Design of the Ladder Multi-slot Fractal Split Growth Array Antenna

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Abstract. According to the performance requirements of the ultra-wideband multi-band compatible antennas for microwave band multi-network integration systems, the present paper originally combines the structure of ladder multi-slot, "Embedded" slot fractal iteration and the split growth array, designs a ladder multi-slot fractal split growth array antenna. The result of test indicates that this antenna can completely cover all working frequency bands of the mobile communication system, 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. With the advantages of small size, high radiation intensity and stable radiation characteristics, it can be applied to large-scale applications in the multi-network system of microwave frequency band.

1. Introduction

It is the most important trend of wireless communication development in the 21st century that a variety of wireless communication application systems working in different frequency bands are integrated together to realize wireless communication frequency band reuse and multi-frequency band compatibility and form a multi-network integration system with super compatibility. Mobile communication systems, radio frequency identification systems, ultra-wideband communication systems and mobile digital television systems are all wireless communication applications operating in the microwave band. If they can be integrated together, multi-network and multi-band in the microwave band can be realized.

2. Brief introduction of ladder multi-slot fractal split growth array antenna

The iterative law of trapezoidal multi-slot fractal structure is shown in Figure 1. The initial structure of the trapezoidal multi-slot fractal structure is a square, which is equally divided into 10 rows, 10 columns, 100 small squares, and the second row, the fifth column, the sixth column, the fourth row, the fourth column, the fifth column, the sixth column, column 7, row 6, column 3, column 4, column 5, column 6, column 7, column 8, row 8, column 2, column 3, column 4, column 5, column 6, column 7, column 8, 7th column, 8th column, 9th column, a total of 20 small squares are dug, forming a trapezoidal multi-slot, leaving 80 equally divided square areas, then obtaining a 1st-order multi-slot fractal structure. The 80 square regions of the 1st-order multi-slot fractal structure are respectively subjected to trapezoidal multi-slot fractal iteration, and a 2nd-order multi-slot fractal structure is obtained. By continuing the iteration in this way, a high-order trapezoidal multi-slot fractal structure can be obtained.

The trapezoidal multi-slot structure has a plurality of linear slits of different lengths, and their
working frequencies are different. The radiation superposition of multiple slits can obtain a working frequency band with a larger bandwidth. The trapezoidal multi-flap fractal structure generated according to the "embedded" slot fractal iterative method has the wide-band working capability of the trapezoidal multi-slot structure and the high self-similarity of the "embedded" slot fractal structure, enabling single-band ultra-wideband operation.

![Iterative Rule of Trapezoidal Multi-Slit Fractal Structure](image)

**Figure 1. Schematic diagram of iterative rule of trapezoidal multi-slit fractal structure**

3. Brief introduction of split growth array structure

The antenna array composed of multiple array elements can effectively improve the radiation intensity of the antenna. Although the working bandwidth of a single trapezoidal multi-slot fractal antenna is large, the radiation is dispersed in a wide operating frequency band, and the radiation intensity is weak. Multiple trapezoidal multi-slot fractal antennas are arranged to form an antenna array, and the radiation of the antenna can be enhanced by the principle of radiation superposition. The split growth array structure is a rectangular array structure as a basic structure, and the antenna array is iteratively generated according to the "central burrowing, edge growth" growth mode.

The iterative law of the slot growth array structure is shown in Figure 2. The initial structure of the split-growth array structure is a rectangular array consisting of 8 rows and 8 columns of 64 array element antennas, and a total of 16 array element antennas in the center of 4 rows and 4 columns are excavated, and are in the center of the four sides of the rectangular array. Growing a small rectangular array of 4 rows and 4 columns with a total of 16 array elements, a first-order slot growth array structure can be obtained. The four small rectangular arrays of the first-order split-growth array structure are excavated from the center of the two rows and two columns of a total of four array element antennas, and "growth" a row of two rows and two columns at the center of the outer three sides of the small rectangular array. A micro-rectangular array of four array elements can obtain a second-order split-growth array structure.

![Iterative Regularity of Split-Growth Array Structure](image)

**Figure 2. Schematic diagram of iterative regularity of split-growth array structure**
4. Structure Design of the Antenna

The antenna substrate used in the antenna design is a low-loss epoxy glass cloth substrate having a relative dielectric constant of 6, a rectangular shape of the substrate, a size of 48 mm × 48 mm, and a thickness of 1 mm. The antenna radiating patch and the antenna grounding plate are made of copper.

The overall structure of the antenna comprises a substrate, an antenna grounding plate attached to the back surface of the substrate, and a trapezoidal multi-slot fractal split-growth array radiation patch attached to the front surface of the substrate. The antenna grounding plate is an all-electric grounding structure. The structure of the trapezoidal multi-slot fractal split-growth array radiation patch is as shown in figure 3, which uses a split-growth array structure as a basic array arrangement structure, each of which has a size of 2.4 mm × 2.4 mm in the split-growth array structure. At the center of the array antenna area, a trapezoidal multi-slot fractal antenna is placed. The trapezoidal multi-slot fractal antenna uses a second-order trapezoidal multi-slot fractal structure. An antenna feed point is provided at the center of the bottom edge of each trapezoidal multi-slot fractal antenna.

