ANALYSIS OF MULTIREFLECTOR ANTENNA CLUSTERS BY SPECTRAL METHODS

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ABSTRACT.

This paper analyzes multireflector antennas making use of spectral domain techniques. The behaviour of the multireflector antenna is determined by means of a transference function that relates the plane wave spectrum of an incident signal on this antenna to the plane wave spectrum reflected by the structure. Multireflector antenna clusters that synthesize specific radiation patterns have also been undertaken.

The paper allows us to generalize the identification of every reflecting object through a transference function that relates the incident spectrum to the reflected one. This will permit us to analyze reflection problems with multiple structures.

INTRODUCTION.

In order to obtain the transference function that characterizes the multireflector antenna, we have studied the reflected fields produced by parabolic and hiperbolic surfaces that integrate the multireflector structure.

Reflector antennas have usually been analyzed by geometrical optics based on ray tracing. In this paper physical optics approximation has been used for characterizing reflector elements. It has been found the induced current distribution that an incident spectrum produces on the reflector surface. Using this current we get the reflected field and their plane wave spectrum.

Once the behaviour of a multireflector antenna has been defined by an equivalent transference function we have shifted feeding sources from system focus and we have studied radiation patterns produced by several sources placed around the focus of a Cassegrain antenna.

MULTIREFLECTOR TRANSFERENCE FUNCTION.

The electromagnetic conduct of a multireflector antenna is defined by a transference function that relates the incident plane wave spectrum with the reflected one.

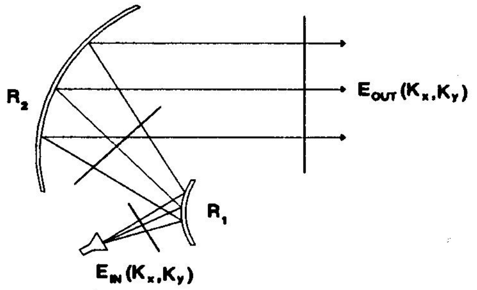


Fig. 1.- *Multireflector antenna.*

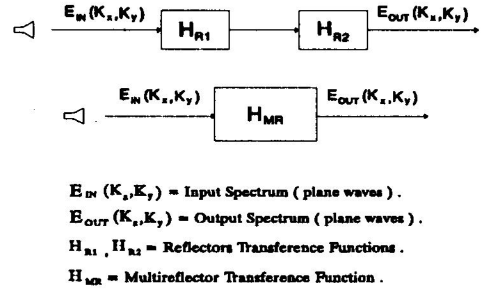


Fig. 2.- *Multireflector transference function.*

The transference function of this Cassegrain multireflector antenna is obtained combining transference functions of parabolic and hyperbolic reflectors. The formulas employed with spectral analysis, which multireflector description requires, are summarized in the following picture.

Plane Wave Spectrum: $\psi = \int\int p(k_x,k_y)\, e^{-j\vec{k}\cdot\vec{r}}\, dk_x dk_y$

Cylindrical Wave Spectrum: $\psi = \sum_j \int c_j(k_z)\, H_n^{(i)}(K_\rho \rho)\, e^{jn\phi}\, e^{-k_z z}\, dk_z$

Spherical Wave Spectrum: $\psi = \sum_j e_j h_n^{(i)}(kr)\, P_n^m(\cos\theta)\, e^{jm\phi}$

Cyl. Spec. - Pl. Spec. Conversion: $p(k_\rho \cos\beta, k_\rho \sin\beta) = \frac{1}{\pi k_\rho} \sum_{n=-\infty}^{\infty} j^n c_{in}(k_\rho) e^{-jn\beta}$

Sph. Spec. - Pl. Spec. Conversion: $p(k\sin\alpha\cos\beta, k\sin\alpha\sin\beta) = \frac{1}{\cos\alpha}\frac{1}{\pi k^2} \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} j^n \left(-\frac{m}{|m|}\right)^m \cdot \frac{1}{\sqrt{2(2n+1)}} e_{inm} e^{jm\beta}\, \bar{P}_n^{|m|}(\cos\alpha)$

