A Study on Radiation Characteristics of Horn Antennas with a Hexagonal Beam

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1 Introduction

Large reflector antennas for space-use have mostly non-circular aperture because of deployable structures in antennas and a multi-facet paraboloidal reflector. Typical antennas will be employed on MUSES-B satellite [1] and a solar power satellite [2]. When such a reflector is illuminated with a circular beam on the basis of the conventional technique, the spillover or non-illumination occurs. In order to reduce such losses, it is desirable to match the beam shape of the primary radiator with the reflector shape. The beam shape of the primary radiator can be formed using a higher mode horn or a horn array [3].

This paper describes the numerical analysis results of primary radiators adapted for a hexagonal aperture antenna [4], [5]. Two types of the modified horn antennas are introduced. The electromagnetic field distributions and radiation characteristics are investigated. The relations between the beam shape and the antenna parameters are clarified as a result.

2 Analysis Method

The geometries of the antennas are shown in Fig. 1. A hexagonal pyramidal horn antenna is one whose opening is flared in the direction of sides of the hexagonal waveguide as shown in Fig. 1(a). The side lengths of the hexagonal aperture and waveguide are $D/2$ and $a/2$, respectively, and the flare angle is α. Let the origin O be the antenna aperture center, and let the z-axis coincide with the antenna axis.

The other horn antenna is a conical horn antenna with wedges on the wall as in Fig. 1(b). The six wedges making an angle θ_w with height h_w are protruded at equal intervals on the wall. The diameters of the aperture and waveguide are D and a, respectively.

The electromagnetic field in the waveguide can be obtained by solving two dimensional Helmholtz equation. For a hexagonal waveguide and circular waveguide with wedges, the finite element method is used to fit with the complicated cross-sections of the waveguides. It is assumed that the amplitude distribution on the actual horn aperture is the same as that of the waveguide, and the phase distribution is spherical surface whose phase center is located on the apex of the horn. From the field distribution on the aperture, the radiation pattern is obtained by the aperture integration method which can be used in the near-field region.

3 Hexagonal Pyramidal Horn

The electric field distributions in the hexagonal waveguide are shown in Fig. 2. Two modes corresponding to TE_{11} mode of a circular waveguide are excited, depending on the directions of the hexagon. In the mode 1 and mode 2, the horn is fed with the electric field in the direction of x-axis and y-axis, respectively. For a = 9.525mm, the cut-off frequencies of the mode 1 and 2 are 20.26GHz and 20.22GHz, respectively.

Figure 3 shows the radiation pattern of the hexagonal pyramidal horn which is excited with the mode 1 at 22GHz. The antenna parameters are D = 50mm, a = 9.525mm and α =10 degrees. The observation plane is fixed in the near-field region of z = 27.3mm. For a cassegrain antenna, the edge level of subreflector is usually determined in the range of $-15 \sim -20$dB. It is seen that the equi-level contour of -15dB is a hexagon. The contour is, however, deformed from a regular hexagon.

The relation between the beam shape and the distance from the aperture is shown in Fig. 4(a), where the parameter is the aperture size D. The abscissa shows the distance from the aperture in wavelength. The coordinate shows the beam shape parameter. The beam shape parameter is obtained as the ratio of width of -15dB contour in the x-direction to that in the y-direction from the radiation contour pattern.

The curves have maximal and minimal points. The beam pattern best resembles a regular hexagon at the minimal point. When the distance z is moved away from the minimal point, the beam shape becomes ellipse because of coming up to the far-field region.

The relation between the beam shape and the distance from the aperture is shown in Fig. 4(b), where the parameter is the flare angle. The curves have also maximal and minimal point. The best hexagonal beam can be formed at the minimal point. The minimal point moves farther as the flare angle gets larger.

