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Comparative Optical Analysis of Offset Reflector Antenna in GRASP

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***Abstract*—**In this paper comparison of Reflector Antenna analyzing techniques based on wave and ray nature of optics is presented for an offset reflector antenna using GRASP (General Reflector antenna Analysis Software Package) software. The results obtained using PO (Physical Optics), PTD (Physical theory of Diffraction), and GTD (Geometrical Theory of Diffraction) are compared. The validity of PO and GTD techniques in regions around the antenna, caustic behavior of GTD in main beam, and deviation of GTD in case of near-in sidelobes of radiation pattern are discussed. The comparison for far-out sidelobes predicted by PO, PO + PTD and GTD is described. The effect of Direct Radiations from feed which results in feed selection for the system is addressed.

***Keywords*—**Geometrical optics & geometrical theory of diffraction, offset reflector antenna, physical optics & physical theory of diffraction, PO & GO comaprison.

I. INTRODUCTION

A scattering problem consists of a known incident field and a scatterer with known geometry and electrical surface properties. The goal is to compute the total radiated field. Asymptotic high frequency techniques, 'physical optics' based on wave theory and 'geometrical optics' based on ray theory are extensively used for reflector antenna analysis and are found in literature [1,…,11]. In this paper a 1m offset reflector antenna is analyzed at 10 GHz frequency using GTD, PO, and PO + PTD techniques in GRASP software by TICRA. The results are compared and their validity in regions around the reflector antenna is stated. The PO is valid in main beam and near-in sidelobes but deviates at far-out sidelobes. When PO is supported by PTD the far-out sidelobes prediction is as good as that predicted by GTD at a cost of increased computation time especially in case of large scatterers. On the other hand GTD exhibits caustic in main beam region and predicts far-out sidelobes with good accuracy. Geometrical optics techniques are less accurate at lower frequencies than PO techniques and the accuracy of GO increases with the frequency.

The radiation pattern is superposition of reflector scattered field and direct radiations from feed. The selection of feed is important for sidelobes reduction and is addressed in this paper.

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II. OFFSET REFLECTOR ANTENNA GEOMETRY

The geometry used in analysis is shown in Fig. 1 along with its dimensions and rays plot. The reflector antenna is 1m in diameter with circular rim; focal length is 1m and an offset equal to 0.1m. Linearly polarized Gaussian feed model with taper angle of 25.94 degree and taper of -12 dB at edge of reflector with respect to its center is used.

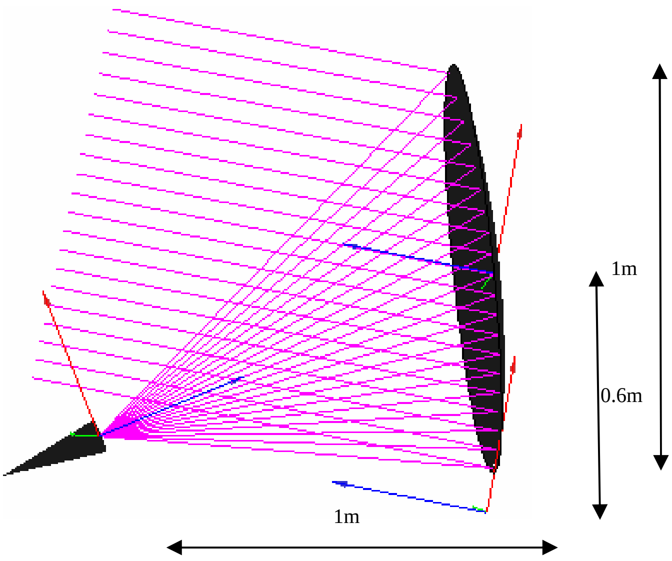


Fig. 1 Offset reflector antenna geometry

III. FEED RADIATION PATTERN

The radiation pattern of Gaussian beam model of feed used in analysis is shown in Fig. 2. The radiation pattern of feed is important because it contributes to the radiation pattern calculation especially when feed becomes visible and its contribution is greater than the sidelobes from the reflector scattered radiation pattern. The GTD method inherently takes the shadowing effect into account by adding the direct ray from the feed when it is not shadowed by the reflector. The PO method requires that the field from feed is added to the scattered field from the reflector. In PO the feed contribution in the main beam is not very important as the contribution is significantly small. But at wide angles (rear side of reflector) the feed radiations are very important to be considered while predicting the wide angle side lobes. If direct radiations from feed are not added in the PO calculated field, then the calculated pattern resembles the radiation pattern of the feed in that particular direction.

