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OFFSET SPHERICAL REFLECTOR ANTENNA WITH LOW CROSSPOLARISATION

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INTRODUCTION

In view of the emphasis now attached to low sidelobe envelopes for satellite communications, an increasing importance has been given to dual offset antennas for small earth stations. The above mentioned offset geometry is particularly interesting because it avoids subreflector and feed blockages which are responsible for rising sidelobes. The spillover effects in the offset plane can be minimised by aligning the plane of offset orthogonally to the geostationary orbit.

Several designs can be found in the literature and a comparative study of three of them was presented by Clarricoats et al (1). At one extreme of this comparison, the highest efficiency (up to 85%, measured) is achieved by shaping both reflectors which is associated to expensive manufacturing processes. At the other extreme, the comparison refers to an investigation performed by Ramanujam et *al* (2) about the use of a spherical main reflector associated to a phase correcting subreflector possessing axis symmetry. Among the three examples, the former configuration presents the lowest fabrication costs but also the lowest efficiency (65%,theoretical) (2).

Attracted by the costs characteristics of the spherical reflector, this study aims to present a few modifications in the geometry initially considered in Reference (2). These modifications lead to designs with a higher efficiency, a larger clearance from the sidelobe specifications, and a significant reduction on the farfield crosspolarisation. To illustrate this we take the gregorian configuration.

SPHERICAL REFLECTOR WITH CIRCULAR APERTURE

Ramanujan et *al* [2] have investigated the performance of dual offset antennas with a spherical main reflector projecting a circular aperture in the plane xy (see Fig.1). Under Geometrical Optics constraint, the subreflector is designed to correct the spherical aberration in order to produce a uniform phase on a aperture on the plane xy. The feed model used in this design study was supposed to radiate a spherical wave with phase center at the origin O and power pattern described by $\cos^N\theta$

As the sphere center $(0,0,Z_E)$ is on the z-axis, this subreflector is a section of a circularly symmetric surface and its shape is found following the formulation given by Holt and Bouche (3). The design of the system is made by imposing two conditions for the rays crossing the aperture at the points $X_C \pm R_X$ in plane of symmetry: (A) on the top of the subreflector X_T to avoid subreflector blockage, and (B) on the feed cone $2\theta_C$ in order to have some control of the subreflector edge illumination. For the gregorian configuration, the spherical aberration introduces distortion in the aperture field generating a concentration of power at the upper portion of the aperture. This distortion can be reduced and the gain optimised by adjusting the feed offset angle θ_O.

For the Gregorian configuration described in Table 1, Fig. 2 shows the results obtained by varying the offset point X_C. It is possible to infer from those curves that higher gain is obtained by using larger subreflector surfaces. It is also possible to observe that there is a small control over crosspolarisation once the reflector dimensions and feed parameters are chosen.

As mentioned before, this work aims to introduce a few modifications in the geometry described in *Reference* (2). First, the center of the spherical main reflector $(X_E,0,Z_E)$ is allowed to vary along the symmetry plane. This additional freedom brought into the design is used to enforce a third (C) condition on the sub reflector dimension Ds besides (A) and (B) mentioned above. The subreflector shape is obtained by imposing these three conditions onto the formulation presented by Chang and Rusch(3).

For a comparison, Table 2 shows the values obtained for the gregorian geometry outlined in Reference (2) where a 64% efficiency is achieved. Our investigation takes the same feed model, aperture and subreflector dimension Ds and allows X_E to be adjusted for a range of values of X_C that is limited by the feed blockage and the degradation of performance. A clearance $F=5\lambda$ is imposed in the design as the top of the subreflector is not restricted to the negative portion of the X-axis.

Figs. 3.a shows the efficiency and crosspolarisation *obtained* by using Physical Optics (PO) integration on both reflectors. When compared to the values in Table 2 , the possibility of adjusting X_E permits to increase the efficiency up to 68%. The crosspolarisation pattern shows a minimum that will be subject of further analysis.

The control of the clearance F and the subreflector dimension Ds, not possible when $X_E=0$, results in more compact design. As is observed in Fig.3.b, it also offers the option of adjusting the feed offset angle along the bore sight direction $(\theta_O=0)$ which reduces spillover effects on the asymmetry plane pattern.

