Design of the Photonic Crystal Slot Fractal Array Ultra Wideband Antenna

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Abstract. According to the performance requirements of the multi band compatible antennas for the mobile communication system, the radio frequency identification system, the ultra wideband system and the mobile digital TV system, the present paper originally combined photonic crystal structure, embedded slot fractal, rectangular array antenna, relative dielectric constant gradual thin film, potassium tantalum niobate thin film, Fe-based nanocrystalline alloy coating and graphene conductive ink, and designed a photonic crystal slot fractal array ultra wideband antenna. The result of test indicates that this antenna has strong anti-EMI capability, large performance redundancy and ultra wideband operation capability. 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 small size, high radiation intensity, stable and reliable operation performance; it is a microwave band multi network integration antenna with excellent performance.

1. Introduction
The 21st century is a century of rapid development of wireless communication technology. The wireless communication application system represented by mobile communication system has made considerable progress in technology. The second, third and fourth generation mobile communication systems have been put into use successively, and the fifth generation mobile communication system has also been technically mature, and will be commercial operation in 2020. The radio frequency identification system, the ultra wideband system and the mobile digital TV system have also been more and more widely used, leading the continuous development of wireless communication application technology.

The second generation to the fifth generation mobile communication system, the radio frequency identification system, the ultra wideband system and the mobile digital TV system are wireless communication systems working in the microwave band, and their working modes and terminal devices are similar. Multi network integration is one of the most important trends in the development of wireless communication technology in the 21st century. The multi network integration system in microwave band needs to integrate the mobile communication system, the radio frequency identification system, the ultra wideband system and the mobile digital TV system. The multi network integration antenna in microwave band needs to realize multi band compatibility. In China, 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]. The antenna needs to cover all the working frequency bands mentioned above, and has strong anti-electromagnetic interference ability, large performance redundancy, and meets the requirements of small size, high radiation intensity, and stable operation performance.

2. Brief Introduction of Photonic Crystal Slot Fractal Structure

The iterative process of the photonic crystal slot fractal structure is shown in Figure 1. The original structure of the photonic crystal slot fractal structure is a square patch; it is dividing into seven rows and seven rows with 49 small squares. As shown in Figure 1 (b), 9 small squares were dug out, and 40 small squares were left, a photonic crystal slot is formed, the 1st-order photonic crystal slot fractal structure is obtained. Make photonic crystal slot fractal iteration in the 40 small squares, the 2nd-order photonic crystal slot fractal structure is obtained. In this way, the higher order photonic crystal slot fractal structure can be obtained by iteration.

The photonic crystal slot fractal structure is a new embedded slot fractal iteration method, which has the advantages of both photonic crystal structure and embedded slot fractal structure, and has excellent broadband performance. Using this embedded slot fractal in antenna design, the fractal slot structure can be introduced into the antenna radiation patch without changing the overall shape of the antenna radiation patch. The self-similarity of the fractal slot structure can make the internal of the antenna radiation patch have uniform current distribution and ensure the stable ultra-wide band operation performance of the antenna.

3. Brief Introduction of Relative Dielectric Constant Gradual Thin Film

The chemical stability of the polyethylene terephthalate (PET) thin film is very good, it can withstand oil, acid, alkali and most solvents, it can work normally in a wide temperature range. Using it as antenna dielectric substrate can ensure that the antenna has stable physical and chemical properties.

The relative dielectric constant gradual PET thin film can be divided into several rectangular small areas. The relative dielectric constant of each small area gradually changes along the length and width of the thin film. The relative dielectric constant of each small area gradually increases in the order from left to right and from top to bottom. When the thin film is used as dielectric substrate in the design of array antenna, the relative dielectric constant of the dielectric substrate of each antenna is different, so the operating frequency of each antenna is different. When the operating frequencies of different antennas are close to each other, their radiation will overlap to form a working frequency band with higher radiation intensity and wider working bandwidth, thus improving the radiation performance and bandwidth performance of the array antenna.