4 Conical Horn with Wedges

Figure 5 shows the electric field distribution of the circular waveguide with wedges, corresponding to TE_{11} mode of circular waveguide, where a = 9.525mm, θ_w = 83.5 degrees and h_w = 1mm. For this mode, the radiation pattern is shown in Fig. 6. The beam shape is a hexagon as well as that of the hexagonal pyramidal horn at z = 27.3mm. The change of the beam shape with the distance from the aperture shows a similar tendency to the hexagonal pyramidal horn.

The electric field distributions corresponding to TE_{31} mode of circular waveguide are shown in Fig. 7. There are two modes. In the mode 1, the electric vectors flow from a wedge to a wedge, whereas in the mode 2, the electric vectors keep away from a wedge. For these case, the null is formed at boresight and the sidelobes appears at periphery of the boresight in the radiation patterns.

5 Conclusion

It is shown that two types of horn antennas can form a hexagonal beam shape. The best hexagonal beam can be obtained at the optimum distance from the aperture. In order to form the regular hexagonal beam, it may be necessary to combine several different modes.

References

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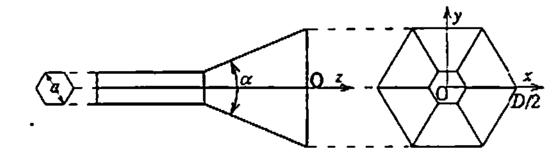
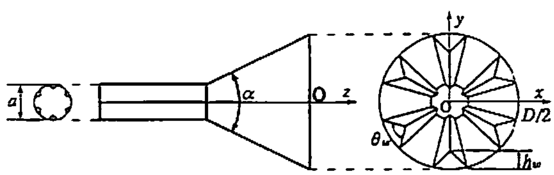
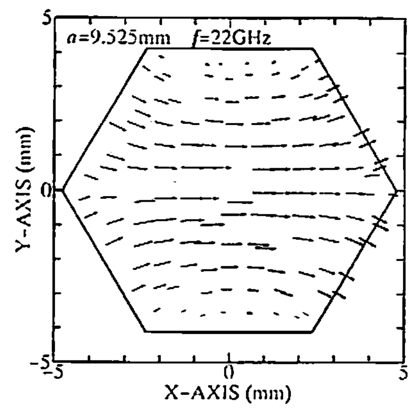


(a) Hexagonal pyramidal horn.

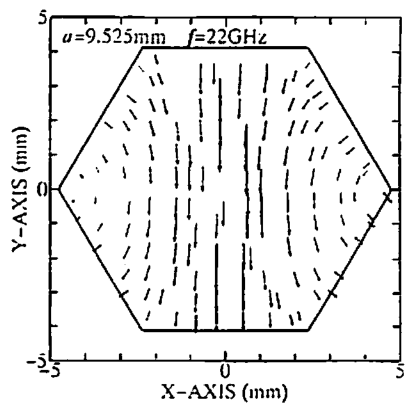


(b) Conical horn with wedges.

Fig. 1. Geometries of the horn antennas.



(a) Mode 1.



(b) Mode 2.

Fig. 2. Electric field in the hexagonal waveguide.