IV. GO + GTD TECHNIQUE

The offset reflector antenna system was analyzed in GRASP by using GTD object. The GTD object in GRASP offers the user to select ON or OFF for GO, GTD, and Direct Feed contribution fields. The cases with and without considering the direct radiations from feed were analyzed. During analysis both GO and GTD fields of GTD object were set to ON. The results are shown in Fig. 2. There is caustic in the main beam region and will be discussed in IX. The results with and without feed differs for wide angle sidelobes. The GO+GTD exhibits caustic at 146 degrees in addition to the main beam caustics due to edge diffracted rays. The abnormality in GO+GTD (without considering the direct field from the feed) calculated radiation pattern is observed at angles equal to 122 and 174 degrees, which is not present in the case when feed direct radiations are added to the predicted field from the GO+GTD. This abnormality disappears due to direct radiation from feed. The feed becomes visible at 117 degrees and the contribution from feed causes a peak in the radiation pattern. The radiation pattern falls from peak ahead of 117 degrees as the feed is shadowed again by the reflector again.

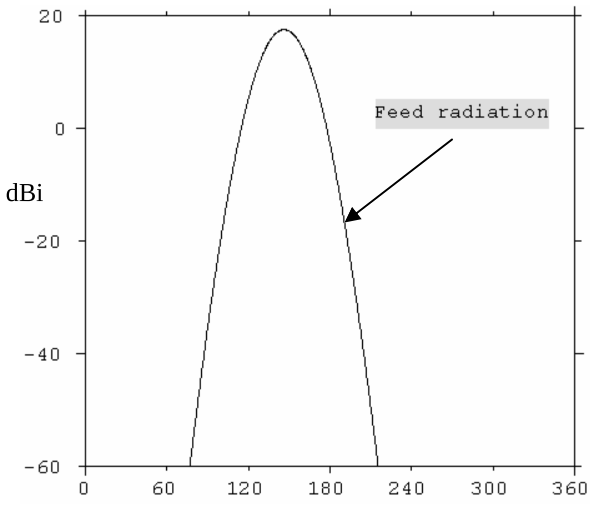


Fig. 2 Radiation pattern of Gaussian feed model

V. PHYSICAL OPTICS (PO)

The PO object in GRASP is used to calculate the PO field from the reflector system. Both cases, with and without feed contributions were considered as depicted in Fig. 3. The feed contribution in case of PO is more severe when the feed becomes visible, where the predicted radiation pattern resembles the feed's radiation pattern. When the field from feed is added to the main reflector's field, a peak is observed at 117 degrees as was observed in case of GO+GTD. The edge diffracted rays causes a peak at 146 degrees, which is lower than that predicted by GO+GTD. The field predicted by PO only for angles between 50 to 110 degree and -50 to -150 degree is not accurate as will be shown shortly, when a comparison with the PO+PTD will be presented in VII.

