A NEW "SHADOWING" TECHNIQUE IN REFLECTOR ANTENNA SYNTHESIS

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Abstract

A new shadowing technique in reflector antenna synthesis has been introduced, based on the properties of the pseudo-sampling representation of the fields scattered by a reflector. The diffraction effects of the reflector rim is taken into account evaluating asymptotically the pseudo -sampling series.

Complex radiation diagrams, as those relative to shaped and/or contoured or multibeam antennas, are today required for many applications. Reflector antennas are generally used with complex feed systems in order to satisfy the prescribed constraints. The analysis of these systems can be efficiently performed by means of the pseudo-sampling approach [1] which reduces drastically the computer time. On the other hand, the synthesis of such antennas is generally performed by optical techniques and/or "crude" numerical optimization method, as minimax.

Two antenna synthesis problems can be stated as follows: 1) power synthesis; field synthesis. The power synthesis has been considered in Ref. [2,3]. In this note we deal with the field synthesis problem. For simplicity we consider a two dimensional scalar case.

Let us consider the field E(θ) scattered by a parabolic cylinder (see Fig.1):

$$E(\theta) = \int_{-a}^{a} J(x) \exp(j\Delta) \exp(j\beta x \sin\theta)\, dx \qquad (1)$$

wherein J is proportional to the current induced or the reflector, and:

$$\Delta = \beta \frac{x^2}{4f} (\cos\theta - 1)$$

As shown in [1] E(θ) can be expressed in terms of the pseudo-sampling series as follows:

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$$E(\theta) = \sum_{-N}^{N} I_n \psi_n(\theta) \tag{2}$$

wherein:

$$I_n = \int_{-a}^{a} J(x) \exp(jn\pi\frac{x}{a}) \, dx \tag{3}$$

are the pseudo-samples and:

$$\psi_n(\theta) = \frac{1}{2a} \int_{-a}^{a} \exp\left[j(\beta\sin\theta - \frac{n\pi}{a})x\right] \exp\left[j\Delta\right] dx \tag{4}$$

are the pseudo-sampling functions related to the Fresnel integrals [1].

As can been seen, the series (2) expresses the fields both in the forward and the rear region with the same coefficients (pseudo-samples) I_n. This fact implies that, if we know or if we estimate the fields $E_o(\theta)$ in the forward region, we can obtain by an appropriate technique [4] the pseudo-samples I_n and consequently the field $E(\theta)$ in the rear region.

Now, we introduce the basic idea of our synthesis procedure: we assume that the primary field produced by the illuminating system $E_i(\theta)$ is equal and opposite to the field scattered by the reflector in the rear region, hence:

$$E_i(\theta) = -E(\theta), \qquad \text{for } \theta_\circ \leq |\theta| \leq \pi \tag{5}$$

This ansatz is justified from the consideration that in the case of an infinite reflector the shadow of the reflector is "perfect" and the relation (5) is exactly verified. In the practical situation of finite dimensional reflector the relation (5) can be considered as an approximation in an appropriate region, e.g., where the rim diffraction can be neglected.

The synthesis procedure can be started as follows:
given a radiation diagram $E_o(\theta)$, we obtain the samples I_n by a point matching technique, hence:

$$E_o(\theta_i) = \sum_{-N}^{N} I_n \psi_n(\theta_i) \qquad i=1,\ldots,2N+1; \quad |\theta_i| \leq \theta_{max} \tag{6}$$

wherein θ_{max} defined the angular range wherein the field is given. The radiation diagram $E_i(\theta)$ of the feed system is:

$$E_i(\theta) = -\sum_{-N}^{N} I_n \psi_n(\theta), \qquad \theta_\circ \leq |\theta| \leq \pi \tag{7}$$

Now, we noted that (7) is appropriate when diffraction effects can be neglected. We are therefore lead to use the asymptotic form of the pseudo-functions $\psi_n(\theta)$ for large values of the wavelength, hence, in order to reduce the effect of the rim diffraction, the following asymptotic evaluation has been considered:

$$E_i(\theta) = -\sum I_n \; \phi_n(\theta), \tag{8}$$

wherein

$$\phi_n(\theta) = \lim_{\beta\to\infty} \psi(\theta) = \exp\left[j\frac{(\beta a\sin\theta - n\pi)^2 . f}{\beta a^2(1-\cos\theta)}\right] \sqrt{\frac{\pi f}{\beta a^2(1-\cos\theta)}}\exp(-j\pi/4) \tag{9}$$

and are the asymptotic evaluation of the ψ_n to the first order, e.g., including only the "reflection" contribution due to the stationary point. The summation in (8) includes only the indices related to a stationary point comprised in the range $\theta_0 \leq |\theta| \leq \pi$.

The above procedure has been applied in order to synthesize a prescribed pattern with a constant phase and with the amplitude shown by Fig.2 (solid line). The assumed reflector diameter 2a and focal length f are respectively 50λ and 25λ. The radiation diagram computed using the synthesized illumination is given in the same Fig.2 (dotted line).

