RADIATION CHARACTERISTICS OF RADIAL RIB DEPLOYABLE REFLECTORS

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Large deployable reflectors are likely to be used on future spacecraft for generating narrow beams. The small footprints on the earth will enable frequency reuse by means of spatial isolation and a single large reflector with an array feed could produce a multibeam antenna. There are a number of possible ways of constructing a reflector which can be launched in a folded configuration and then deployed in space. This paper reports a detailed theoretical study of the radiation characteristics of radial rib reflectors. This type of reflector consists of a reflective mesh supported by a number of radial ribs connected to a central hub, Figure 1. It is relatively easy to produce and the technology has been verified by a number of companies. In an idealised model it can be considered that the ribs are parabolic and the contour of the mesh between the ribs is a section of a parabolic cylinder.

As with any reflecting surface which deviates from a true parabola it has distorted radiation characteristics which may in some cases limit the use of the reflector. By comparison with a smooth parabola the gain is reduced; the main beam broadens; the first few sidelobes are suppressed and the level of the far sidelobes is increased considerably.

The radial rib reflector has been analysed by previous workers [1,2] who have used simplifying assumptions to predict some of the co-polar characteristics. In this study we mathematically model the radial rib reflector surface and then predict the far-field patterns using a general reflector analysis computer program based on surface current integration. This involves no approximations apart from the accuracy of the description of the reflector surface. The general computer program is necessarily time consuming and so in addition an analytic approach has been used to predict the general behaviour of the radial rib reflector. This makes use of the symmetry properties of the surface and expresses the complex exponential term in the radiation integral as a sum of Bessel functions. We have found that only a few terms are needed to approximately predict the co-polar beam broadening effects and the sidelobe behaviour.

The general form of the co-polar radiation patterns are shown in Figure 2. This compares a symmetric 100λ diameter reflector with F/D = 0.4 and 16 ribs to the equivalent smooth parabola. The on-axis feed has a $\cos^q\theta$ type pattern and the edge illumination on the reflector is -10 dB. The effects of feed blockage have not been included. The general features mentioned above are evident. The major difference from the smooth parabola is the presence of the sidelobes marked Regions A and B. The position of these is a function of both the number of ribs and the azimuthal angle ϕ. Figure 2 is for $\phi = 0$ whilst Figure 3 shows the case of $\phi = 5.625$ degrees which corresponds to a quarter the distance between ribs. The sidelobe region A has nearly disappeared in this plane. The analytic model enables regions A and B to be separately identified. Region A has a dependence of the form cos $(N_g \phi)$ where N_g is the number of ribs. It is thus a maximum along the ribs and the centre of the panels and a minima in between. As the number of ribs increase, the level of the initial peak in region A gets smaller and moves out to larger angles. As the diameter of the reflector increases the level of the initial peak gets larger and the ratio of its position to the reflector diameter remains approximately constant. The sidelobe region B has a dependence of the form cos $(2N_g \phi)$ and thus varies azimuthally at twice the rate of region A. The region of the main beam and first few sidelobes are ϕ independent and so the level of the first few sidelobes are always suppressed relative to a smooth parabola.

Figure 4 shows the equivalent cross-polar patterns for a feed with a peak cross-polarisation of - 30 dB. In the plane where the region A co-polar sidelobes disappear, there are significant cross-polar sidelobes. The presence of the rib-related sidelobes could have a significant impact on the potential use of the radial rib reflector as a multibeam satellite antenna.

The gain and efficiency of a radial rib reflector do not scale directly with normalised diameters. If the number of ribs is kept constant and the diamter increased then the phase error at the edge of the reflector increases. This can be partly compensated by refocussing the feed but leads to loss of gain. Figure 5 shows the aperture efficiency for three diameters of reflector against the number or ribs. As the number of ribs increases the efficiency tends towards the smooth parabola case but only slowly. In practise the maximum number of ribs will be limited by mechanical constraints at the hub so loss in efficiency is inevitable for a large diameter.

References

1. Ingerson, P.G. and Wong, W.C.: 'Analysis of deployable umbrella parabolic reflectors', IEEE Trans. AP-20 1972, p. 409-414.

2. Rush, W.V.T. and Wanselow, R.D.: 'Gore related sidelobes of an umbrella reflector': 1980 IEEE Ant. & Prop.Symp. Proc. p. 481-484.

Fig. 1: Radial rib reflector

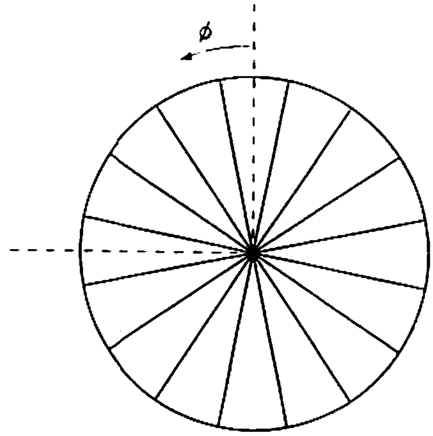

Fig. 2:

