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A BEAM STEERABLE DUAL-REFLECTOR ANTENNA

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Introduction

Since recent geostational satellites for communication are correctly positioned and their drifting angle is within one or two degrees, a wide scanning angle is not required for the ground station antenna. It is, therefore, obvious that a limited steerable antenna whose important parts (such as the main reflector and the primary radiator) are fixed, is suitable for the ground station antenna. Such an antenna can offer substantial economic advantages over the fully steerable antenna.

Many beam steering methods have been developed for the large spherical reflector antenna. But the spherical reflector antenna is not very suitable for the ground station antenna, because a movable primary radiator is necessary for steering its radiated beam.

It is well known that the Cassegrain antenna with the parabolic reflector can steer its beam over small angles by rotating its sub-reflector. Though its steerable range is small, other characteristics and structure of the antenna are appropriate for the ground station antenna.

Consequentry we propose a dual-reflector antenna which has a sufficient scanning angle characteristic. Its structure is similar to the Cassegrain antenna and reflector shapes are modified so as to be appropriate for scanning. The reflector curves are designed as follows.

Two-dimensional design of the mirror curves

In Fig.1 the sub-reflector is rotated about C, and the inclination angle with respect to the antenna axis is φ_0. In this condition reflector curves are determined so that the equiphase surface of the radio wave from the primary radiator is perfectly directed to θ_0. Moreover they are designed to be symmetrical about with their center axes. Then if the sub-reflector is rotated $-\varphi_0$, the beam is directed to $-\theta_0$.

Consider Fig.2. In the unrotated state the sub-reflector is symmetrical about the X-axis, its slope at the apex is normal to the X-axis. So the rotated apex (u_1, v_1) and its slope are determined by C and φ_0. The ray strikes against (u_1, v_1) from the focus F and is reflected to the main reflector. After the reflection on the main reflector the ray reaches to the phase front. If the optical total path length from the focus to the phase front is given, then a point (x_1, y_1) on the main reflector and the slope of the reflector are determined. Since the reflector is symmetrical about the X-axis, a point (x_2, y_2) and the slope are also determined. The second ray travels to (x_2, y_2), is reflected to the sub-reflector, and a point (u_2, v_2) on the sub-reflector is uniquely determined from the total path length. Next, the symmetrical point (u_3, v_3) is obtained. The third ray strikes against (u_3, v_3) from the focus and determines a point (x_3, y_3) and the slope.

Continuing this procedure, a succesion of points and slopes on each reflector surface is obtained. Consequentry this antenna can perfectly direct its beam in the direction θ_0 and $-\theta_0$, and if θ_0 is small, it is expected that it can also steer its beam between θ_0 and $-\theta_0$ without large gain reduction.

The method mentioned above is a modification of a designing method for the dielectric bifocal lens[1].

Experimental results

A model antenna was constructed in order to experimentally verify the design principle. We calculated the reflector curves on the two-dimensional plane by the geometrical optics method and our trial model has reflector surfaces which are obtained by rotation of the two-dimensional curves about their center axes. Our model antenna is shown in Fig.3. It is 1.2 m in diameter and designed at 50 GHz. Other parameters are:

$$\theta_0 = 2^\circ,\quad \varphi_0 = 6^\circ,\quad C = 431.50$$

The surface roughness of the main reflector is 0.1 mm r.m.s.

Experimental results are shown in Fig.4. Solid lines correspond to H-plane patterns of the antenna when the sub-reflector is rotated about C. And dotted lines correspond to TE_{01}^{0} mode patterns. The gain is 50.2 dB 26%. at $\varphi = 0^\circ$, and the maximum gain is 51.0 31%. dB at $\varphi = 10^\circ$. Moreover, when the sub-reflector and its axis of rotation C, are moved toward the main reflector, the gain is improved to 52.3 dB at $\varphi = 0^\circ$. The broken line 2 shows the locus of the maximum gain point when the sub-reflector is moved and rotated the correct amount φ. The broken line 1 shows the locus of the maximum gain point of a standard Cassegrain antenna with the same diameter when the sub-reflector is rotated.

Conclusion

The results shown prove that our model antenna has a wide range steerable angle and the above technique is useful for designing a limited steerable antenna.

Reference

1. R. M. Brown, Dielectric Bifocal Lenses, IRE Natl. Conv. Record Pt. 1, 1956

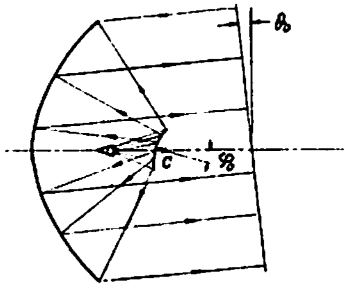

Fig.1 Beam steerable dual-reflecter antenna

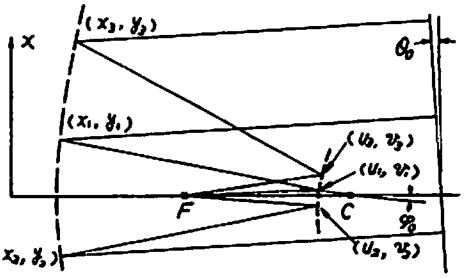

Fig.2 Designing of the reflector curves by lattice method

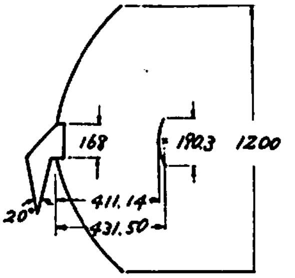

Fig.3 Model antenna

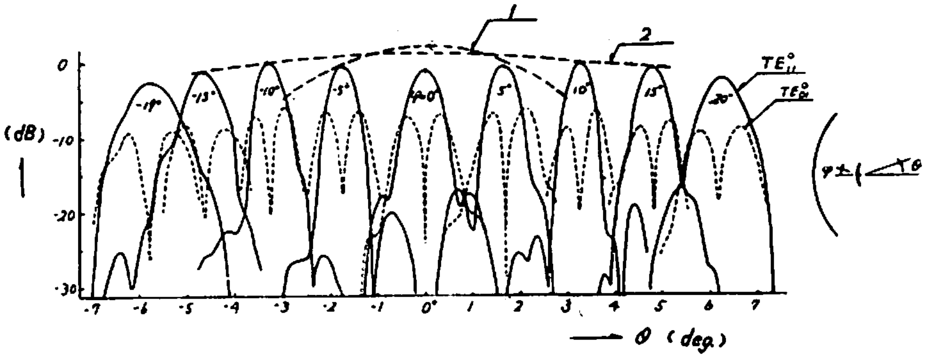

Fig.4 Typical patterns