LOWER COST ANTENNAS FOR THE HIGIIER MICROWAVE BANDS

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ABSTRACT

The paper describes development work carried out on two types of antenna. In both cases the emphasis is on low cost solutions to well known problems. A method for compensating the irregular surface of a paraboloidal reflector by figuring the surface of a Cassegrainian subreflector is described and practical results outlined. An integrated link repeater station design using lens antennas is described and its performance reported; this approach is advocated for low cost repeaters requiring small antennas.

INTRODUCTION

The increased pressure on space in the radio frequency spectrum is resulting in ever higher frequency bands being brought into commercial use. Two familiar problems associated with the use of higher frequencies are the demand for closer mechanical tolerances on antennas and the need to use large numbers of repeater stations because of the propagation characteristics of the atmosphere. The production of large reflectors to precise tolerances is very costly. The first section of the paper describes how the performance of an imprecise reflector may be improved when used in a Cassegrain configuration by suitably contouring the subreflector to compensate the imperfections of the main reflector. On terrestrial link circuits it is likely that repeater stations will be required at intervals of only a few kilometres. The cost of these repeaters must be made as low as possible because of the large numbers to be used. It has been suggested that they could be mounted on 'lamp posts' and for this a single structure to contain both equipment and antennas is needed. The second part of the paper describes a practical system in which low cost dielectric lens antennas have been used.

1. COMPENSATION OF AN IMPERFECT REFLECTOR

The surface of a paraboloidal reflector typically exhibits two types of deviation from the ideal surface; closely spaced tool marks, scratches and other indentations and more gradual high spots and depressions whose correlation interval is large compared with the operating wavelength. The present method provides a means of compensating these errors of long correlation interval when the reflector is used in a Cassegrain system. (Ref.1). The principle of the method may be seen in fig. 1. Ray ABCO strikes undistorted surfaces; ray XY strikes a depression on the primary reflector. To compensate for this and equalise the two paths ABCO and XYZO a raised area is arranged on the subreflector at Z. The method may be regarded as a generalisation of methods previously described by which particular systematic 'errors' have been removed, for example, the correction of spherical surfaces using non-hyperbolic subreflectors. In such cases the errors are circularly symmetrical about the axis of the reflector.

METHOD

The profile of the reflector is measured with the aid of an accurate templet and a tapered feeler guage. Sufficient points must be measured to define the

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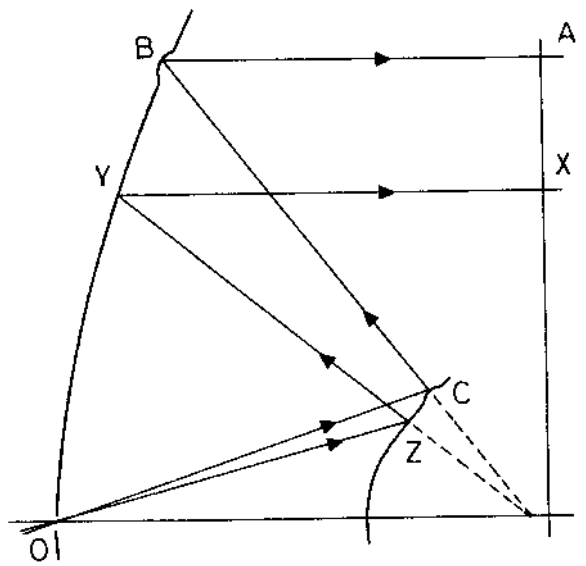