Pl. Spec. - Pl. Spec. Translation: $p'(k_x', k_y') = p(k_x', k_y')\, e^{-jk_z' z_0}$

Cyl. Spec. - Cyl. Spec. Translation: $c_{l\nu} = \sum_{i=1}^{2} \sum_{n=-\infty}^{\infty} \frac{1}{2} c_{in}(k_\rho')(-1)^n \left(\frac{y_0}{|y_0|} j\right)^{\nu+n} H_{\nu-n}(k_\rho' |y_0|)$

Sph. Spec. - Sph. Spec. Translation: $e_{l\nu m}' = \sum_{n=|m|}^{\infty} \sum_{i=1}^{2} \sum_{p} \frac{e_{inm}}{2} (-1)^m (j)^{\nu+p-n} (2\nu+1) \cdot a(m,n\,|-m,\nu\,|p)\, h_p^{(i)}(kz_\nu)$

Fig. 3.- *Spectral formulas employed with multireflector antenna analysis.*

PARABOLIC REFLECTOR TRANSFERENCE FUNCTION.

First of all a parabolic reflector antenna has been characterized by a transference function relating the input plane wave spectrum to the output one. A complete diagram of a single reflector analysis is shown in figure 4. Spectral responses of an offset parabolic reflector with a source placed at focus and outside of focus are presented in figure 5.

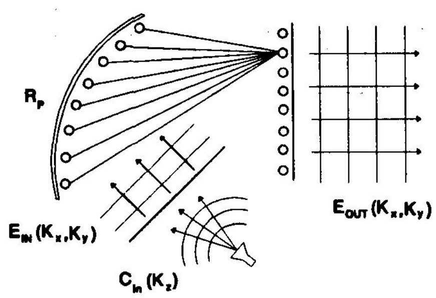


Fig. 4.- *Diagram employed in reflector analysis.*

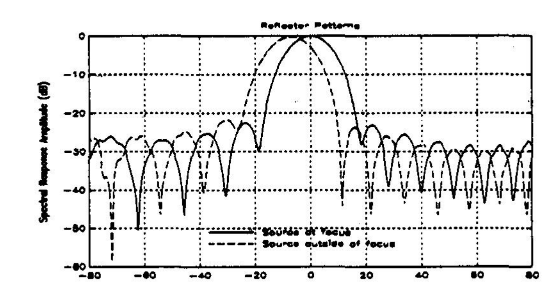


Fig. 5.- *Parabolic reflector radiation patterns.*

Next, we offer some results about the evolution through several planes of the amplitude and phase of electromagnetic fields reflected by a parabolic antenna. The results have been got propagating the reflected plane wave spectrum. In figures 6 and 7 it can be observed the electromagnetic field produced by an offset parabolic reflector (D=20λ, f/D=0.5) with a source that has a 10 dB fall at reflector corner and placed at focus.

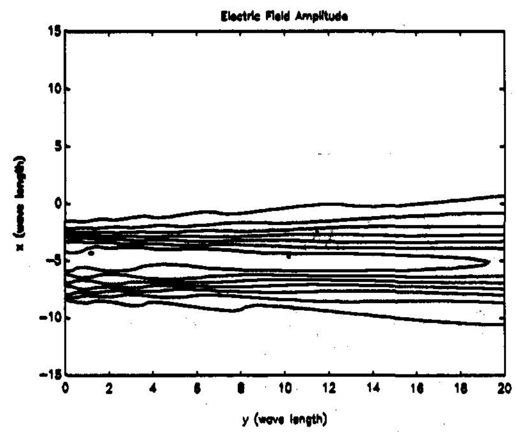


Fig. 6.- *Electric field amplitude.*

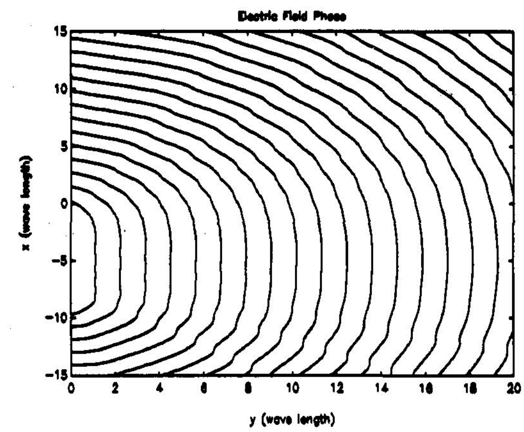


Fig. 7.- Electric field phase.