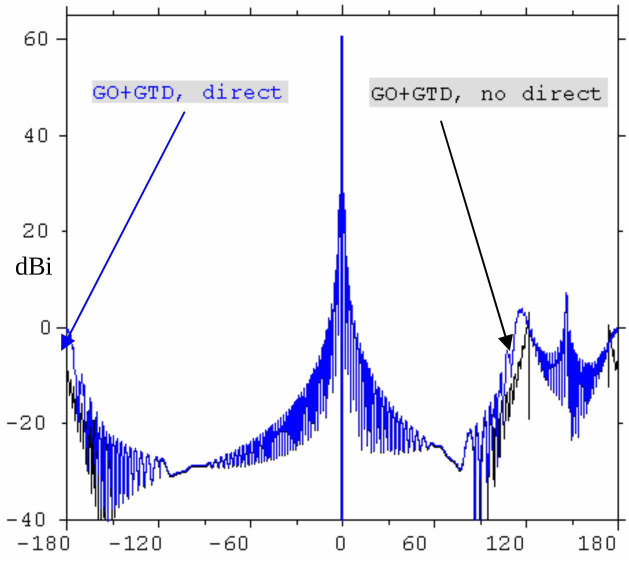


Fig. 3 Comparison of GO+GTD technique with and without feed direct radiations

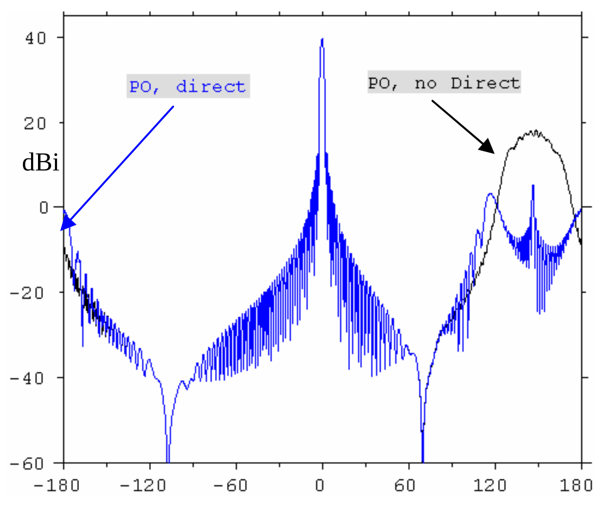
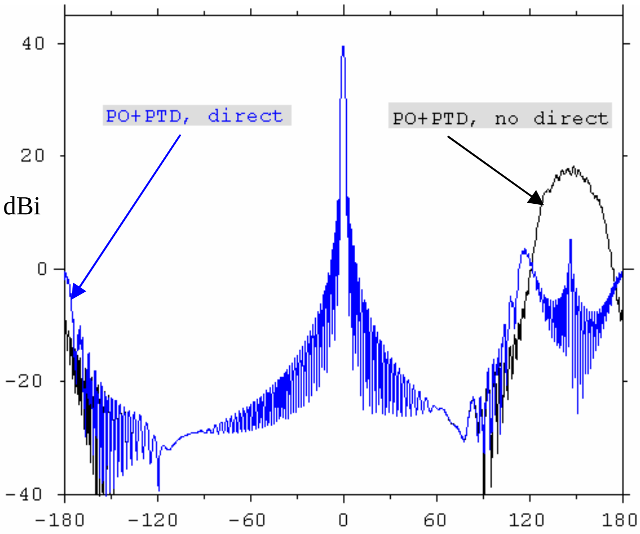


Fig. 4 PO with and without feed direct radiations

VI. PO +PTD

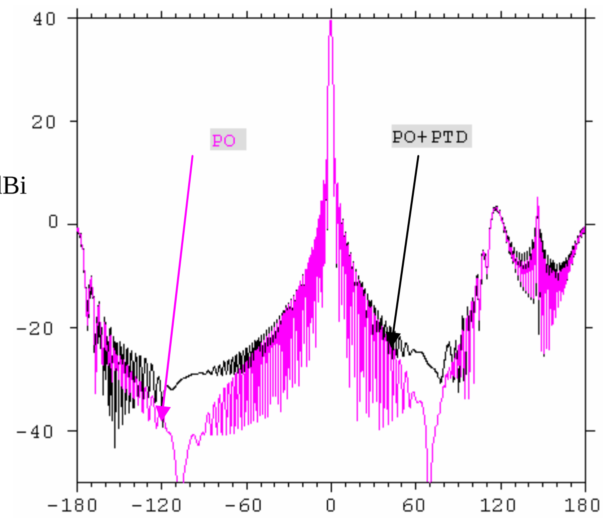
The case of PO+PTD is shown in Fig. 5, and the same type of arguments can be produced for this case. The wide angle sidelobes predicted by PO+PTD technique are more accurate [7]. For small reflector antennas there is almost no difference in computation time by using PO+PTD as compared to GTD but in case of large reflector antennas, the PO+PTD technique is computationally expensive as more points are required for PO+PTD convergence.