Fig.1. PRINCIPAL OF COMPENSATION METHOD

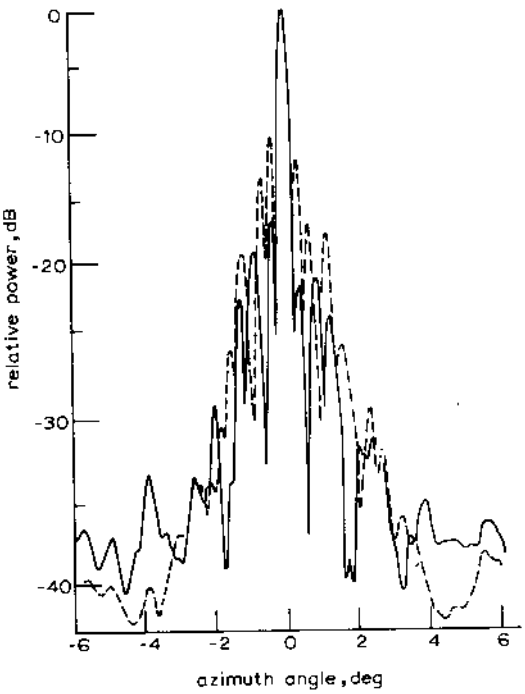

Fig.2
RADIATION PATTERNS
---- Before Correction
—— After Correction

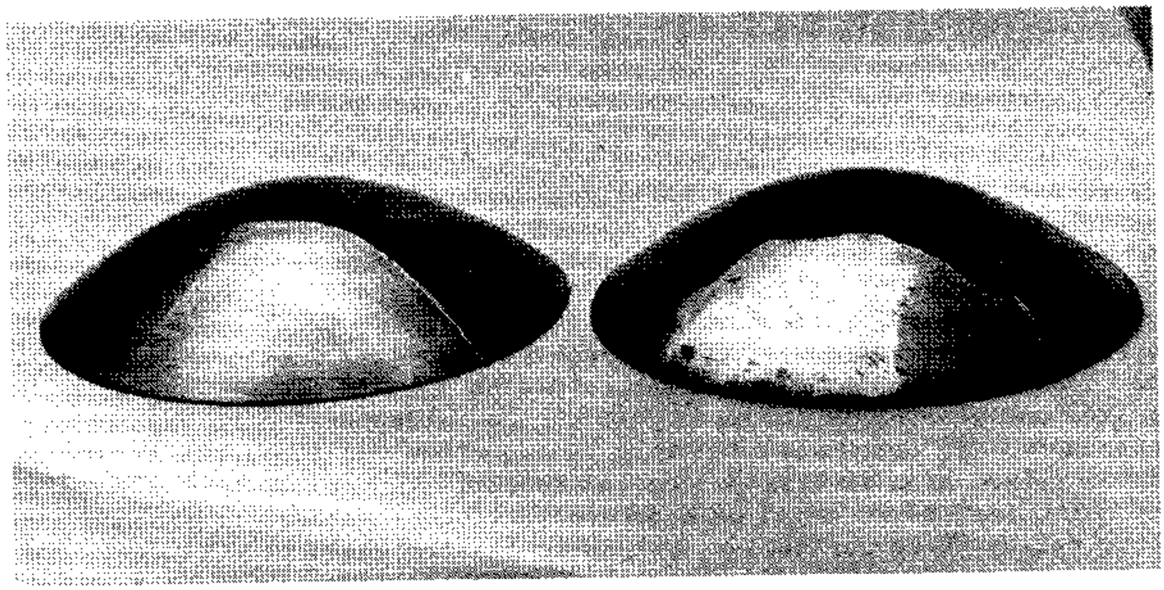

Fig.3
HYPERBOLOIDAL AND CORRECTED SUB-REFLECTORS

surface accurately. In a practical case where a reflector 2.8m in diameter was to be compensated for operation at 36GHz the surface error was measured at 25mm intervals along 16 radii - a total of 1200 points. At present the required subreflector profile is computed by a simple ray-optics technique; a full diffraction theory method has not yet been developed. In some cases the mapping of the errors onto the subreflector can be realised exactly, but the computed subreflector surface may contain singularities or convolutions which cannot be physically realised. This occurs when rays cross between the reflectors and will reduce the effectiveness of a realiseable solution. In many instances the surface error will exhibit a marked circularly symmetrical component - this is typical of spun reflectors. In some cases it may be possible to simplify the problem by averaging the errors measured along each radius. In this case the computed subreflector profile will also be circularly symmetrical and may therefore be machined on a lathe. In the general case the subreflector may be turned to approximate shape but must be finished on a digitally controlled milling machine, the data required to control the machine being computed from the error data.

RESULTS

The improvement obtained on an antenna using a 2.8m diameter focal plane reflector with a subreflector of 300mm diameter and eccentricity 1.24 is illustrated in fig 2. In this case only circularly symmetrical errors were compensated, but a 2.9dB increase in gain was achieved, the aperture efficiency rising from 11% to 22%. A much better primary reflector of similar size was fully compensated and an improvement of aperture efficiency from 34% to 48% obtained. Figure 3 shows a normal subreflector and a fully compensated one. It will be seen that compensation improves all the radiation pattern defects arising from the imperfect dish; gain is increased, main beam width decreased and sidelobe levels reduced. With the fully compensated subreflector it could be demonstrated that rotation of the subreflector drastically modified the performance of the antenna. The costs of the main and sub reflectors for 2.8m focal plane antennas of comparable performance at 36GHz have been compared for the conventional approach and the method now proposed. The conventional method requires a special quality main reflector with an r.m.s. error less than 0.5mm and uses a hyperboloidal subreflector. The compensation method makes use of standard spun reflector whose r.m.s. error is less than 1.5mm together with a compensating subreflector. The cost of the two reflectors and subreflector support for the conventional antenna is 33% greater than for the compensated antenna even when measuring, computing and machining times are included.