In figures 8 and 9 it is presented the amplitude and phase of the former electromagnetic field on two planes placed 2λ and 22λ from reflector surface. We can see that the amplitude is more uniform at larger distances and we can see that constant phase planes indicate the advance direction of the reflected field.

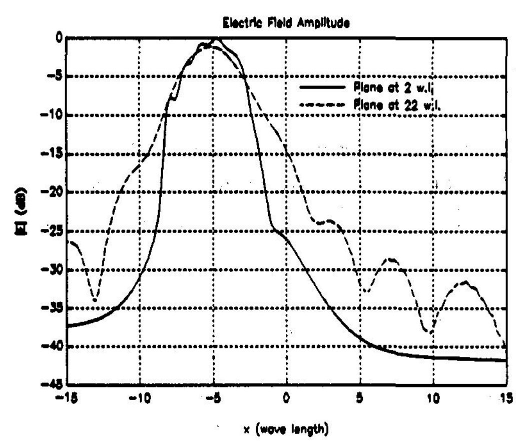


Fig. 8.- *Electric field amplitude.*

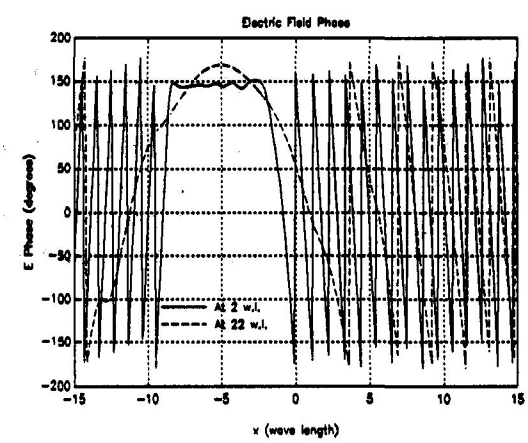


Fig. 9.- *Electric field phase.*

Finally, we have studied an offset parabolic reflector with source shifted from parabolic surface focus in order to study this well known effect. It permit us to point the radiation pattern of the parabolic reflector in another direction. Figures 10 and 11 show the evolution of the electromagnetic field produced by an offset parabolic antenna (D=20λ, f/D=0.5) with a feeding source that has a 10 dB fall at reflector corner and shifted 2λ from focus.

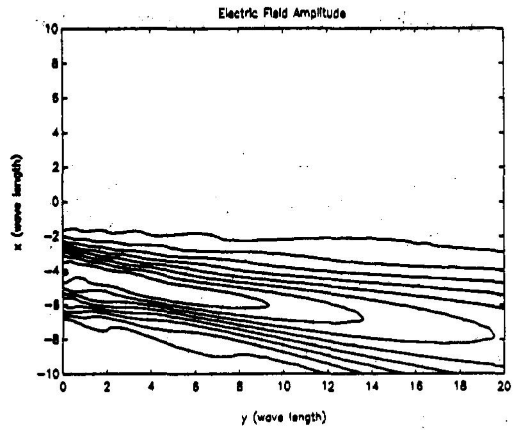


Fig. 10.- *Electric field amplitude.*

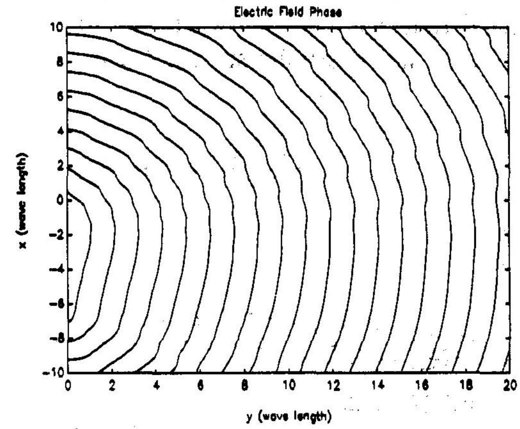


Fig. 11.- *Electric field phase.*

HYPERBOLIC REFLECTOR TRANSFERENCE FUNCTION.

