Gradual Dielectric Constant Induction Array Fractal Antenna Used for Mobile Digital TV System

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Abstract. According to the requirements of the mobile digital TV system, the present paper creatively combined cross fractal antenna, induction array antenna, gradual dielectric constant film, graphene conductive ink and nano silver conductive ink, designed a gradual dielectric constant induction array fractal antenna used for mobile digital TV system. The result of test indicates that this antenna completely covered the working frequency band of the mobile digital TV system. This antenna has the advantages of small size, wide bandwidth and more redundant performance, and it has stable radiation performance and excellent physical and mechanical performance. This antenna can ensure the good transmission quality of wireless signal in mobile digital TV system in various harsh electromagnetic environments.

1. Introduction

The mobile digital TV system is a brand-new high-definition interactive digital TV system. It is mainly used in urban public transport vehicles and private vehicles such as buses, BRT, light rail vehicles, etc. It can receive television, participate in television shopping, remote video interaction, online vehicle entertainment. It can provide a good interactive video and entertainment experience for vehicle drivers. The mobile digital TV system has gradually become the "standard" of new vehicles on the road, and has become a new media with great influence [1-5].

The mobile digital TV system transmits and receives wireless signals based on satellite; the performance of antenna has a decisive influence on the performance of the mobile digital TV system. The working frequency band of the mobile digital TV system stipulated by ITU is 11.700-12.200 GHz. The mobile digital TV antenna must cover 11.700-12.200 GHz band completely, satisfy the requirements of small size, wide bandwidth and more redundant performance, has stable radiation performance and excellent physical and mechanical performance [6-8].

2. Brief introduction of cross fractal structure

The iterative process of cross fractal structure is shown in Figure 1. Its original structure is square, divided into three rows, three columns, a total of nine small squares, dig out four small squares, located in the upper left corner, lower left corner, upper right corner, lower right corner, retain five small squares, which constitutes the 1st-order cross fractal structure. Do cross fractal iteration on each square of the 1st-order cross fractal structure, can obtain 2nd-order cross fractal structure. Followed this iteration, can get high-order cross fractal structure [9-10].
3. **Brief introduction of induction array antenna**

The induction array antenna is composed of a central feed antenna patch and a surrounding array of induction antenna patches. When the feed antenna patch works, its radiation energy will be absorbed by the induction antenna patch, resulting in the induction radio frequency current, thereby generating the induction secondary radiation. Reasonably adjusting the distance between the feed patch and the induction patch can make the current on them have the same or similar phase, and their radiation can be superimposed, which will greatly enhance the radiation intensity of the array antenna.

4. **Brief introduction of gradual dielectric constant film**

The structure of the gradual dielectric constant film is shown in Figure 2. The gradual dielectric constant film divides the PET film into several different regions, one region corresponds to a radiation patch in the array antenna, and the relative dielectric constant of each region changes gradually according to certain laws. After using this film in the design of array antenna, the working frequency of each radiation patch is different. Their working frequency points are close, and their radiation and working frequency bands will be superimposed, thus improving the radiation performance and bandwidth performance of the array antenna.
Figure 2. Schematic diagram of the gradual dielectric constant film.

5. Structure design of the gradual dielectric constant induction array fractal antenna used for mobile digital TV system

In the design, the PET film is used as the antenna substrate material. The shape of the PET film is rectangular, the size is 5.2 mm×5.2 mm, and the thickness is 0.1 mm. PET film substrate can resist oil, dilute acid, dilute alkali, most solvents, can work normally in the temperature range from -70°C to 150°C, and has little effect on its mechanical properties at high and low temperatures. The chemical stability of PET film is very good; it can ensure that the antenna has stable physical and chemical properties.