4. Brief Introduction of Potassium Tantalum Niobate Thin Film, Fe-Based Nanocrystalline Alloy Coating and Graphene Conductive Ink

The potassium tantalum niobate is a high dielectric constant and low loss compound with good thermal stability, chemical stability and mechanical stability, and it can form an efficient electric field shielding layer to prevent external electric field from interfering with the antenna. The Fe-based
nanocrystalline alloy is an ideal high-performance soft magnetic material with super high permeability, good corrosion resistance, magnetic stability and low loss; it can effectively prevent the interference of external magnetic field on the antenna. The combination of the potassium tantalum niobate thin film and the Fe-based nanocrystalline alloy coating can effectively prevent the interference of electromagnetic field around the antenna to the radiation of the antenna. Graphene has high electron mobility, and graphene conductive ink can pass through a high intensity of radio frequency current. Using graphene conductive ink watermarking to fabricate antenna radiation patch can improve the radiation intensity of antenna. Graphene conductive ink does not contain metal, which can effectively prevent the antenna radiation patch from being corroded.

5. Structure Design of the Antenna

In the design, the relative dielectric constant gradual PET thin film is used as the antenna substrate material; its schematic diagram is shown in Figure 2. The shape of the PET thin film is rectangular, the size is 20 mm×20 mm, the thickness is 0.2 mm. The thin film consists of four rows, four columns 16 small areas. A number in Figure 2 represents the relative dielectric constant of a small area. The relative dielectric constant of each small area gradually changes along the length and width of the thin film. The small area with the smallest relative dielectric constant is in the upper left corner, and its relative dielectric constant is 15.0. The small area with the largest relative dielectric constant is in the lower right corner, and its relative dielectric constant is 21.0. The relative dielectric constant of each small area gradually increases in the order from left to right and from top to bottom. The difference of relative dielectric constant between two adjacent small areas is 1.0.

Integral layered cross section structure of antenna is shown in Figure 3. The antenna ground plate is fully conductive structure, and the structure of the photonic crystal slot fractal array feed radiation patch is shown in Figure 4. 16 photonic crystal slot fractal small antennas are arranged in rectangular array structure to form an antenna array. Each small antenna is obtained by photonic crystal slot fractal iteration in a rectangular region with a size of 4.9 mm x 4.9 mm. The small antenna uses the 2nd-order photonic crystal slot fractal structure. Each small antenna has an antenna feeding point at the bottom edge center. Although the bandwidth of a single photonic crystal slot fractal small antenna is large, its radiation intensity is still weak. A number of small antennas are arranged in a rectangular array structure to form an antenna array, so that their radiation can be superimposed to further enhance the radiation intensity of the antenna.

The shape of the potassium tantalum niobate thin film is rectangular, the size is 20 mm×20 mm, the thickness is 0.3 mm, and the relative dielectric constant is 200. The size of the Fe-based nanocrystalline alloy coating is the same as that of the potassium tantalum niobate thin film. The Fe-based nanocrystalline alloy is a kind of amorphous alloy material with low loss and high permeability; it is mainly made of iron element, with a small amount of niobium, copper, silicon and boron added; it is made by rapid solidification process. The antenna radiation patch and antenna ground plate are made of graphene conductive ink watermarking.
6. Fabrication and Test of Antenna Sample

According to the above design, the antenna sample is fabricated, and its radiation performance and pattern performance is tested, the result is shown in Figure 5. The tested results show that the antenna's working frequency range is 0.551-16.875 GHz, the operating bandwidth is 16.324 GHz, and the octave bandwidth is 30.63. The minimum value of the return loss of the antenna is -46.89 dB. 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. The tested results show that this antenna has good omnidirectional radiation capability.

(a) The antenna's return loss performance (b) The antenna's radiation pattern

Fig.5 The test results of the antenna's radiation performance

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 photonic crystal slot fractal array ultra wideband antenna. The tested results show that this antenna has strong anti-EMI capability, large performance redundancy and ultra-wideband capability. This antenna can completely cover the working frequency bands of four wireless communication application systems. This antenna has small size, strong radiation performance and reliable working ability. This antenna is expected to be widely used in microwave band multi network integrated system.

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