

**DIFFRACTION SYNTHESIS OF REFLECTOR ANTENNAS:
AN EFFICIENT APPROACH FOR THE OPTIMIZATION PROCEDURE**

J.R. Bergmann, F.L. Teixeira and F.J.S. Moreira
Catholic University of Rio de Janeiro
Marques de São Vicente 225, RJ, Brazil

I. INTRODUCTION Shaped reflector antennas for spacecraft applications have been designed using diffraction synthesis techniques based on optimization methods [1]. These techniques are very demanding from a computational point of view and they rely on efficient numerical codes as the repeated evaluation of Physical Optics (PO) current integration is required. A reduction in the computing time can be achieved by an adequate starting point of the optimization procedure. In general, standard surfaces obtained by simple pre-synthesis analysis are used to initialize the iteration. The critical point of searching for a start is here addressed by adopting a strategy that employs the reflector obtained from the GO (Geometrical Optics) synthesis to initialize the diffractive scheme. The same optimization scheme is used to solve the PO and GO steps. To illustrate the approach, it is applied to design a reflector antenna to satisfy the BRASILSAT satellite specifications.

II. REFLECTOR SYNTHESIS PROCEDURE The numerical procedure adopted here is similar to the one described in Reference [1]. There, the reflector surface is expressed by a polynomial and Fourier series

$$z(x,y) = a_1 x + a_2 y + a_3 xy + a_4 x^2 + a_5 y^2 + \sum_{n=1}^{N_x} \sum_{m=1}^{N_y} b_{nm} f_n(x) f_m(y) \quad (\text{Eq.1})$$

where $f(x) = 1, \sin(x), \cos(x), \sin(2x), \dots$ for $n=1, 2, 3, 4, \dots$. The reflector shape is controlled by the coefficients in the above equation, and these can be varied so that the gain of the antenna conforms to that specified at the sample points. The gain $G^{PO}(u,v)$ of the antenna is calculated using PO currents on the reflector and are compared to the specified gains $G^S(u,v)$ through a one side sum of the residues as below

$$F = \sum_{j=1}^{N_u} \sum_{k=1}^{N_v} \Delta_{jk}^2 \quad \text{for } \Delta_{jk} = [G_{jk}^S - G_{jk}^{PO}] / \Delta G > 0 \quad (\text{Eq.2})$$

where ΔG is the tolerance. The summation covers Nyquist cells on a regular grid of direction cosines (u,v) with N_x and N_y intervals. Finally, the coefficients $[a_i, b_{mn}]$ are varied in a search to minimize the above objective function F .

III. THE GO INITIAL SOLUTION The usual starting for the iteration is a section of a paraboloid or a surface obtained by adjusting the quadratic polynomial to produce an elliptical beam. As mentioned before, we took a different approach by initializing the diffractive optimization with the Geometrical Optics solution for the problem. Thus, for a given set of coefficients (Eq.1), it is possible to calculate the farfield density of

power $G^{GO}(u,v)$ by using the Geometrical Optics formulation in [2]. In this fashion, a procedure similar to the one described before can be established by replacing G^{GO} in the objective function. However, to keep the rays within the desired coverage area during the GO iterative procedure the rays in the reflector edge are enforced on the boundary of the coverage area. This is achieved by adding to F a term obtained from the residues of the boundary equation Ω_m as follows

$$F_{GO} = \sum_{j=1}^{N_u} \sum_{k=1}^{N_v} \Delta_{jk}^2 + W_n \sum_{m=1}^M \Omega_m \quad \text{for } \Delta_{jk} = [G_{jk}^E - G_{jk}^{GO}] / \Delta G > 0 \quad (\text{Eq.3})$$

for the points (N_x, N_y) in the Nyquist grid and for the M points on the boundary at dashed line. The weight W_n is empirically found. The convergence of this procedure is found by a slow deformation of the boundary from a circular shape towards the desired contour.

IV. BRASILSAT COVERAGE To illustrate the synthesis strategy outlined in the previous section, it has been applied to design the BRASILSAT shaped contour radiation patterns. It requires a 27 dBi level within the national boundary as shown by the dashed line in Figures 2 and 3. The shaped reflector has an approximated diameter of $D=1.8$ meters and the feed is assumed to be of $\cos^N \theta$ type. For the GO step of the synthesis, it was used a grid with 15 points within the coverage area and 20 on the boundary. The number of coefficients used in the series was $N_x=N_y=5$ which are associated with the number of sampling points. For the PO step, only the 15 interior points were used for checking the farfield pattern. To evaluate the strategy employed here, Fig.2 shows the objective function at each iteration of the PO synthesis by using three types of starting values: a paraboloid (A), a surface where the coefficients of the quadratic polynomial were set to generate an elliptical beam with the approximate width of the Brazilian coverage (B) and the reflector given by the GO synthesis (C). In the last case, only four iterations were necessary to reach the desired goal. The overall computer time involved in Case C is dominated by the PO step since the GO synthesis is faster than one PO iteration. The radiation pattern given by the initial GO solution is shown in Fig.2. Despite the fact that the 27 dBi contour (represented by the -7.1 dB contour) resembles the desired shape, the pattern does not meet the specification. The diffractive effects, not included in the GO synthesis, round the beam shape at the edge of the coverage area. However, the reflector given by the GO step may represent a convenient start for the PO step as the approach brought a significant reduction in the computing time since the whole GO synthesis is faster than one PO iteration. The final radiation patterns given by the PO synthesis are shown in Fig.3.a-b.