The antenna structure comprises a PET film substrate, a induction array fractal antenna radiation patch mounted on the front of the PET film substrate and a ground plate of the antenna mounted on the back of the PET film substrate. The ground plate of the antenna is a fully conductive grounding structure, and the induction array fractal antenna radiation patch structure is shown in Figure 3. The induction array fractal antenna radiation patch is divided into 13 square areas, the size of the central area is 2.6 mm×2.6 mm, and a feed fractal antenna is placed; the central area is surrounded by 12 edge areas, the size of each edge area is 1.3 mm×1.3 mm, and an inductive fractal antenna is placed. The feed point of the array antenna is located at the bottom edge of the feed fractal antenna. The size of the feed fractal antenna is 1.8 mm×1.8 mm, and the size of the inductive fractal antenna is 0.9 mm×0.9 mm. Fractal antennas use the 2nd-order cross fractal structure.

The PET film structure of the antenna is shown in Figure 4, it is divided into 13 square areas, the size of the central region is 2.6 mm×2.6 mm, and its relative dielectric constant is 4.0; the central region is surrounded by 12 edge regions, the size of each edge region is 1.3 mm×1.3 mm. The relative dielectric constant of each edge region varies clockwise from the upper left edge region. The relative dielectric constant of each edge region is 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, and 21.0 in turn. The central region of PET film substrate corresponds to the feed fractal antenna located at the central area of the induction array fractal antenna radiation patch. The edge regions of PET film substrate correspond to the inductive fractal antenna located at the edge areas of the induction array fractal antenna radiation patch. After using this PET film substrate in array antenna design, the relative dielectric constant of PET film substrate corresponding to each inductive fractal antenna is different. The 12 inductive fractal antennas have different working frequency points, and
their radiation and working frequency bands will overlap each other, forming a working band with larger radiation intensity and wider working bandwidth.

The antenna grounding plate and feed fractal antenna are made of graphene conductive ink, and the inductive fractal antenna is made of nano silver conductive ink. Graphene conductive ink has high carrier mobility, it can be used to print antenna ground plate and feed antenna, which can increase the antenna current intensity and improve the radiation ability of feed antenna. Nano silver conductive ink has higher conductivity, which can ensure that the induction antenna produces stronger induction radiation. Graphene conductive ink contains no metal at all, nano silver conductive ink has a low metal content, they are not easy to be corroded in open-air working environment, and can ensure the antenna has a high working stability.

Figure 3. The induction array fractal antenna radiation patch structure.

Figure 4. The gradual dielectric constant PET film structure of the antenna

6. Fabrication and test of the gradual dielectric constant induction array fractal antenna sample
According to the above design, the gradual dielectric constant induction array fractal 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 this antenna's working center frequency is 12.000 GHz, the antenna's working frequency range is 10.328-14.346 GHz, the antenna's working bandwidth is 4.018 GHz, the antenna's relative bandwidth is 32.57%, the minimum value of return loss is -39.31 dB. This antenna completely covered the working frequency band of the mobile digital TV system.

As can be seen from Figure 6, the E and H plane patterns of the antenna have good omni directional coverage characteristics.

Figure 5. The return loss performance test results of the gradual dielectric constant induction array fractal antenna.

Figure 6. The radiation pattern test results of the gradual dielectric constant induction array fractal antenna.

7. Conclusion
According to the requirements of the mobile digital TV system, the present paper designed a gradual dielectric constant induction array fractal antenna used for mobile digital TV system. With a total of 13 radiation patches, the size of this antenna is only 5.2 mm×5.2 mm×0.1 mm, which is the smallest size and thickness of mobile digital TV antenna known at present. It has the advantages of both micro-antenna and ultra-thin antenna, and has unique advantages in the miniaturization of antenna. This antenna has a large performance redundancy, and its bandwidth is up to 4.018 GHz and the minimum return loss is -39.31 dB. This antenna can ensure good transmission quality of the wireless signal of the mobile digital TV system in all kinds of harsh electromagnetic environment. This antenna structure
has low metal content, is not easy to be corroded during long-term operation, and has high radiation stability. This antenna fully covers the operating frequency band of the mobile digital TV system, and it is a miniature and ultra-thin mobile digital TV antenna with excellent performance. This antenna has the advantages of small size, wide bandwidth, large performance redundancy, stable radiation performance and excellent physical and mechanical performance. This antenna will be widely used in the mobile digital TV system.

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