DETERMINATION OF THE PHYSICAL OPTICS VALIDATION REGION BY COMPLEX SOURCE-DUAL SERIES APPROACH

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Abstract: *Physical Optics(PO) is a very famous method to analyze the scattering from the large structures for example reflector screen. Therefore, determination of the valid region of PO is important in the application. Because very few techniques give this kind of exact data. Here, PO is applied to 2D circular front-fed symmetrical reflector fed by a directive feed antenna which can be solved by complex source-dual approach. Then this dual series are converted to a Riemann-Hilbert Problem (RHP) which is a kind of Method Of Regularization(MOR). Finally, PO and MOR results are compared and regions where PO doesn't give accurate results are determined. The all computations are performed for E-polarization*

1.Introduction

Scattering from structures with a large aperture is the subject of the asymptotic techniques. A famous one of these techniques is PO[1]. Here we considered the scattering from 2D circular symmetrical front-fed reflector antenna excited bya directive feed. Reflector antennas are very important part of the modern communication systems especially in the point to point communication.That is a radiated electromagnetic wave from a point is received by another single point (or direction). This is the main beam direction of the reflector antenna. However, the directions except the main beam is also important to obtain the whole radiation pattern. Because, the reflectors can be used to receive datas off the main beam directions as well like the bistatic radars.

In this study, we applied PO to 2D circular screens by combining Complex Source Point Method(CSPM)[2] with PO to simulate the directive radiation pattern of the feed antenna. Therefore a more realistic model of the reflector antenna system is performed. On the other hand, to check the validation region of PO, the same problem is solved with an exact analytical-numerical technique with a guaranteed convergence and accuracy for all observation directions[3]. The result of this MOR is accurate and we can use it as reference data to check PO.

PO depends on the Geometrical Optics(GO) fields and accurate where the GO fields dominant with respect to the diffracted fields. For a fixed geometry, the reduction of the edge illumination, reduces the diffracted field. So normally, we expect that PO converges to exact data. Unfortunately, it is observed that the reduction of edge illumination causes a disagreement between PO and MOR. We can conclude from this result that diffracted field becomes dominant with respect to incident field.

2.Description of MOR

The geometry of the problem is a two dimensional perfectly conducting and infinitely thin circular screen(reflector) which is illuminated by a symmetrical directive feed antenna.(See Figure 1). The radius of circle is a. We used the combination of two relatively novel methods in the analysis of reflectors[4-6]. The first one is CSPM. Principally, by adding an imaginary part to the source location, one obtains a directive feed. The source directivity parameter is b(or kb). Second is the scattering of this beam field from the screen. Formulation starts with a integral equation which is a result of boundary condition on metal screen.

$$E_z^{in}(\vec{r}) = -\int_{M\cup S} J_z(\vec{r}')G_{zz}^E(\vec{r},\vec{r}')d\vec{r}' \qquad (1)$$

Then all the variables can be written in Fourier Series form and substituted into the equation (1). Later, we obtain a dual series equation from this integral equation as

$$\sum_{n=-\infty}^{\infty} x_n J_n(ka)H_n^{(1)}(ka)e^{in\phi} = -\sum_{n=-\infty}^{\infty} e_n^{in}e^{in\phi} \qquad \phi\in M \quad (2)$$

$$\sum_{n=-\infty}^{\infty} x_n e^{in\phi} = 0 \qquad \phi\in S \quad (3)$$

where x_n and e_n^{in} are Fourier Series coefficients of surface current density and incident field. This dual series can be converted to a certain canonical form which is returnable to Riemann-Hilbert boundary value problem. Then RHP can be solved by using Plemelj-Sokhotski formulas for a circular contour. Finally, a resultant algebraic matrix equation is obtained. This solution of RHP is the analytical inversion of the static part having the logarithmic(in E case) singularity. Then the remaining part can be solved with a stable and convergent numerical algorithm. Because, the operator of the matrix equation is compact in Hilbert Space(i.e. a bounded operator in L_2). Therefore, it is a Fredholm Second Kind matrix equation and so Fredholm theorems are valid. This means that existance and uniqueness of the solution is presented. For the same reasons, the exact solution can be obtained with any desired accuracy.

3.Numerical Results

Radiation patterns are obtained by two methods defined before. Generally, mechanism of the scattering from the reflector surface can be explained as follows. There are two diffracted fields from two edges and incident field, besides creeping waves from convex part of the reflector surface and whisperring gallery modes from concav part. All kind of interactions of these contributions causes the radiation pattern. But, for small aperture angle of the reflector only diffracted rays from edges and incident field become dominant. İn the back side region(shadow region of incident field) two edge diffracted rays interfers and oscillations appears in the pattern. In the spillover lobe, which is the largest lobe, the incident field is dominant so oscillations come from the back lobes decrease and disappear on the top of the spillover lobe. The second important region that we called region 2, between spillover lobe and small angles which surface effects become dominant. İn region 2 diffracted rays and incident field interfer and oscillations appears in the pattern. For some cases like incident field sharply drops then oscilations in region 2 reduce.