2. A LOW COST REPEATER STATION

Simple low cost repeater stations will require antennas providing only moderate gain as the deflection limits of simple 'lamp post' supports are not suited to very narrow antenna beamwidths and the short path lengths envisaged do not need extremely high antenna gain. In arriving at a practical design the following constraints were considered:

1. Provision of a single enclosure for two antennas and equipment.

2. Reduction of the number of surfaces requiring accurate manufacture.

3. Flexibility to allow for path geometry.

4. Aesthetically pleasing appearance.

5. Minimisation of effects of weather on performance

6. Ease of maintenance.

7. Low cost.

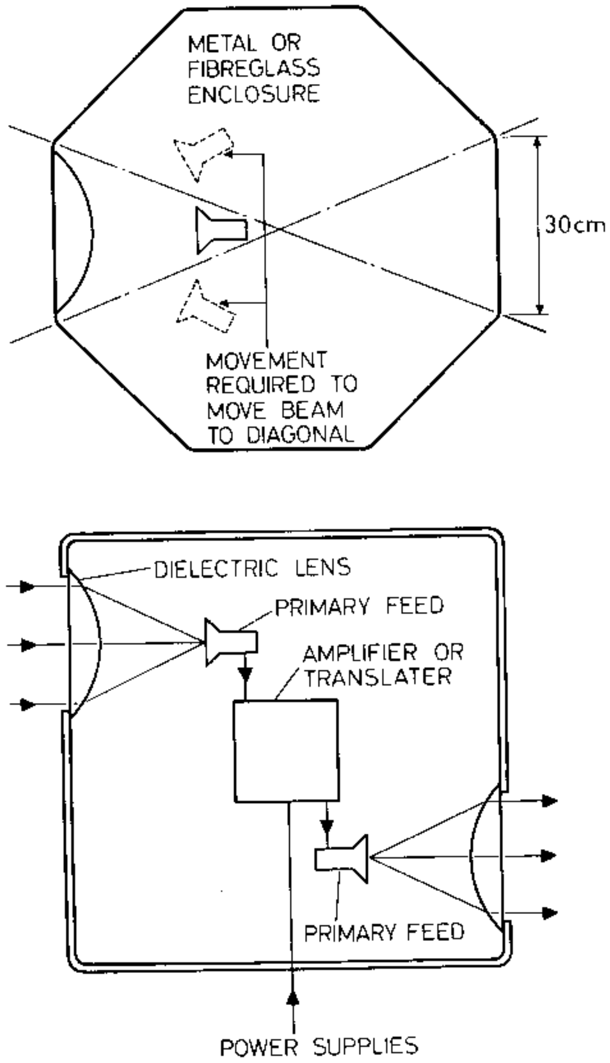

Fig.4. DIAGRAM OF INTEGRATED REPEATER STATION

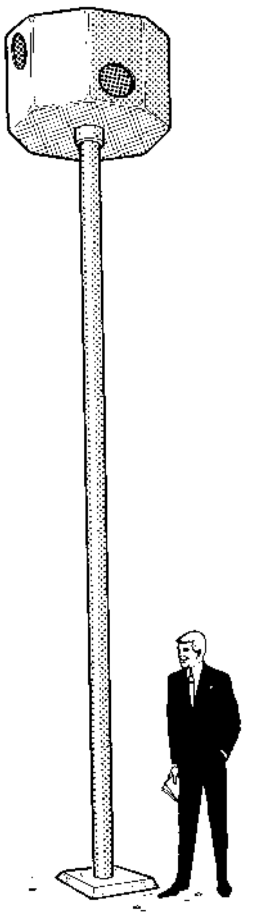

Fig.5. COMPLETE INSTALLATION

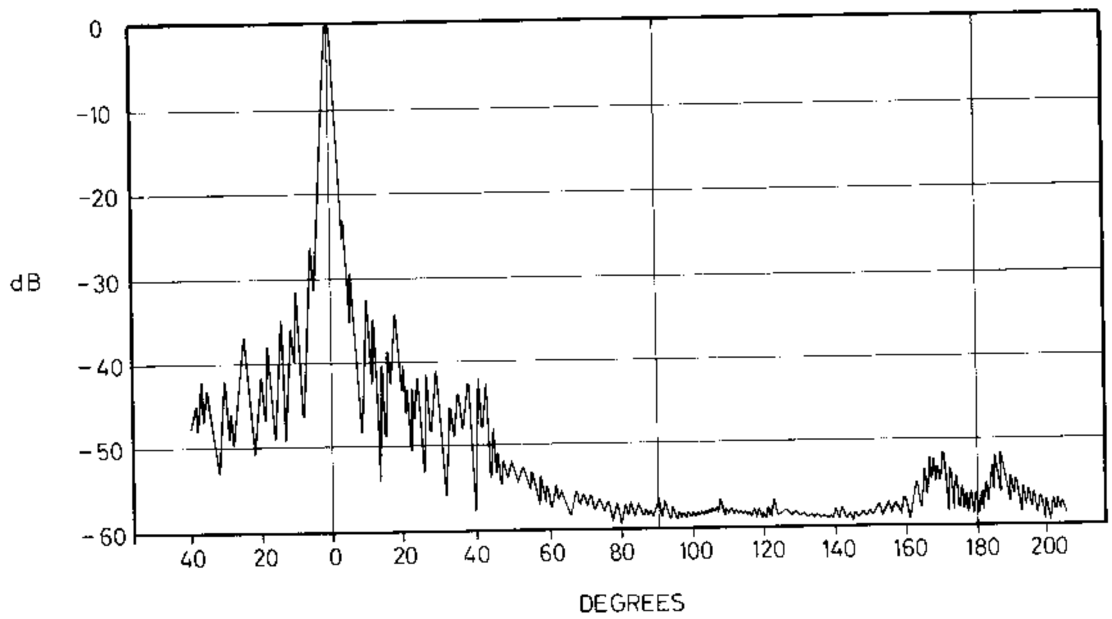

Fig.6. RADIATION PATTERN OF PROTOTYPE REPEATER

The essentials of the new design are shown in Fig 4. Dielectric lens antennas are fitted into two faces of an octagonal enclosure and are illuminated by horns placed inside it. The transmitting and receiving horns are situated conveniently for the amplifier or transposer to be placed between them. By motion of the horn the beam from each antenna may be scanned in azimuth over the whole angle (45) between adjacent diagonals of the enclosure. Thus by positioning the lenses in appropriate faces any relative bearing between transmit and receive paths may be accommodated. Fig 5 shows a complete pole mounted installation. The prototype enclosure was metallic, but it is envisaged that fibreglass would be used for quantity production. The lenses, which were 250mm diameter with a focal length of 400mm, were made of polyethylene. A