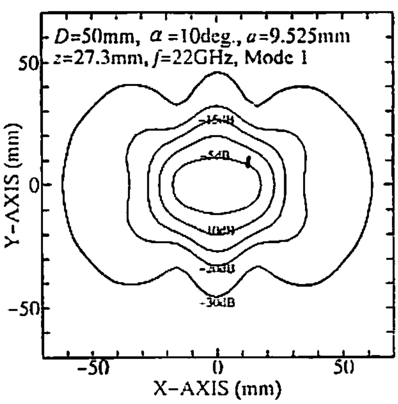
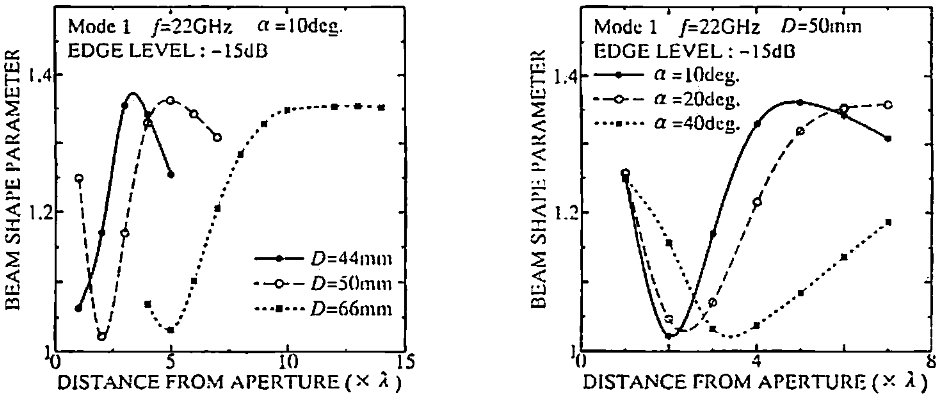


Fig. 3. Radiation pattern of the hexagonal pyramidal horn.



(a) Parameter : Aperture size.

(b) Parameter : Flare angle.

Fig. 4. Relation between beam width and antenna parameter.

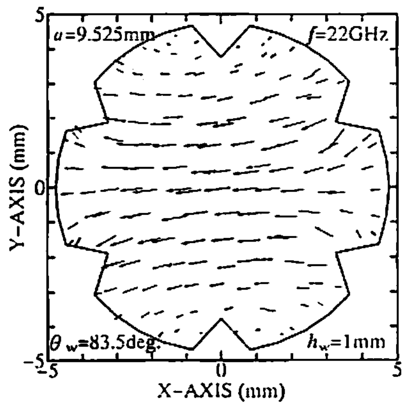


Fig. 5. Electric field in the circular waveguide with wedges.

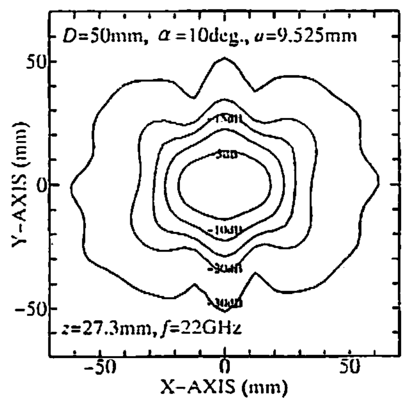
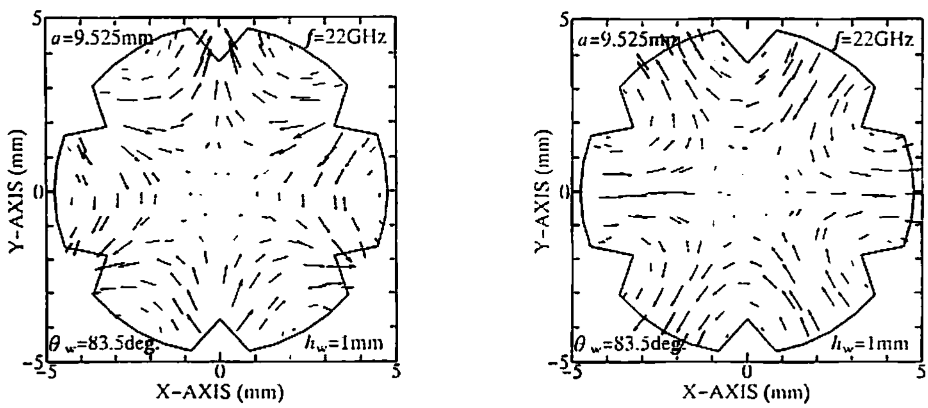


Fig. 6. Radiation pattern of the conical horn with wedges.



(a) Mode 1.

(b) Mode 2.

Fig. 7. Electric field corresponding to TE_{31}.