Copolar patterns for ϕ = 0 plane

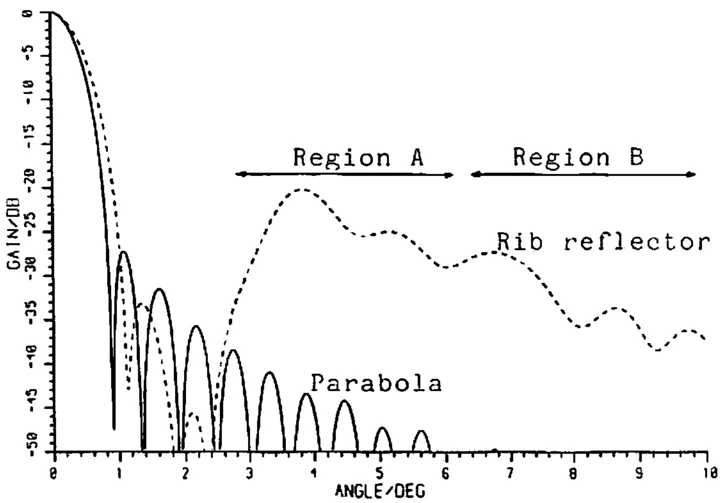

Fig. 3:

Pattern for ϕ = 5.625° plane

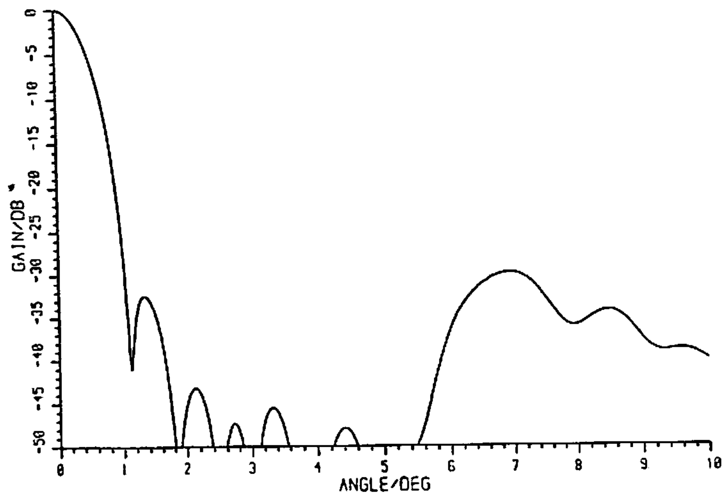

Fig. 4a:

cross-polar pattern for ϕ = 0 plane

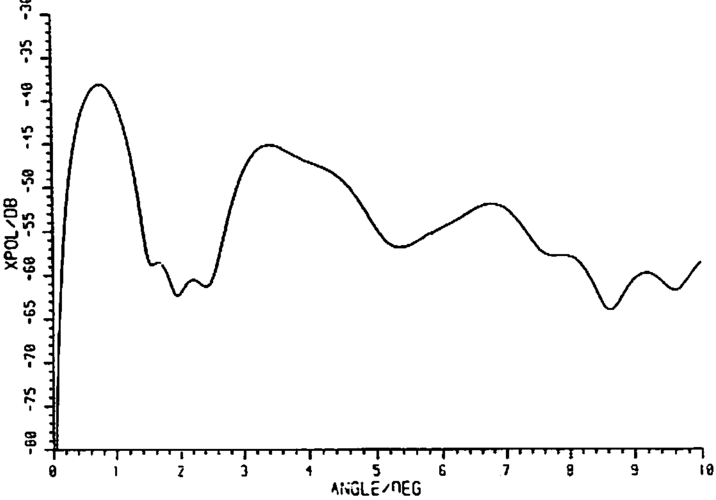

Fig. 4b:

ϕ = 5.625° plane

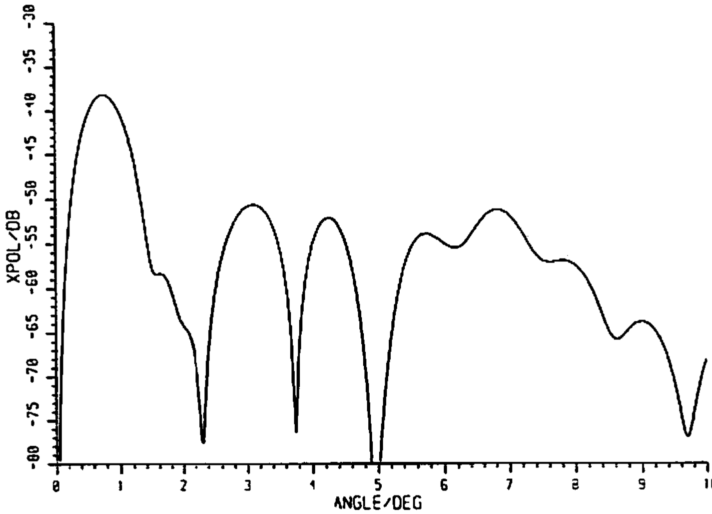

Fig. 5:

Efficiency for
(a) D = 50λ
(b) D = 100λ
(c) D = 200λ