The split-growth array structure used in this antenna is a 2nd-order split-growth array structure, which is in a rectangular region consisting of 20 rows and 20 columns and a total of 400 square regions, in the first row, the tenth column, the eleventh column, 2nd, 10th, 11th, 3rd, 9th, 10th, 11th, 12th, 7th, 8th, 9th, 12th, and 13 columns, 14th column, 5th row, 7th column, 8th column, 9th column, 12th column, 13th column, 14th column, 6th row, 9th column, 10th column, 11th column, 12 columns, 7th row, 4th column, 5th column, 7th column, 8th column, 9th column, 10th column, 11th column, 12th column, 13th column, 14th column, 16th column, Column 17, 8th, 4th, 5th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 16th, column 17, line 9, column 3, column 4, column 6, column 7, column 8, column 13, column 15, column 16, 17 Column, column 18, row 10, column 1, column 2, column 3, column 6, column 7, column 8, column 13, column 14, column 15, column, 19 columns, 20th column, 11th 1st column, 2nd column, 3rd column, 6th column, 7th column, 8th column, 13th column, 14th column, 15th column, 18th column, 19th column, 20th column, 12th Rows 3, 4, 5, 6, 7, 8, 13, 13, 14, 15, 16, 17, and 18 Columns 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, and 17, 14th, 4th, 5th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 16th, 17th, 15th, 9th, 10th, 11th, 12th, 16th, 7th, 8th, 9th, 12th, 13th, 14th, 17th Column 7, Column 8, Column 9, Column 12, Column 13, Column 14, Line 18, Column 9, Column 10, Column 11, Column 12, Line 19, Column 10. In the eleventh column, the 20th row, the tenth column, the eleventh column, a total of 144 square areas are placed with array element antennas.

![Figure 3. Schematic diagram of trapezoidal multi-slot fractal split-growth array radiation patch structure](image-url)
5. Fabrication and Test of Antenna Sample

According to the above design, the antenna sample is fabricated, its radiation performance is tested, and the result is shown in Figure 4 and Figure 5.

As can be seen from Figure 4, the antenna has an operating frequency range of 0.386-17.442 GHz, a working bandwidth of 17.056 GHz, a bandwidth octave of 45.19, and an antenna return loss of less than -10 dB over the entire operating band. And the minimum value of the return loss is -43.22 dB. The antenna fully covers all working frequency bands, radio frequency identification bands, ultra-wideband communication bands and mobile digital TV bands of the second to fifth generation mobile communication systems.

As can be seen from Figure 5, the antenna has good omnidirectional radiation capability. This antenna has excellent overall performance. With 144 array elements, the antenna measures only 48 mm × 48 mm × 1 mm. It is better at miniaturizing the antenna, and the antenna can be placed in various mobile terminals. The antenna uses a single ultra-wide operating band with a bandwidth exceeding 17 GHz to achieve simultaneous coverage of all working frequency bands, radio frequency identification bands, ultra-wideband communication bands and mobile digital TV bands of the second to fifth generation mobile communication systems. The ultra-wideband stable operation has unique advantages; the return loss value of the antenna is low, and the return loss value of most regions in the working frequency band is lower than -40 dB, and the antenna has large performance redundancy. It can guarantee the transmission quality of multi-network wireless communication signals in complex electromagnetic environment.

![Figure 4 The antenna's return loss performance](image1)

![Figure 5 The antenna's radiation pattern](image2)
6. Conclusion
In this paper, a trapezoidal multi-slot structure, an "embedded" slot fractal iterative structure, and a split-growth array structure are fused together, and a trapezoidal multi-slot fractal split-growth array antenna is designed. The antenna is embedded based on a trapezoidal multi-slot structure. The "fractal iteration" is obtained, and the trapezoidal multi-slot fractal structure is obtained. As the array element antenna, the single-band ultra-wideband operation of the array element antenna is realized. The plurality of array element antennas are arranged in a split-growth array structure to form an antenna array, so that the antenna array has self-similarity similar to the fractal structure, and the antenna array can maintain excellent broadband working ability while enhancing the radiation intensity of the antenna. The measured results show that the antenna has a single ultra-wide operating frequency band, which can completely cover the second to fifth generation mobile communication frequency bands, radio frequency identification frequency bands, ultra-wideband communication frequency bands and mobile digital TV frequency bands, satisfying small size and high radiation intensity. The requirements, with stable radiation characteristics and large performance redundancy, can be applied to large-scale applications in the microwave band multi-network integration system.

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