Second Figure presents radiation patterns for different source directivity parameters kb. By decreasing edge illumination, it is observed that PO differs from MOR in region 2 and at back side lobes. This difference may be increased by choosing a special kind of incident feed pattern as approximately uniform on screen part and sharply drops zero on slot part. This observation means that the diffracted field becomes dominant to GO fields in region 2 or more importantly on the surface of the reflector screen. Figure 3 presents the plots for different aperture dimensions and, as expected, PO gives better result when the aperture dimension is increased. Because, for the same incident field, the diffracted field decreases when the aperture size is increased. Figure 4 shows four plots for different aperture angles with the same incident illumination. When the aperture angle is small, then diffracted field becomes stronger compared to incident field. But, the diffracted field is smaller for larger aperture angle. This explains the variation in region 2. Furthermore, the reason of increasing oscillations at back side lobes for increasing aperture angle is the stronger creeping waves.

4.Conclusi on

In this study, the accuracy of PO is checked by a MOR.This is performed for a front-fed symmetrical reflector antenna system. It is observed that PO and MOR don't coincide when diffracted field is dominant to GO fields. Sometimes, oppositely, we understand the dominat field part by looking the difference of two plots. For example an unexpected result is that the disagreement between two plots increases when edge illumination is reduced. On the other hand, PO can be extended by PTD and becomes accurate for all observation angles. But it needs extra work and also one important purpose of us to understand radiation mechanism by looking the difference of two plots.

References

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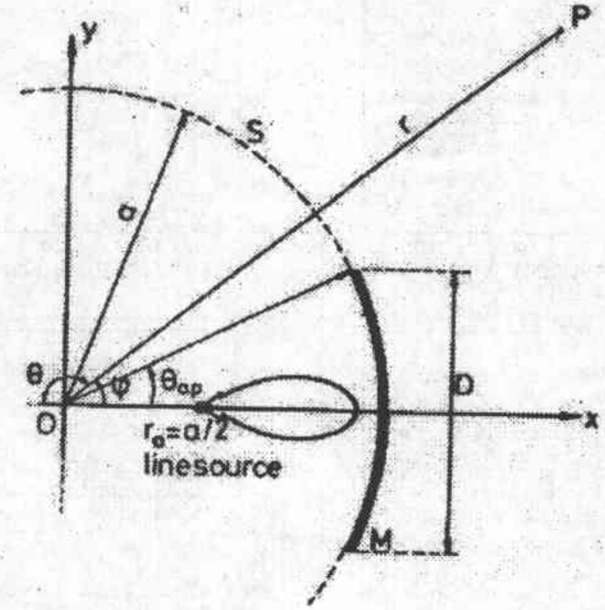

Figure 1: Geometry of the Problem

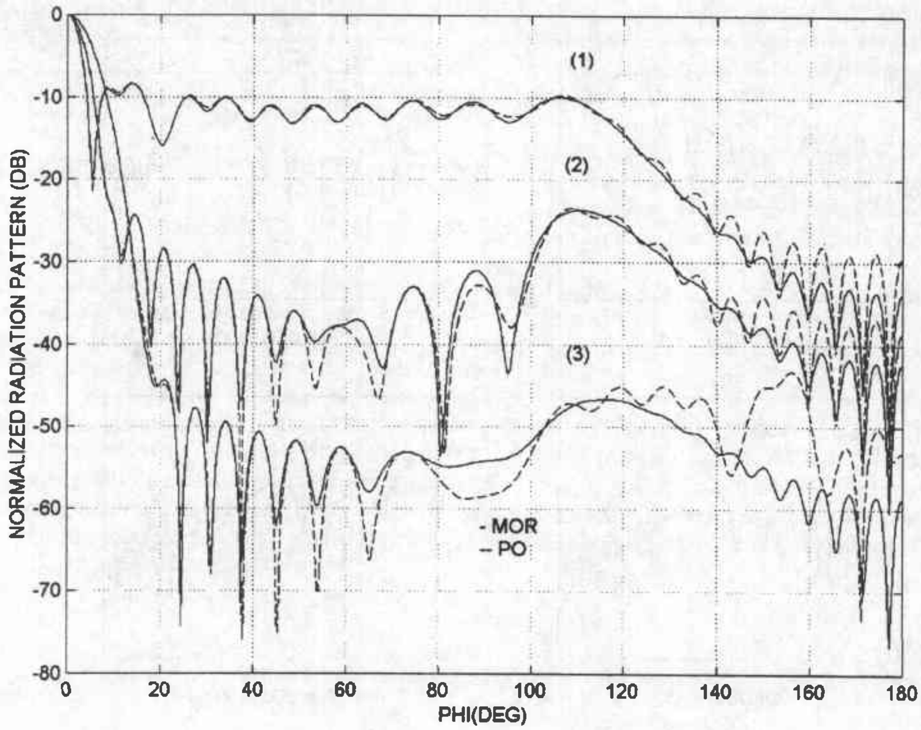

Figure 2: Radiation patterns for different source directivity parameters: (1) kb=0 (2) kb=3 (3) kb=9 and a=10λ, $\theta_{ap}=30^{\circ}$