SPHERICAL REFLECTOR WITH ELLIPTICAL APERTURE

As shown in Fig.6, the aperture power distribution has elliptical contours. A further increase in the efficiency can be achieved by making the aperture perimeter elliptical in order to have a more uniform distribution over the aperture. This approach is particularly interesting for the gregorian configuration where the major axis of the power contours are along the asymmetry plane.

By keeping the aperture area constant, Fig.5 shows the efficiency obtained for different R_Y/R_X ratios considering the three cases indicated in Fig.3.a : (A) for maximum efficiency, (B) minimum of crosspolarisation, and (C) for $\theta_0=0°$. For these cases the efficiency goes above 70% and for (I) the stretching of the aperture gives a 8% increase when compared to the results shown in Table 2.

Another characteristic of the elliptical aperture design is the higher edge taper for the aperture illumination, specially along the asymmetry plane, that results in lower peak levels for the first side lobes in this plane.The PO power pattern for the gregorian geometry in Reference (2), shows a marginal clearance for the first sidelobe peaks in the asymmetry plane, when compared with the specified side lobe envelope. In Fig.4, the power radiation patterns obtained for the design with maximum efficiency (I), shows the first sidelobes peaks -6dB bellow the specifications.

DESIGN FOR LOW CROSSPOLARISATION

Figure 3 shows an interesting feature of the crosspolarisation performance. Although it is not possible to eliminate the aperture field depolarization by adjusting the reflector axes, as in the confocal conics case, it is possible to adjust the geometry for very low levels of crosspolarisation. Assuming a linearly polarised feed, an analysis of the aperture depolarisation introduced by the double reflection shows that no rotation is found on two lines over the aperture plane: the X-axis (symmetry plane) and a circumference with radius

$$R_{XP}=[R_E{}^2-(l_o+\cot(\theta_o/2)X_E)^2]^{1/2}$$

and center at the point X_E.

A significant reduction in the crosspolarisation component of the aperture field is obtained by making this circle to pass over the more illuminated area of the aperture. This area is associated with the rays coming close to the feed axis θ_o. Thus, geometries that produce low crosspolarisation can be directly obtained by adding to the design a fourth condition given by

$$X_o(\theta_o)=X_E+R_{XP}$$

where X_o is the aperture point mapped by the ray along the feed axis. For the Cassegrian version, the design for low crosspolarisation is associated with lower efficiencies.

Fig.7 shows the distribution of the crosspolar component over the aperture for designs obtained for different values of X_C. At the valley ,X_C=97, it is possible to observe the circle with zero crosspolarisation represented by the dashed line.

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(1) Clarricoats, P.J.B., Brown, R.C., and Ramanujan P.,1987, IEE Proc., Part H, 134, 538-544.

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(3) Holt,F.S. and Bouche,E.L., 1964, IEEE Trans, AP-12, 1964, 44-47.

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TABLE 1 — Parameters for design study

Aperture Diameter	$D = 2R_x = 2R_y = 172\ \lambda$
Spherical Reflector Radius	$R_E = 344\ \lambda$
Feed Cone Angle	$2\ \theta_c = 50°$
Feed Radiation Pattern Attenuation at θ_c	-20 dB

TABLE 2 - Predicted performance of the Gregorian antenna outlined in Ref.(2)

Efficiency	64.1 %
Crosspolarisation	-38.4 dB
Clearance (F)	20.0 λ
Projected Subreflec. Dimension (D_S)	43.7 λ
Overall length (L)	190.0 λ
Overall height (D+Ds+F)	235.7 λ

