QUADRIFILAR FRACTION-TURN CONE TYPE HELIX ARRAY ANTENNAS

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1. INTRODUCTION

The conventional wide-beam, circular polarized wave UHF and VHF antennas used to be very large in construction. Kilgus(1) invented a quadrifilar fraction-turn cylinder type helical antenna. This type of antenna consists of two pairs of independent antenna elements arranged orthogonally. The antenna is supplied with two currents of the same amplitudes but 90 deg phase difference. Thereby, circular polarized wave is radiated. Its radiation pattern becomes a cardioid type offering a wide beam width. In addition, the size can be smaller. Therefore, this type antenna can conveniently be applied to satellite use. This quadrifilar fraction-turn cylinder type helical antenna is already used for the circular polarized wave antenna for the communication satellite applications.

The authors attempted to improve the performance characteristics of this type of antenna by modifying the shape from cylinder to cone type. Using the moment method,(2) various characteristics of the antenna were analyzed and improved. This paper describes the results and the operating mechanism of this antenna.

Also, the authors attached a reflector plate to this antenna to modify to an arrayed antenna. These results are also included. The results were verified by an experiment for good agreement.

2. DESIGN OF QUADRIFILAR FRACTION-TURN CONE TYPE HELICAL ANTENNA

When the shape of the antenna is determined, the parameters of a cone, as shown in Fig.1, should be designed in the following manner. A total of \( R_1 + R_2 + L_h \) should become \( \lambda/2 \) all the time, where \( R_1 \) is the radius of the lower face and \( L_h \) is the length of the spiral part of the side face. At that time, an intersection angle is defined by the angle between the spiral and a straight line drawn from the vertex of the cone down to the side face. The intersection angle is represented by symbol \( \alpha \). The antenna element is wound on the cone surface while maintaining angle \( \alpha \) constant.

In this paper, a design center frequency is set to 750 MHz together with a number of fractional windings of \( N=1/4 \) turn. \( R_1=0.05\lambda (=2.0\text{cm}) \) and half vertex angle \( \theta_0 \) is 45 deg. Theoretical analysis was applied to the cone type antennas with angle \( \theta_0 \) of 45 deg. Also, the antennas were actually modeled and their impedances were measured. The results are shown in Fig.2. Experimental values are rather scattering but the tendency is similar to the theoretical values. Figure 3 shows the theoretical pattern of horizontally and vertically polarized waves on the horizontal and vertical planes at the design center frequency of 750 MHz for the cone type helical antenna, with \( \theta_0 \) varied. Experimental values are also described.

3. QUADRIFILAR FRACTION-TURN CONE TYPE HELICAL ARRAY ANTENNAS WITH A REFLECTOR PLATE

This paper describes an analysis by the moment method with the antenna of quadrifilar fraction-turn cone type helix array antenna. For the analysis, the coordinate was taken as shown in Fig.4, then X-Z plane was assumed to be an infinite reflection plate with an antenna spacing of \( W \). Thus, the antenna gain and pattern were theoretically analyzed. The following
paragraphs describe the characteristics with 4-array of the antenna elements. The highest gain is obtained from system of Fig.5, namely about 4 dB in terms of relative gain. This system is fixed for the description in the following paragraphs, then W and H are varied to study the change of various antenna characteristics, where W is the length of a side of the square shape formed by the antenna elements and H is the distance from feeding point to the reflector plate. Figure 6 shows the change of gain at a design frequency of 750 MHz with variable W and H, where W represents the spacing between antenna elements and H is the distance between the feeding point and the reflector plate.

For theoretical analysis, W and H were changed by 0.05λ units between W=0.4 and 1.0λ and between H=0.3 and 1.0λ. When H is small referring to Fig.6, the gain changes rather by a smaller amount when W varies. However, the gain changes more largely from about H=0.5λ, while the value of gain being lowered in general. The gain reaches a minimum at about H=0.6λ. Then, the gain again increases with larger H. Beyond about H=0.8λ, rather large gain can be obtained. In the authors case, the maximum gain was 9.7 dB(W=0.6λ, H=0.75λ). High gain can generally be obtained at W=0.6λ.

Figure 7 shows the frequency characteristics at W=0.6λ. With small H, the gain changes in a narrower range, when frequency varies. With larger H, the gain changes more greatly and sharply. The relative gain may sometimes becomes lower than 0 dB. A steep fall of gain occurs at a lower frequency when H is larger.

Radiation pattern is then discussed. Because of the symmetry of the elements, arrayed antenna remains in the same shape even after a revolution of 90 deg. Therefore, the horizontal and vertical plane patterns of vertical polarized wave correspond respectively to the vertical and horizontal plane patterns of horizontal polarized wave.

Figure 8 shows the horizontal plane pattern of horizontal and vertical polarized waves when W=0.6λ and H are varied at a design center frequency of 750 MHz. At about H=0.6λ, no maximum value is obtained in front direction. When H becomes larger (than 0.7λ), the width of main beam is narrower.

Figure 9 illustrates the frequency characteristics at H=0.75λ, W=0.6λ. Wide main beam can be obtained with small sidelobe in low frequency range. As the frequency increases, the main beam becomes narrower with larger sidelobe.

4. CONCLUSION

A quadrifilar fraction-turn helical antenna has been analyzed in the basic characteristics as a single unit, together with an experiment studying impedance and pattern. The experimental values are compared with the theoretical values, resulting in a fair agreement. Then, the antenna is modified to the 4-array system. The 4-array system is proved to have circular polarized characteristics with a simple and small construction. With H=0.75λ, the antenna of a relative gain of about 10 dB can be given. In the result, the antenna can be used as a small antenna for marine satellite use.

The authors will further develop the system by attaching sub-reflector plate and affixing cylindrical metal rim to each antenna element, and so on.

REFERENCES:
Fig. 1. Quadrifilar fraction-turn cone type helix antenna configurations

<table>
<thead>
<tr>
<th>horizontally polarized wave</th>
<th>vertically polarized wave</th>
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<tr>
<td><strong>vertical pattern</strong></td>
<td></td>
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<tr>
<td>a) $\theta_0=15^\circ$</td>
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<tr>
<td>b) $\theta_0=45^\circ$</td>
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Fig. 2. Input impedance characteristics of quadrifilar fraction-turn cone type helix antenna ($N=1/4$ turn, $\theta_s=60^\circ$)

Fig. 3. Radiation pattern of quadrifilar fraction-turn cone type helix antenna ($N=1/4$ turn, $f=750$ MHz)

Maximum gain 4.11 dB (relative gain)

Fig. 4. Quadrifilar fraction-turn cone type helix array antenna with reflector plate and its coordinate system

Fig. 5. Feed system of quadrifilar fraction-turn cone type helix array antenna

$W=0.40\lambda-1.00\lambda$
$H=0.30\lambda-1.00\lambda$
Fig. 6. Gain of quadrifilar fraction-turn cone type helix array antenna with variable $W$ and $H$ ($W=0.4\lambda-1.0\lambda$, $H=0.75\lambda-0.85\lambda$)

Fig. 7. Frequency characteristics of gain of quadrifilar fraction-turn cone type helix array antenna with reflector plate ($W=0.6\lambda$, $H=0.75\lambda-0.85\lambda$)

Fig. 8. Horizontally polarized wave of horizontal pattern of quadrifilar fraction-turn cone type helix array antenna with reflector plate ($W=0.6\lambda$)

Fig. 9. Frequency characteristics of horizontal pattern of quadrifilar fraction-turn cone type helix array antenna with reflector plate ($H=0.6\lambda$, $H=0.75\lambda$)