We have also characterized an hyperbolic antenna, which is the secondary reflector in Cassegrain systems. The method we have employed is based on physical optics and we have followed the same steps than with parabolic reflectors. In figures 12 and 13 we have the amplitude and phase of the electromagnetic field reflected by an offset hyperbolic structure (D=5λ, c=5λ and e=2) with a source placed at focus.

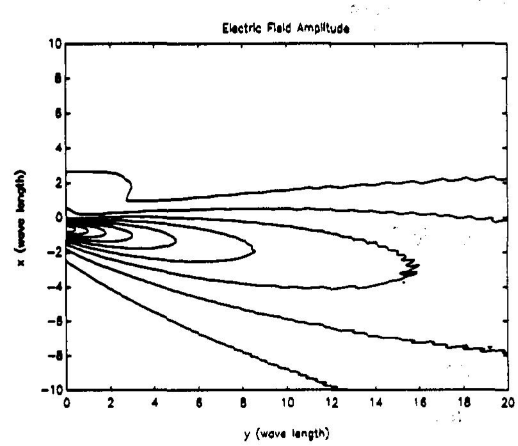


Fig. 12.- *Electric field amplitude.*

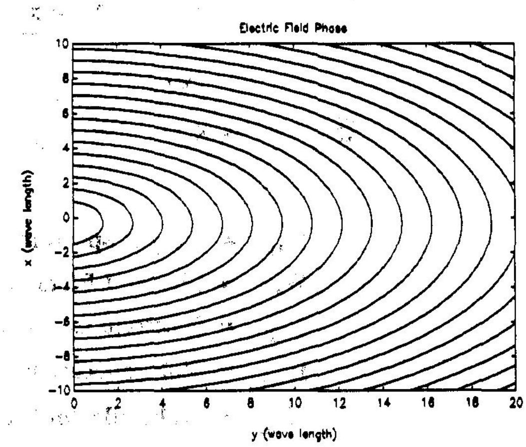


Fig. 13.- *Electric field phase.*

MULTIREFLECTOR ANTENNA CLUSTER ANALYSIS.

After analyzing parabolic and hyperbolic reflectors, we can combine their transference functions and study a Cassegrain system integrated by such reflecting surfaces. In figures 14 and 15 we can see the electromagnetic field reflected by a Cassegrain antenna, integrated by an hyperbolic reflector whose reflected field has been shown in the former section, and by a parabolic reflector. The source has been placed at hyperbolic surface focus.