plano-convex lens was used. This has the advantage of a flat outer surface but the disadvantages compared with a meniscus lens of poorer performance off axis and large on-axis reflections. Coating or grooving of the lens surfaces to reduce reflections have been considered but have not yet been applied. Polyethylene sheds water well and does not provide a key for ice or snow build-up. No separate radome is needed as with most other systems. The radiation pattern of the prototype is shown in Fig 6. Its gain was 33dB. A further reduction in sidelobe levels could be obtained if the internal surfaces of the box were made to absorb incident signals which at present are reflected, some of them emerging from the lens to form unwanted sidelobes. Although the illumination of the lens has not yet been carefully optimised an aperture efficiency of 55% is obtained. By placing a plane reflector obliquely behind the lens and folding the optical path so that the horn fires vertically upwards, the antenna is made even more compact and the centre of the enclosure is cleared to allow the mounting pole to be passed right through the enclosure. This allows the repeater to be lowered down the pole for maintenance in a manner similar to tall street lanterns. In its folded configuration the antenna may be compared with a horn-fed offset paraboloid with a radome; such a system would be more expensive when built to similar tolerances.

CONCLUSION

Two practical examples have been given which illustrate the way in which unorthodox solutions may have to be found in exploiting the higher microwave bands if costs are to be contained.

ACKNOWLEDGEMENTS

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REFERENCES

1. E. A. Parker & P. R. Cowles, Elec. Letters, 8, No 14 June 72.