Theta (degree)
Fig. 5 PO+PTD with and without direct radiations from feed

VII. Comparison of PO and PO+PTD

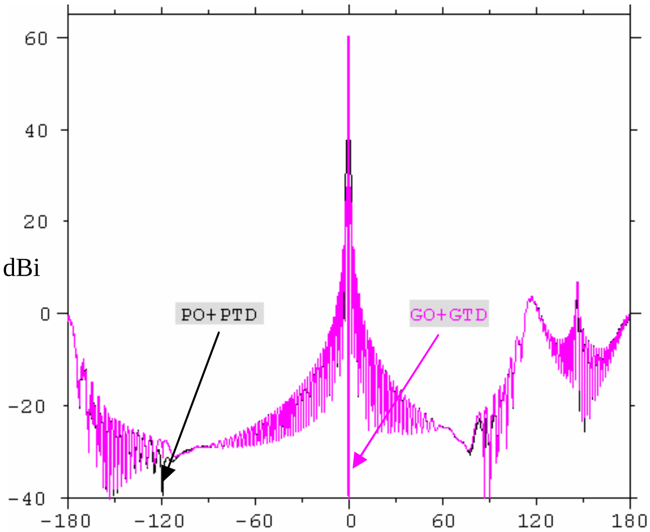
The comparison of PO with PO+PTD method is depicted in Fig. 6, with direct radiations from feed considered in both cases. The differences are seen at angles as discussed in V, PO only case. The PO+PTD method is more accurate for far-out side lobes as compared to PO only [7].



Theta (degree)
Fig. 6 Comparison of PO and PO+PTD

VIII. PO+PTD versus GO+GTD

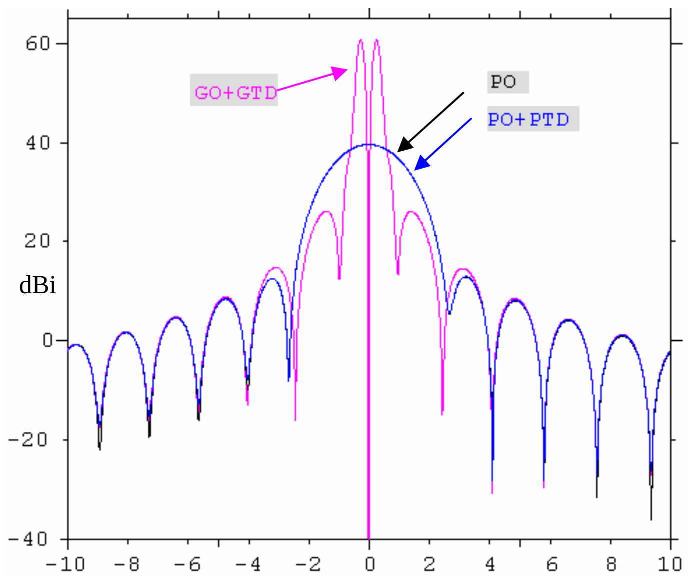
As depicted by Fig. 7, there is a good match between fields predicted by GO+GTD and PO+PTD except the caustic region. Both methods have their own advantages. As stated earlier the GO+GTD exhibits caustic in main beam but is faster than PO+PTD especially in case of large reflector antenna analysis. Both methods predict far-out sidelobes with good accuracy. However at low frequencies the PO based techniques are more accurate than GO based techniques [3].



Theta (degree)
Fig. 7 Comparison of GO+GTD with PO+PTD

IX. GO+GTD Caustic and PO, PO+PTD

The caustic exhibited by GO+GTD in the main beam is shown in Fig. 6. The field predicted by GO+GTD differs from the field prediction by PO and PO+PTD in near-in sidelobes. In main beam region GO+GTD technique is not valid leaving the opportunity for the use of PO or PO+PTD. PO and PO+PTD are in well agreement with each other in main beam region and near-in sidelobes.