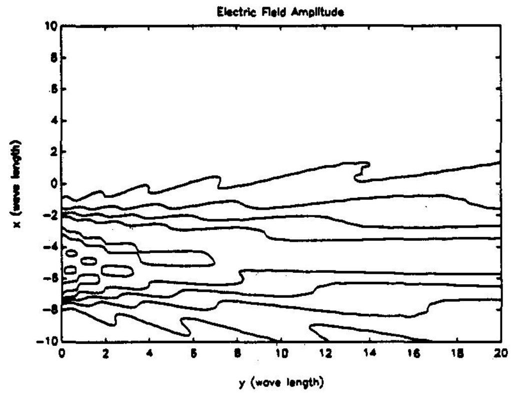


Fig. 14.- *Electric field amplitude.*

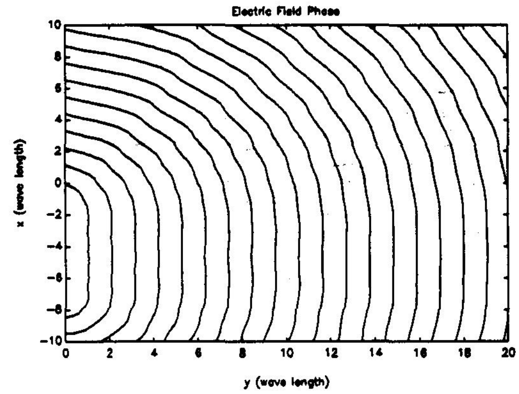
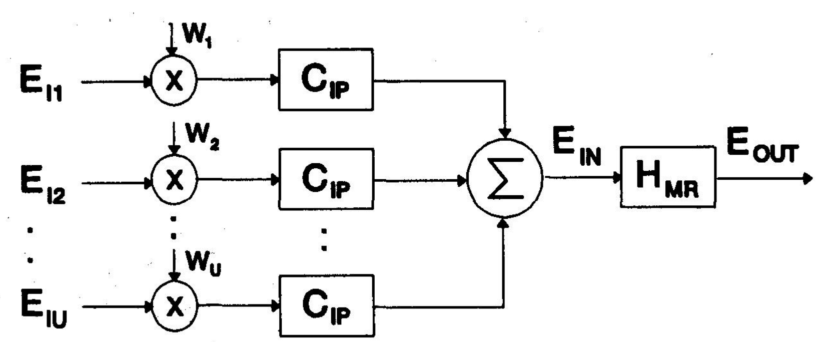


Fig. 15.- *Electric field phase.*

A general method for analyzing this multireflector system has been employed, and this method allows us to place sources outside of Cassegrain focus. A diagram of this method is shown in next figure.



E_{IJ} = J-Input Spectrum (cylindrical or spherical waves) .
W_J = Cluster J-Element Weight .
C_{IP} = Spectrum Conversion to plane waves .
E_{IN} = Multireflector Input Spectrum (plane waves) .
H_{MR} = Multireflector Transference Function .
E_{OUT} = Multireflector Output Spectrum (plane waves) .

Fig. 16.- Multireflector antenna cluster analysis by spectral methods.

We have a cluster of sources with generic spectral content. Each source spectrum, which can be a plane, cylindrical or spherical one, must be weighted by its concerned weight. After that it is represented in terms of an input plane wave spectrum. Next, employing the multireflector transference function, we get the output plane wave spectrum reflected by the Cassegrain antenna. This output spectrum is directly related to its radiation pattern.

Finally we have studied a Cassegrain cluster configuration integrated by three sources with suitable weights. In figure 18 we can see the radiation patterns produced by each source.

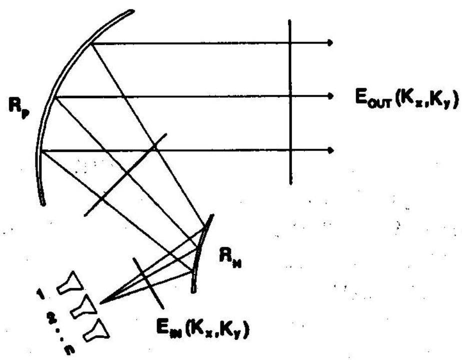


Fig. 17.- Cassegrain multireflector antenna with source cluster.

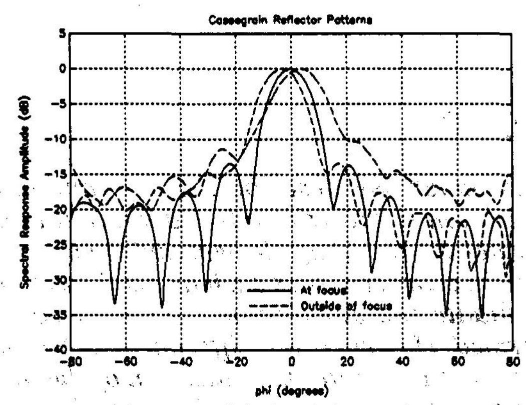


Fig. 18.- *Radiation patterns of a Cassegrain antenna.*

CONCLUSION.

In this paper we have outlined a method for designing feeding systems based on the characterization of a multireflector antenna in terms of spectral contents of incident and reflected signals. We have got transference functions in spectral domain for parabolic, hyperbolic and Cassegrain reflectors making use of physical optics.

This paper also establishes the basis for studying the reflection produced by several structures using transference functions, that relate the spectral content of the incident signal and the spectrum of the reflected signal. This will allow us to treat with problems in open systems with multiple structures, that introduce electromagnetic interaction.

ACKNOWLEDGEMENTS.

This work has been granted by Comisión Interministerial de Ciencia y Tecnología (SPAIN) within Project TIC 92-0919.

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