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Three-Dimensional Diffractive Gaussian Beam Analysis Method For Multi-Reflector Antennas

Fangyuan Cheng[1], Zejian Lu[1], Hai Wang[1],Xiaoming Liu[1], Junsheng Yu[1] and Xiaodong Chen[2]
[1]School of Electronic Engineering, Beijing University of Posts and Telecommunications, Beijing, China
[2]School of Electronic Engineering and Computer Science, Queen Mary, University of London, London, UK
bjcfy@bupt.edu.cn

Abstract - A three-dimensional Diffractive Gaussian Beam Analysis approach for analyzing quasi-optical multi-reflector systems is presented. The illuminating field over the whole input plane is analyzed into a set of elementary Gaussian beams. These are propagated to the reflector.Geometric Optics initially treats reflection, while edge diffraction is modeled using the canonical problem of a 3-D Gaussian beam incident upon an opaque Kirchhoff half-screen.The output beams can again be expanded into a set of Gaussian beams.The proposed analysis is verified against a GRASP Physical Optics of a multi-reflector antenna system.

Index Terms — Kirchhoff half-screen, multi-reflector antennas,reflection and diffraction,the whole input plane.

I. INTRODUCTION

Antenna systems employed, for example, in millimeter wave and sub-millimeter wave radiometry and radio astronomy applications, are generally complex.Methods for the design verification of quasi-optical (QO) systems are at present very limited.Geometrical Optics (GO) does not account for the effects of boundary diffraction.Physical Optics (PO) is accurate but expensive in terms of computation time and storage for electrically large system[1]. In this connection, the DGBA approach combines the numerical efficiency of GO and the rigor of PO.The current 2-Dimensional DGBA requires the incident wave and reflector to be symmetrical about a certain plane.To overcome this limitation,The 3-Dimensional DGBA proposed in this paper introduces the approach of full plane expansion,which can be applied to stereoscopic system in some practical applications.

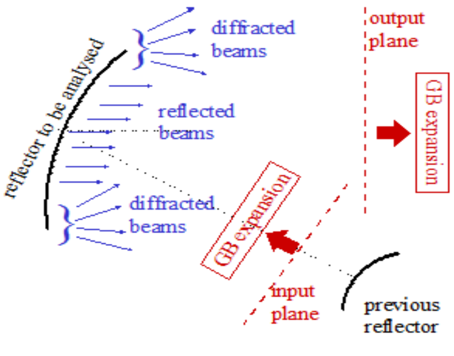

Fig. 1 Process of DGBA method

The process of DGBA method is the following[2] :The source fields that could be from either the feed or the previous reflector are firstly expanded to Gaussian beams by windowed Fourier transform on the input plane;These elementary beams are secondly propagated to the reflector to be analyzed according to Gaussian beam propagation theory;The reflected GBs can be processed by Geometric Optic, and the diffraction coefficients of GBs can be modeled by an equivalent Kirchhoff half plane; Superposition of all the reflected and diffracted Gaussian beams gives a complete description of the field on the output plane.The total output field is again expanded in terms of a GBs expansion.

II. GAUSSIAN BEAM DIFFRACTION

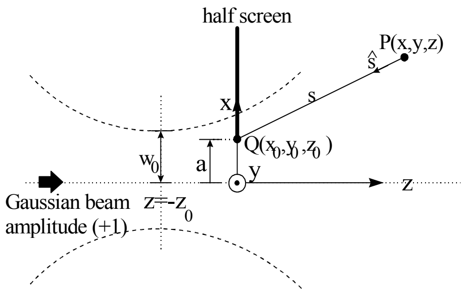

FIG. 2 Geometry of the problem（forward-scattering region）

Fig2 shows the co-ordinate geometry for the simpler case of the normal beam incidence.Diffraction of a Gaussian beam with a circular spot size normally incident upon an opaque Kirchhoff half-screen was investigated based on the boundary-diffraction wave theory[3],The incident beam is assumed to propagate in z-direction and to have the smallest spot size at z=-z_0. P(x,y,z) is the observation point and Q(x_0,y_0,z_0) is a source point of boundary-diffraction located on the boundary of the half-screen.The total diffracted field in the forward scattering region(z>0) at the observation point P can be written as a superposition in terms of complementary error function.

$$U(P)=\begin{cases} U_i(P)-\frac{q(0)}{2q(z)}\mathrm{erfc}(j\left[jk_0(d(y_s)-d(y_p^1))\right]^{1/2}) \\ \exp(-jk_0(d(y_s)-d(y_p^1)-s(Q_d)))U_i(Q_d) & x\le x_s \\ \\ \frac{q(0)}{2q(z)}\mathrm{erfc}(-j\left[jk_0(d(y_s)-d(y_p^1))\right]^{1/2}) & x\ge x_s \\ \exp(-jk_0(d(y_s)-d(y_p^1)-s(Q_d)))U_i(Q_d) \end{cases} \quad (1)$$

