Mobile Digital TV Induction Array Four Helix Antenna

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Abstract. According to the performance requirements of the mobile digital TV system, the present paper originally combines polygonal four helix antenna, induction array antenna, dielectric constant gradient film, graphene conductive ink and nano silver conductive ink, designed a mobile digital TV inductive array four helix antenna. The result of test indicates that this antenna has completely covered the frequency band of the mobile digital TV system. This antenna has strong corrosion resistance and damage resistance, stable physical and mechanical performance and radiation performance, small size, thin thickness and large working bandwidth, so it has broad application prospects.

1. Introduction
With the continuous improvement of urban public transport systems, rail transit systems and the gradual popularization of private cars, most urban residents choose to commute on various vehicles. The mobile digital TV system is a kind of TV system applied to various kinds of high-speed moving vehicles, with high definition and good interactive experience. It can watch HDTV programs, video on demand or watch video back, participate in TV shopping and online video interaction by voice or online and so on. Most urban commuter vehicles are equipped with mobile digital television system, which has become a relatively influential emerging media[1-4].

The mobile digital TV system transmits and receives information through wireless signal transmission with satellites, which is highly dependent on the performance of the antenna. The working frequency band of the mobile digital TV system stipulated by the international telecommunication union is 11.700 ~ 12.200 GHz[5-7]. The mobile digital TV antenna must completely cover the frequency band of 11.700 ~ 12.200 GHz, and has strong corrosion resistance and destructive resistance, stable and reliable physical and mechanical performance and radiation working performance, and can realize small size, thin thickness and large working bandwidth at the same time.

2. Brief introduction of polygonal four helix antenna
The structure of the polygonal four helix antenna is shown in Figure 1, which is a broadband antenna with good anti-destructive performance. The center is a rectangular radiating patch, which is responsible for uniformly feeding the RF currents fed or sensed to the individual spiral radiating arms. The four sides of the rectangular radiation patch are each connected with a polygonal spiral radiating arm composed of a plurality of line segments, and the length of each line segment is gradually reduced from the outside to the inside. The length of each line segment is different, the working frequency is also different, and the radiation of multiple line segments working in different frequency bands are superimposed, so that the spiral spiral radiating arm has better broadband performance. Four completely identical polyline spiral radiation arms can enhance the radiation intensity of polyline four-line spiral antenna, and ensure that the polyline four-line spiral antenna has a good anti-destructive. In
the case of destruction, the polyline four-line spiral antenna can work normally as long as retain one polyline spiral radiation arm.

Figure.1 Schematic diagram of polygonal four helix antenna

3. Brief introduction of induction array antenna
The induction array antenna is an antenna array consisting of the central feed antenna radiation patch and the surrounding induction antenna radiation patch. When the feed antenna radiation patch is working, the radiation energy is absorbed by the induction patch antenna radiation around it, generating an induced RF current, thereby generating induced secondary radiation, and properly adjusting the distance between the feed patch and the sensing patch can make the radio frequency current on the both have the same or similar phase. At this time, the feed radiation and the induced radiation are superimposed in phase, which greatly enhances the radiation intensity of the array antenna.

4. Brief introduction of dielectric constant gradient film
The dielectric constant grading film divides the polyethylene terephthalate (PET) film substrate into a plurality of different regions, so that the relative dielectric of the film matrix region corresponding to each radiation patch in the array antenna constant, gradually changing according to certain laws. After the dielectric constant grading film is used in the array antenna design, the relative dielectric constants of the film substrates corresponding to each radiation patch are different, so each radiating patch has different operating frequencies, and their working frequencies are closer, radiation and operating frequency bands are superimposed on each other to improve the radiation performance and bandwidth performance of the array antenna.

5. Structure design of the 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 6.0 mm×6.0 mm, the thickness is 0.1mm. The antenna structure includes a film substrate, an inductive array four helix antenna radiation patch attached to the front side of the film substrate, and an antenna grounding plate attached to the back of the film substrate. The grounding plate of the antenna is a fully conductive area grounding structure, and the inductive array four helix antenna radiation patch structure is shown in Figure 2.

The inductive array four helix antenna radiation patch is divided into 13 square areas with a central area of 3.0 mm×3.0 mm. Its center place a feed four helix antenna radiation patch. The central area is surrounded by 12 edge areas, each of which is 1.5 mm×1.5 mm, place an inductive array four helix antenna radiation patch in the center of each edge area. The feed point of the inductive array four helix antenna radiation patch is located at the center of the feeding four helix antenna radiation patch.

