EFFECT OF GEOMETRICAL PERTURBATION ON THE RADIATION PATTERN OF PARABOLIC REFLECTOR

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ABSTRACT / The radiation patterns of perturbed two dimensional parabolic reflector fed by a slotted circular cylindrical waveguide for both the TE and the TM modes are examined. The analysis is carried out using Green's function second identity in conjunction with the Moment Method. Results show that the perturbed geometry achieves various degrees of improvements in most antenna's characteristics over the plain parabolic reflector.

***Index Terms* — Antenns, Propagation, Method of moment**

I. INTRODUCTION

Reflector antennas are probably the most important type of antennas for space communication, TV satellite reception and satellite born antennas. Their radiation characteristics and feed systems were the focus of considerable work in the last few decades [1]. The most widely used surface reflector is the parabolic reflector for its superior directivity. However, these reflectors suffer from the back radiation which degrades their forward gain. In recent years several attempts were made to overcome this problem. A rim loaded reflector antenna was investigated with very limited influence on the pattern parameters [2]. A flanged parabolic antenna was attempted but still with no influence on the forward half space while very limited reduction in the rear field was gained [3-4]. Various designs of different antenna surface coating to generate radiator surface impedance were attempted. The results prove mostly a drop of front to back radiation ratio and an increase of the back radiation level [5-8]. In this research an attempt is made to investigate the influence of perturbing the parabolic surface geometry on the standard antenna characteristics like directivity, beam width, back radiation level and level of side lobes and first null. The problem is tackled for both the TM and the TE modes with the source being a slotted circular cylinder. The slot field is assumed to be E_z for the TM and E_ϕ for the TE case. The problem is formulated using Green's second identity generating an integral equation in the unknown surface currents on both the reflector and the circular cylindrical waveguide surfaces. The problem is solved using the method of moment (MoM) to obtain the unknown surface current distribution which, in turn, is used to obtain the far field radiation pattern using the same formulations. Numerical results are obtained for two sets of parameters for both the TM and the TE cases which show superior characteristics for the perturbed parabola over the plain one. The formulation of the problem is presented next along with the method of solution followed by numerical results obtained for two sets of parameters. Our program is checked against some special cases of data published in the literatures [10] and found to obtain identical results.

II. THEORETICAL OVERVIEW

Consider a surface reflector fed by a slotted circular cylinder waveguide with its axis set along the z-direction. Assuming two dimensional analysis with no variation in the z-direction and applying Green's second identity on the boundaries of the source 'S' and of the reflector 'F' one may write [9]:

$$\varphi(\rho,\phi)=\int_{S+F}[\varphi(\rho',\phi')\frac{\partial G(\rho,\phi/\rho',\phi')}{\partial n}-G(\rho,\phi/\rho',\phi')\frac{\partial\varphi(\rho',\phi')}{\partial n}]dC \quad (1)$$

where

$$G(\rho,\phi/\rho',\phi')=\frac{1}{4j}H_0^{(2)}(k\sqrt{\rho^2+\rho'^2-2\rho\rho'\cos(\phi-\phi')})\cdot$$

is the two dimensional Green's function in free space in cylindrical system, and (ρ,ϕ) are the field point, while (ρ',ϕ') are the surface point under the integration sign. Further,

$$\varphi(\rho,\phi)=E_z \quad \text{and} \quad \frac{\partial\varphi(\rho,\phi)}{\partial n}=j\omega\mu H_t$$

for the TM case

$\varphi(\rho,\phi) = H_z$ and $\dfrac{\partial\varphi(\rho,\phi)}{\partial n} = -j\omega\varepsilon E_t$ for the TE case

and the derivative is with respect to the normal to the surface. The subscript t indicates tangential to the surface. Substituting the proper $\varphi(\rho,\phi)$ along with Green's function in equation (1) and assuming the slot field to take the form:

i- For the TM modes

$E_z = E_0 \cos \pi\phi/\phi_0$ ……$-\phi_o/2 \le \phi \le \phi_0/2$ and

E_z is zero otherwise.