We try to find an equivalent geometry for determining the diffracted in the backward-scattering region. The equivalent half-screen must be complementary to the true half-screen to generate a shadow region in the lower half space,a new coordinate system with the transformed (x,y,z) pointing in (-x,y,-z).Hover,the orientation of the half-screen may be non-perpendicular to the direction of the propagation.The coordinate systems are expressed in terms of the half-screen coordinate system by simple translation and rotation around the y-axis:

$$\begin{pmatrix} z_t \\ x_t \end{pmatrix} = \rho \begin{pmatrix} \cos(\varphi-(\pi+\varphi_0)) \\ \sin(\varphi-(\pi+\varphi_0)) \end{pmatrix} + \begin{pmatrix} z_e\cos(\varphi) \\ 0 \end{pmatrix} \qquad (2)$$

$$\begin{pmatrix} z_r \\ x_r \end{pmatrix} = \rho \begin{pmatrix} \cos(\varphi-(\pi-\varphi_0)) \\ \sin(\varphi-(\pi-\varphi_0)) \end{pmatrix} + \begin{pmatrix} z_e\cos(\varphi_0) \\ 0 \end{pmatrix} \qquad (3)$$

III. SIMULATION AND NUMERICAL VERIFICATION

The results to follow are presented for a multi-reflector test case carrying a 183 GHz signal.Fig 4 plots a the backscattered field comparison with PO for various values of the parameter a.The QO arrangement of the system is depicted in Fig. 3. Field plots on various far field planes are shown and the results are compared to those of a physical optics analysis with the commercial reflector analysis package GRASP[4].At 183 GHz the sub-reflector and main reflector have diameters of approximately 21.35 λ and 18.3 λ respectively. The structure was analyzed in two steps. The input field plane for the analysis of the sub-reflector was chosen 0.01m away from the feed.

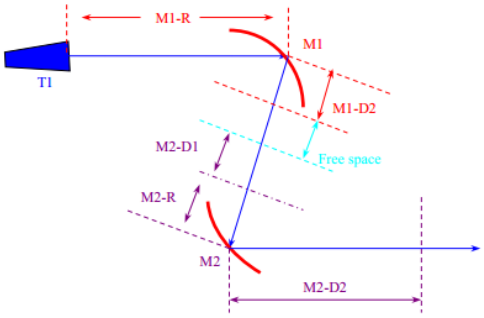

Fig. 3 Geometry of a Cassegruin antenna test case

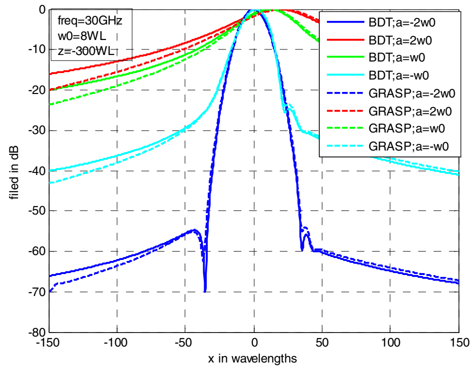

Fig. 4 comparison of the backscattered field with PO for various values of the parameter a

The final results to be shown are of comparative field plots between GRASP and the DGBA.Fig 5., is of the incident field upon the sub-reflector at 183GHz with the results of physical optics. The second in Fig. 6., is the comparison of the far field from the main reflector at 183GHz .

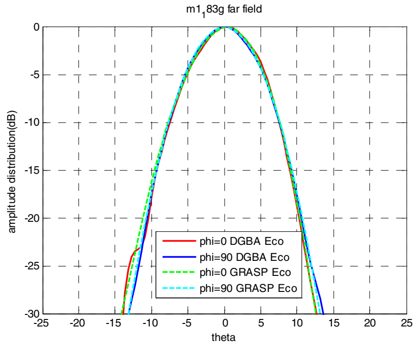

Fig. 5 Cornparison of the far field from the sub- reflector ut 183 GHz with the results of physical optics

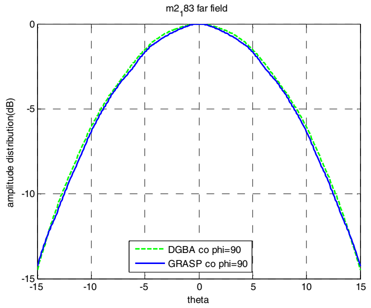

Fig. 6 Cornparison of the far field from the main reflector ut 183 GHz with the results of physical optics

IV. CONCLUSION

The proposed 3-Dimensional DGBA approach of full plane expansion analyzing a quasi-optical multi-reflector system has been presented.This method can be applied to stereoscopic system,where the optical centers of the feed and all of the reflectors can lie on the different planes.It has been tested for a multi-reflector antenna configuration and good agreement with PO has been obtained.

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