Theta (degree)
Fig. 8 GO+GTD caustic and PO & PO+PTD

After few side lobes; the rule of thumb can be found in [7], the field predicted by GO+GTD technique become in agreement with the PO+PTD predicted field.

X. Direct Feed Radiations and Analysis Techniques

A comparison of GO+GTD and PO+PTD with cases of direct radiations from feed considered and not considered is

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presented in Fig. 9. Direct radiations from feed needs attention of the antenna system designer, spatially if the system is being analyzed by PO or PO+PTD technique. In GO+GTD the direct feed radiation are less severe as in the GO+GTD technique the direct feed ray addition is inbuilt in GRASP. While in case of PO or PO+PTD the field from the feed needs to be added to predict the total radiation pattern by PO or PO+PTD.

XI. Importance of Feed Model for PO, PO+PTD Techniques

In the shadow region, the total field is calculated by superposition of scattered field from reflector and direct field radiations from the feed. These contributions are approximately equal in amplitude and opposite in phase. So this is of high importance to select a correct feed model otherwise it will be impossible to cancel out both contribution. The feed model expressed by Spherical Wave Expansion (SWE) is accurate choice for the situation.

XII. Recommendations

Geometrical optics techniques are invalid in caustic region leaving Physical optics techniques as a choice. For wide angle sidelobes calculation geometrical optics techniques are more efficient than techniques based on physical optics. Techniques based on geometrical optics are more efficient in time for analyzing large scatterers. The feed selection is very important to cancel the feed contribution in the feed visible region of the far field sphere, so the radiation pattern of feed needs to be known with good accuracy using SWE.

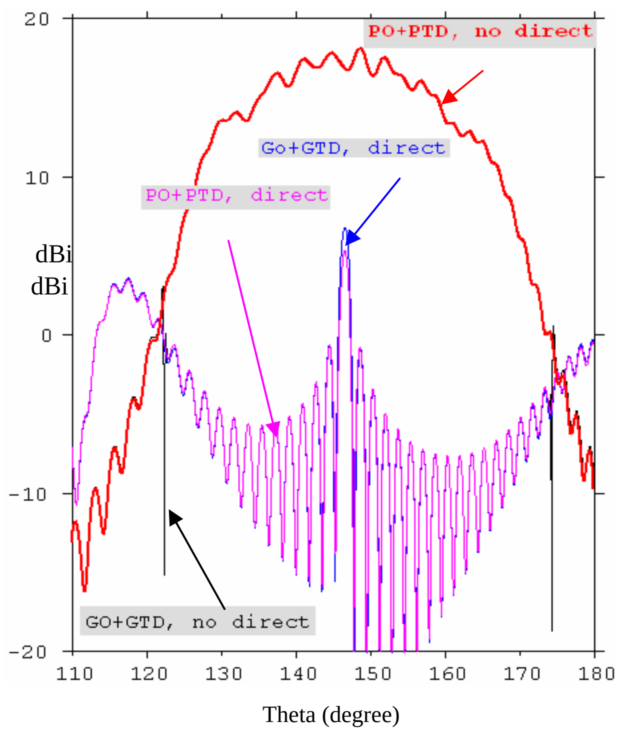

Fig. 9 Direct feed radiations and analysis techniques

XIII. Conclusion

In the paper asymptotic high frequency techniques for reflector antenna analysis i.e. GO+GTD, PO, PTD were compared for their validity in the main beam region and accuracy in the sidelobes prediction. It was found that the main beam and near in sidelobes are predicted accurately by PO, PO+PTD where as GO+GTD exhibits caustics in the main beam region. In case of far out sidelobes the PO is less accurate. The GO+GTD is more accurate when far out side lobes are considered. The accuracy of PO when supported by PTD approximately matches to the accuracy of GO+GTD technique for far out side lobes but at the expense of increased computation time. In physical optics analysis the direct feed radiations needs to be added to the PO calculated field for accurate field prediction. The feed is selected such that the direct feed radiations are cancelled out.

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