Zhijie Hong, Zhenchang Li, undergraduate of the Xiamen University Tan Kah Kee College, their main research direction is microwave antenna design.

References
[1] M. Qian, Y. Wang, Y. Zhou, et al, Digital Communications and Networks 1, 152-159 (2015)
[2] S. J. Chen, D. C. Dong, Z. Y. Liao, et al, Electronics Letters 50, 1111-1112 (2014)
[3] Y. K. Bekali, M. Essaaidi, Microwave and Optical Technology Letters 55, 1622-1626 (2013)
[4] J. L. He, Y. J. Xu, Z. Q. Xu, International Journal of Control and Automation 7, 131-142 (2014)
[5] D. Ma, N. Saxena, Security and Communication Networks 7, 2684-2695 (2014)
[6] X. Wei, T. Mei, L. Yu, et al, Electronics Letters 53, 57-58 (2017)
[7] L. B. Pratap, D. Kundu, A. Mohan, Microwave and Optical Technology Letters 58, 1088-1093 (2016)
[8] J. Carey, International Journal of Digital Television 7, 119-132 (2016)
[9] V. J. Silva, V. F. D. Ferreira, N. S. Viana, IEEE Latin America Transactions 13, 241-249 (2015)