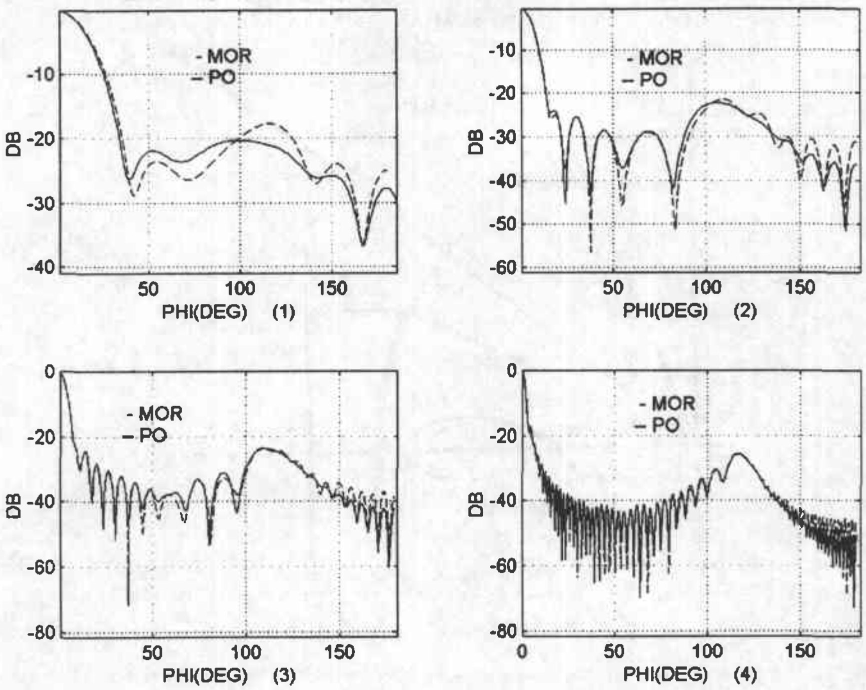

Figure 3: Radiation patterns for different aperture dimensions and edge illumination is fixed i.e.kb=3 and θ_{ap}=30°and (1) a=2λ (2) a=5λ (3) a=10λ and (4) a=30λ

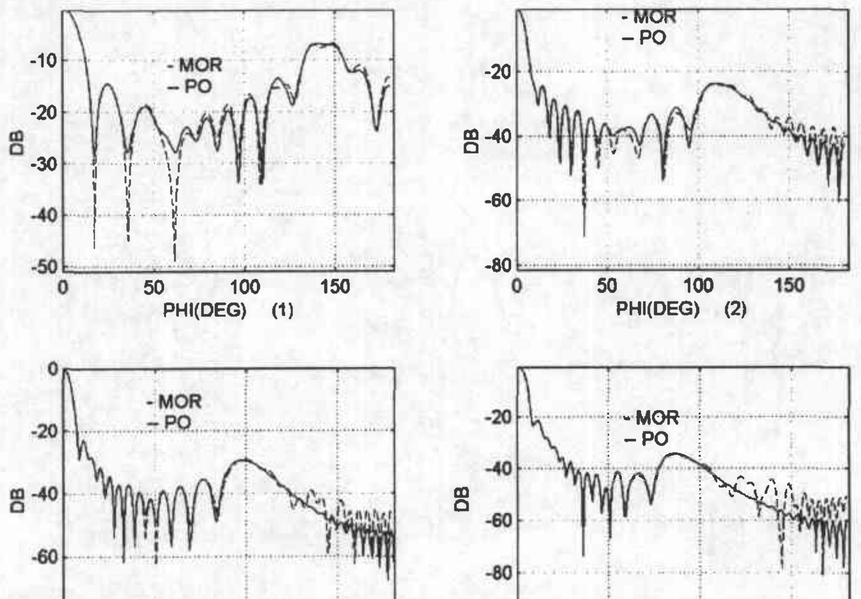

Figure 4: Radiation patterns for different aperture angles kb=3 and a=10λ and θ_{ap}=(1) 10 degree (2) 30 degree (3) 40 degree and (4) 50 degree.