ii- For the TE modes

$E_\phi = E_0$ …………..$-\phi_0/2 \le \phi \le \phi_0/2$ and E_ϕ is zero otherwise.

where ϕ_0 is the slot width. The above substitution for either the TM or the TE case will lead to an integral equation formulation with the tangential magnetic field along the reflector and guide surfaces being the unknown parameter. Employing the standard technique of the MoM and replacing the tangential magnetic field by the induced surface current on the conducting parts of the radiator feed assembly, one may cast the problem into a standard matrix formulation with the current distribution as the unknown. Details of the analysis will not be given here and may be found in Ref [10]. Once this current is obtained, the far field radiation pattern for a specific reflector configuration is readily available using equation (1) where the left hand side is the sought field while the right hand side is completely known.

III. Proposed Perturbed Parabolic Reflector

The above analysis is carried out for a two dimensional parabolic surface reflector obeying the standard parabolic equation: $y = x^2/4f$ with f being the focal length and the feed center is at the focal point. The perturbed parabolic formula is assumed as:

$$y = (x^2/4f)(1 + d_1 x + d_2 x^2)$$

where d_1 and d_2 are perturbation parameters. The source center is kept at the same focal point. Several variations of d_1 and d_2 along with different reflector lengths and radiating guide radii have been attempted. Some of these results are presented in the next section.

IV. Results And Discussion

A computer program based on the above analysis was carried out for several values of the perturbation parameters d_1 and d_2 for a source in the form of a slotted waveguide centered at the focal point. Figs. (1) and (2) show some of the results obtained. In the graphs, R is the radius of the slotted waveguide, L is half length of the reflector, f is the parabolic focal length. All lengths are relative to the wavelength. It is obvious from the graphs that an appreciable increase in the directivity and drop in the side lobes levels and null levels that in some cases exceeds 100% of the original non perturbed parabolic case is achieved. Further, it is noticed that even though the location of the first null is slightly higher for the perturbed structure than the non perturbed one, however, the power level of the perturbed is still lower than that of the non perturbed at its first null location. Also, one can see that the back radiation level in the proposed structure is lower by a value ranging from 1 to 3 dB than the original parabolic one which is an achievement that could not be obtained via other techniques discussed earlier[5-8]. Of course, not any combinations of d_1 and d_2 will result in such superior performance and one must search for proper combinations of them to satisfy his needs.

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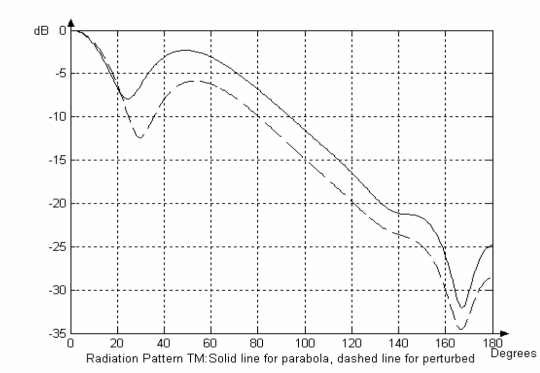

Fig. 1 Radiation pattern (TM) of parabolic and perturbed parabolic for the following parameters: L=1, f=0.7, R=0.05, d1=d2=f

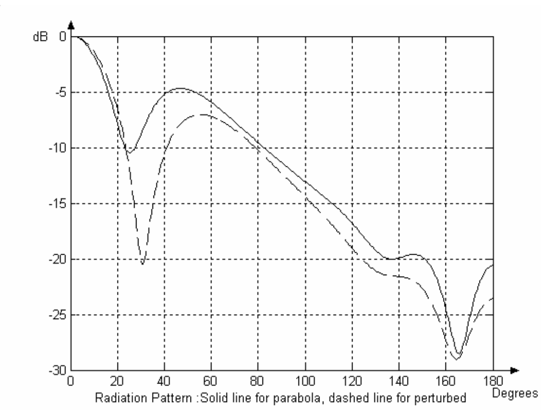

Fig. 2 Radiation pattern (TE) of parabolic and perturbed parabolic for the following parameters: L=1, f=0.5, R=0.2, d1=d2=f.