The size of the feeding four helix antenna radiation patch is 2.6 mm × 2.6 mm, its center is a rectangular radiation patch, the size is 0.6 mm×0.6 mm, a polyline spiral radiation arm consisting of 5 line segments is connected to each of the four sides of the rectangular radiating patch, the line width is 0.2 mm, from the outside to the inside, the length of each line segment is gradually reduced, the lengths of the 5 segments are: 10 mm, 8 mm, 6 mm, 4 mm, 2 mm. The inductive array four helix antenna radiation patch size is 1.3 mm×1.3 mm, its center is a rectangular radiation patch, the size is
0.3 mm × 0.3 mm; a polyline spiral radiation arm consisting of 5 line segments is connected to each of the four sides of the rectangular radiating patch, the line width is 0.1 mm, from the outside to the inside, the length of each line segment is gradually reduced, the lengths of the 5 segments are: 5 mm, 4 mm, 3 mm, 2 mm, 1 mm. The polyline spiral radiation arm from the feeding four helix antenna radiation patch and the inductive array four helix antenna radiation patch, the spiral direction is clockwise rotation, and the angle between adjacent two segments is 90 degrees.

The PET film matrix structure of the antenna is shown in Figure 3, it is divided into 13 square areas with a central area of 3.0 mm × 3.0 mm and the relative dielectric constant of 6.0. The central area is surrounded by 12 edge areas, each of which is 1.5 mm × 1.5 mm, starting from the edge area in the upper left corner, the relative dielectric constant of each edge region changes gradually in a clockwise order, and the relative dielectric constant of each edge region is 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0. The 13 square areas of the film matrix structure, one-to-one corresponding to the feeding four helix antenna radiation patch with radiation array center of inductive array four helix antenna radiation patch and the surrounding 12 inductive four helix antenna radiating patches. After using this film matrix in an array antenna design, the relative dielectric constants of the film substrates corresponding to each of the inductive four helix antenna radiating patches are different, therefore, the operating frequencies of the 12 inductive four helix antennas are different, their radiation and operating frequency bands overlap each other, forming a working frequency band with high radiation intensity and wide working bandwidth.

The antenna grounding plate and the feeding four helix antenna radiation patch are printed by graphene conductive ink, the inductive array four helix antenna radiation patch is printed by nano silver conductive ink. The graphene conductive ink has higher carrier mobility, used to print antenna grounding plate and feed radiation patch can increase the antenna RF current intensity, improve the radiation capability of the feed radiation patch. The nano silver conductive ink has high conductivity, which can ensure that the antenna inductive radiation patch produces strong inductive radiation. The graphene conductive ink is completely metal free, the nano silver conductive ink has a low metal content, they are not easily corroded in open air working environments and can guarantee high stability of the antenna.

![Figure 2](image-url)
6. 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.

As can be seen from Figure 4(a), the antenna's center frequency is 12.000 GHz, the working frequency range is 9.503-14.847 GHz, the operating bandwidth is 5.344 GHz. The minimum value of the return loss of the antenna is -43.15 dB. The measured results show that the antenna completely covers the working frequency band of the mobile digital TV system.

As can be seen from Figure 4(b), both the E and H plane of the antenna have good space omnidirectional working ability.

Compared with the conventional antenna used in mobile digital TV systems, this antenna has a large performance advantage. The antenna has large structural redundancy and is highly resistant to damage. When damaged, the four-helix antenna structure can work normally as long as it retains a polyline spiral radiation arm. The size of this antenna is only 6.0mm × 6.0mm × 0.1mm, which has the advantages of micro-antenna and ultra-thin antenna, and has unique advantages in the miniaturization of antenna. The antenna has high radiation intensity, the minimum return loss is as low as -43.15 dB, and the working bandwidth is up to 5.344 GHz, which can ensure the wireless transmission of mobile digital TV system has good transmission quality in various harsh electromagnetic environments. The antenna structure has a low metal content, is not easily corroded during long-term operation, and has high radiation working stability.
7. Conclusion

According to the performance requirements of the mobile digital TV system for the antenna, this paper designs a mobile digital TV inductive array quad-helical antenna, which uses a folded-line quad-helical antenna structure, and a plurality of different lengths of radiation segments working in different frequency bands form a polygonal spiral radiating arm. Their radiation is superimposed so that the polygonal spiral radiating arm has a wider operating band. Four identically-consistent polygonal spiral radiating arms ensure enhanced resistance to damage while maintaining the radiation. The feeding quad-helical antenna radiation patch and the inductive quad-helical antenna radiation patch constitute an inductive array quadrifilar antenna radiation patch, and the feeding radiation and the inductive radiation are superimposed in phase, which greatly enhances the radiation intensity of the antenna. The use of a polyethylene terephthalate film substrate with a relative dielectric constant in a clockwise gradation as an antenna substrate material ensures excellent physical and mechanical properties of the antenna, enabling 12 inductive quad-helical antenna to operate at different operating frequencies. Using radiation superposition principle to effectively improve the radiation performance and bandwidth performance of the array antenna. The antenna structure is printed by using graphene conductive ink and nano silver conductive ink, which ensures better corrosion resistance of the antenna structure and improves the working stability of the antenna. The measured results show that the antenna completely covers the working frequency band of the mobile digital TV system. The antenna has strong corrosion resistance and damage resistance, stable physical and mechanical performance and radiation performance, small size, thin thickness and working bandwidth. Large, has broad application prospects in the field of mobile digital TV.

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