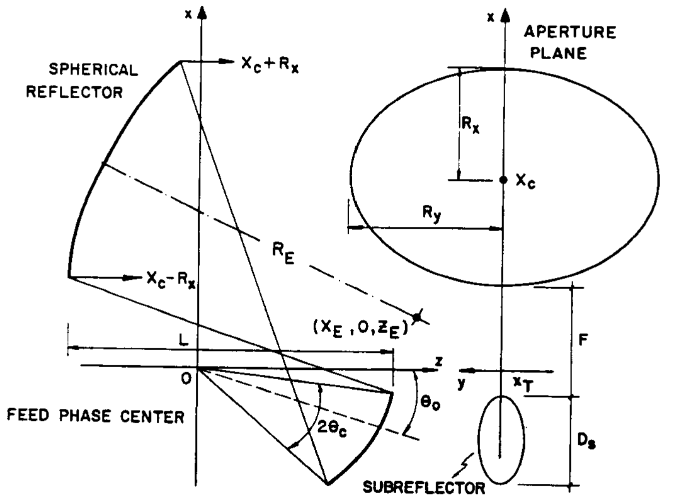


FIG. 1 – GREGORIAN GEOMETRY

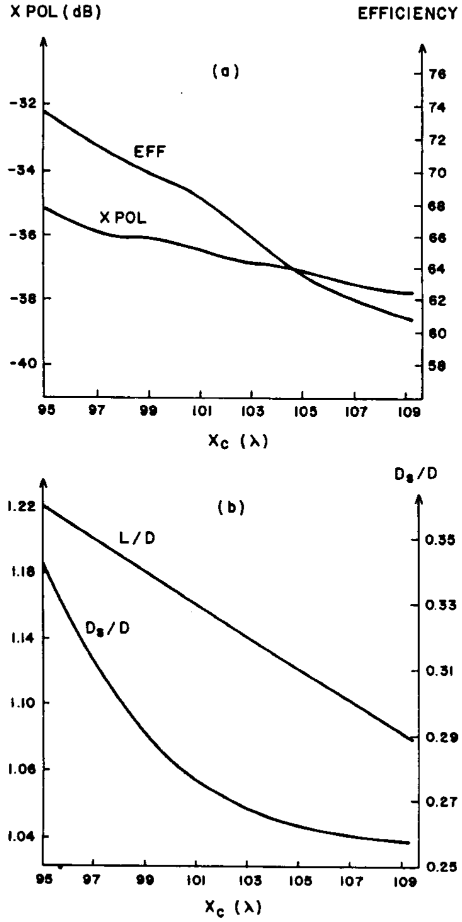


FIG. 2 – PREDICTED PERFORMANCE FOR $X_E = 0$

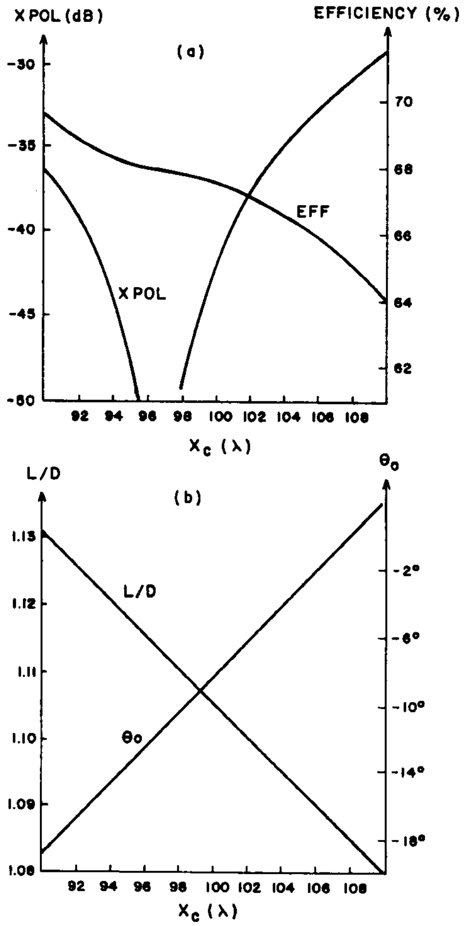


FIG. 3 – PREDICTED PERFORMANCE FOR $X_E \neq 0$

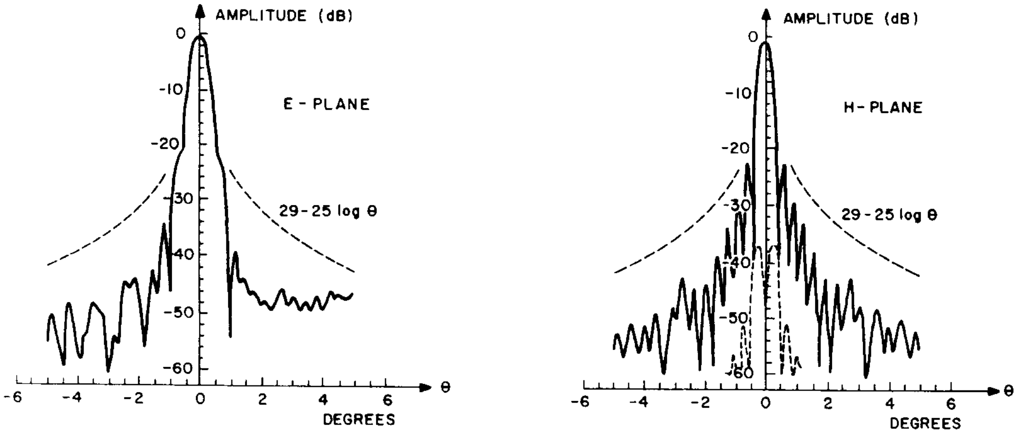


FIG 4 - PREDICTED MAIN LOBE AND NEARIN SIDELOBES