The amplitude and phase of the illumination diagram, synthesized according to the above procedure, are shown respectively by solid line and dots under Fig.3.

References

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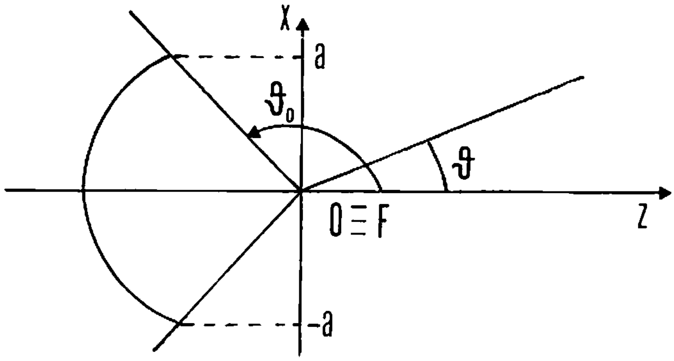

Fig.1: Geometry relevant to the field synthesis problem

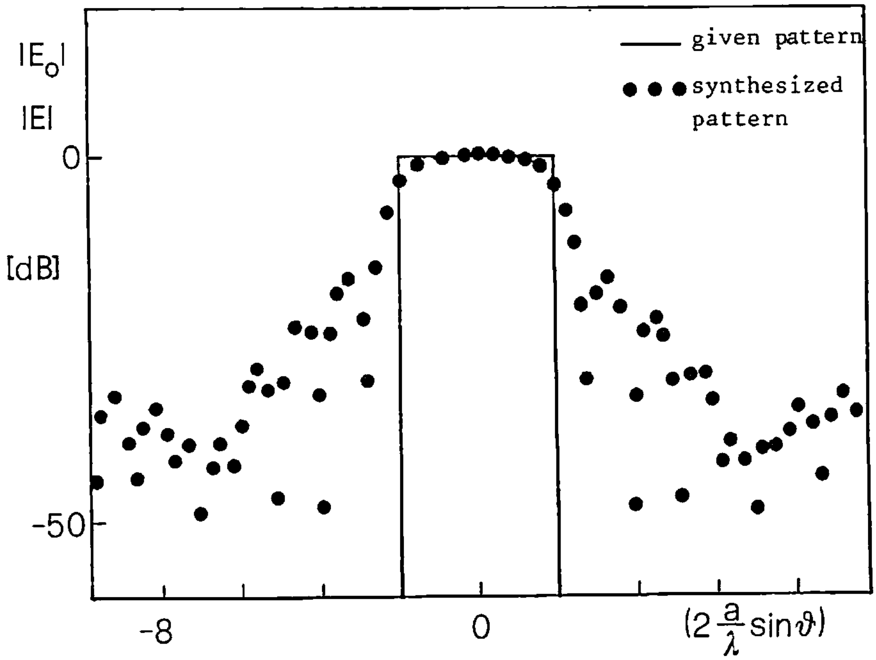

Fig.2: Given and synthesized pattern

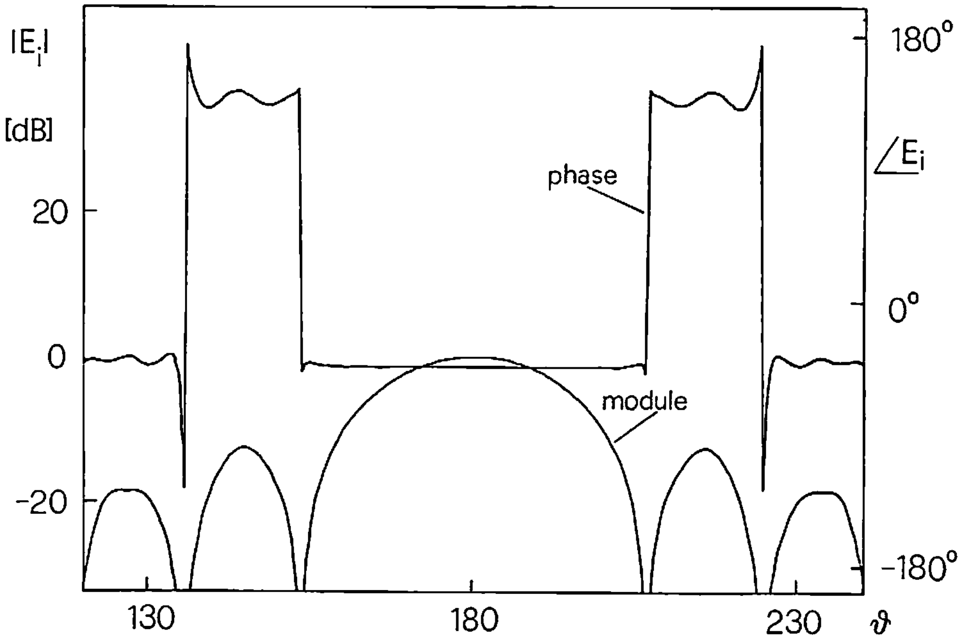

Fig.3: Feed's radiation diagram