REFERENCES

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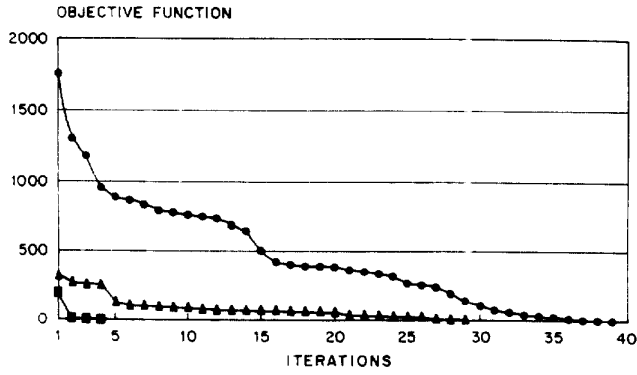


FIG 1 - SEQUENCE OF ITERATIONS FOR DIFFERENT STARTING VALUES
 • PARABOLOID WITH 1.85m DIAMETER
 ▲ ELLIPTICAL BEAM
 ■ GO SOLUTION

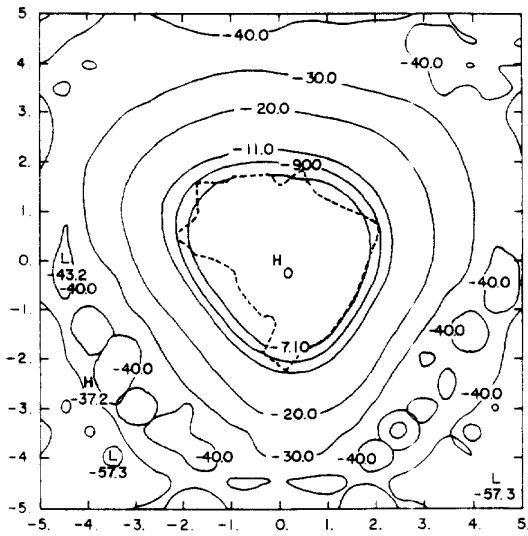


FIG 2 - COPOLAR RADIATION PATTERN FOR THE STARTING SOLUTION C
 CONTOURS ARE REFERRED TO THE (34.1 dBi) PEAK IN dB.

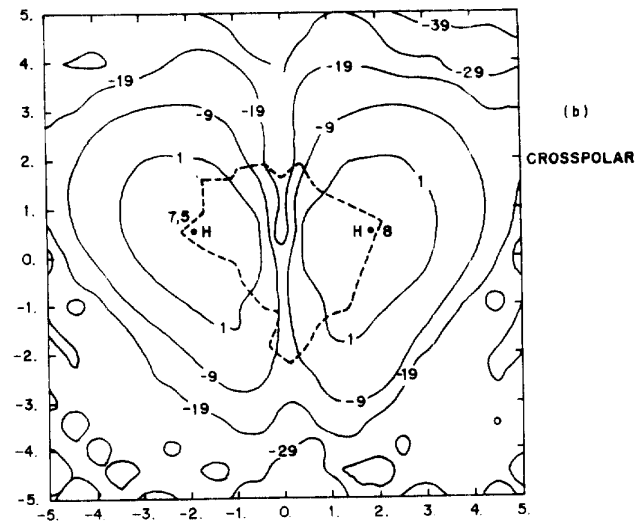
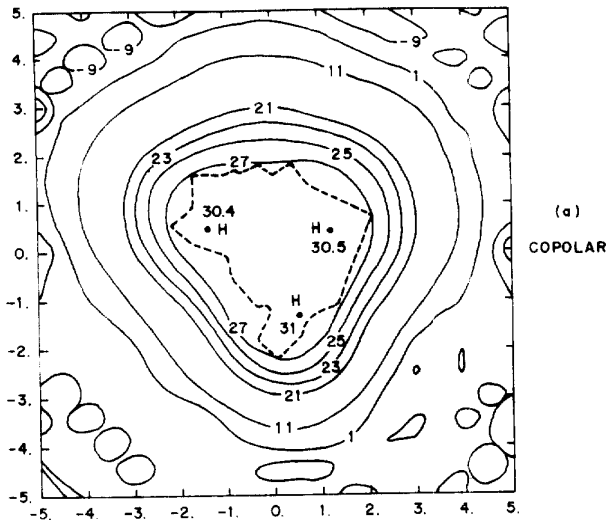


FIG. 3 - RADIATION PATTERN CONTOURS IN dBi
AXES ARE DIRECTION COSINES MULTIPLIED BY D.