—— COPOLOR ----- CROSSPOLAR

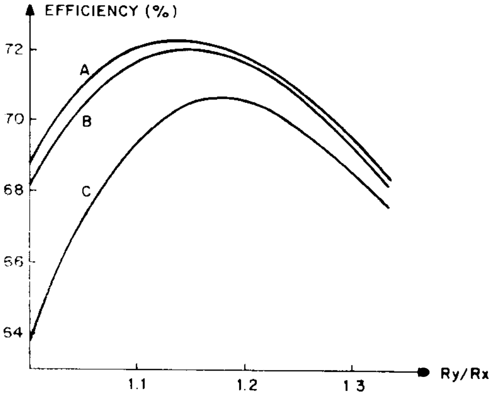


FIG 5 - EFFICIENCY FOR ELLIPTICAL APERTURE

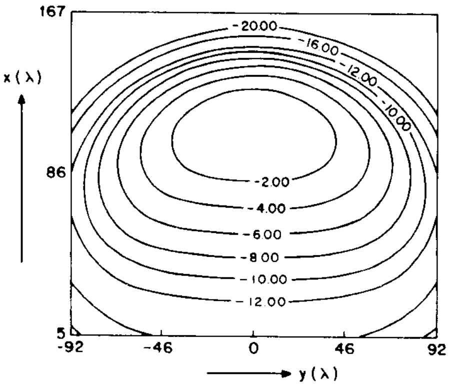
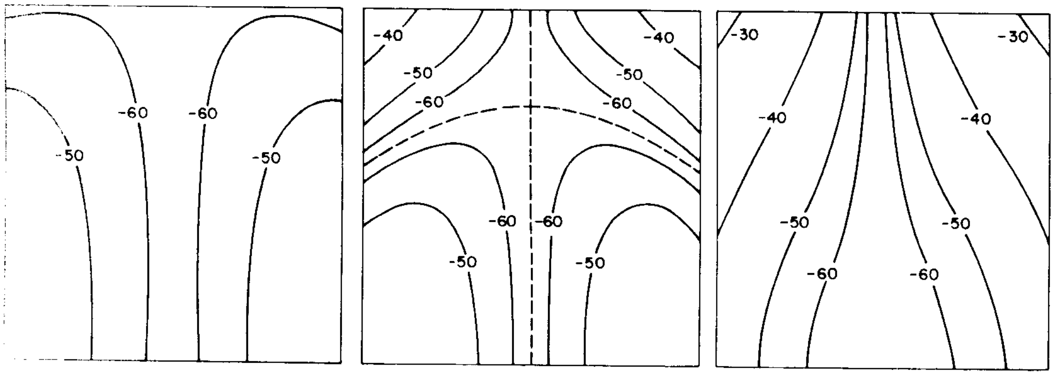


FIG. 6 - APERTURE COPOLAR DISTRIBUTION (in dB)



X_c = 99 λ X_c = 97 λ X_c = 95 λ

FIG 7 - APERTURE CROSSPOLAR DISTRIBUTION (in dB) REFERED TO THE COPOLAR PEAK