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Analysis of Blockage Effects on TEM-Fed Paraboloidal Reflector Antennas
(Part II : TEM Horn Illumination)

by

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Abstract

This note is a follow-up to a previous note [1] on the subject of the evaluation of the blockage effects on the reflector antenna performance. In the previous note, idealized feed illumination patterns, corresponding to 10 dB and 1 dB tapers, were used in the course of the diffraction analysis. In this note, we have used a more realistic TEM feed illumination characteristics in determining the effects of the launcher blockage. As before, it is assumed that the geometrical optics shadowing approach can be used to provide an approximate assessment of the blockage effects in the main beam region.

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Contents

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1. Introduction

In a previous note [1], numerical results were presented for the effects of the TEM-feed launcher blockage on the reflector antenna performance. The main objective was to investigate the blockage effects of the triangular shaped TEM launcher on the reflector pattern. In doing so, several different launcher geometries were considered. For the purpose of parametric studies, it was assumed that the feed illumination pattern was of {cos **Q} type with a spherical wavefront. This simplified model then allowed for useful parametric studies by essentially varying the feed edge illumination tapers.

In this note, we have used a more realistic model for the illuminating pattern of the TEM feed. This pattern provides a realistic feed amplitude pattern and still assumes that the feed generates a spherical wavefront. It is the purpose here to utilize the more appropriate TEM feed pattern in the course of the reflector diffraction analysis. First, the model of the feed pattern is presented and the results are shown on the blockage effects at several frequencies.

As before [1], we limit our analysis to the frequency ranges for which the physical optics modeling of the reflector is accurate. Next, it is assumed that the blockage effect can be characterized by the geometrical shadowing technique.

2. Numerical Results

2.1 Reflector Geometry

The reflector configuration under study in this report is depicted in figure 1. This is a paraboloidal reflector antenna fed by a spherical TEM launcher. The dimensions of the launcher are shown in the figure. The goal is to evaluate how the blockage due to the launcher affects the reflector radiation performance. This is done by using the diffraction analysis approach similar to the one presented in [1]. In order to perform the diffraction analysis, the physical optics analysis technique in conjunction with the geometrical optics shadowing of the launcher is used. Obviously, in the process of performing the diffraction analysis one must know what the illumination characteristics of the TEM launcher is.

2.2 A More Realistic Illumination Model

Based on a TEM field description [2], numerical data are presented to characterize the field of the TEM launcher. Figure 2 shows the principal field distribution of the launcher at several locations. The most important feature is the profound differences of the field variation along the x and y axis (principal planes). The cross polarized (x-directed) field component is also available. It is observed however that the field is predominantly y-polarized and possesses a spherical wavefront.

In order to able to utilize the above described field illumination into the reflector diffraction

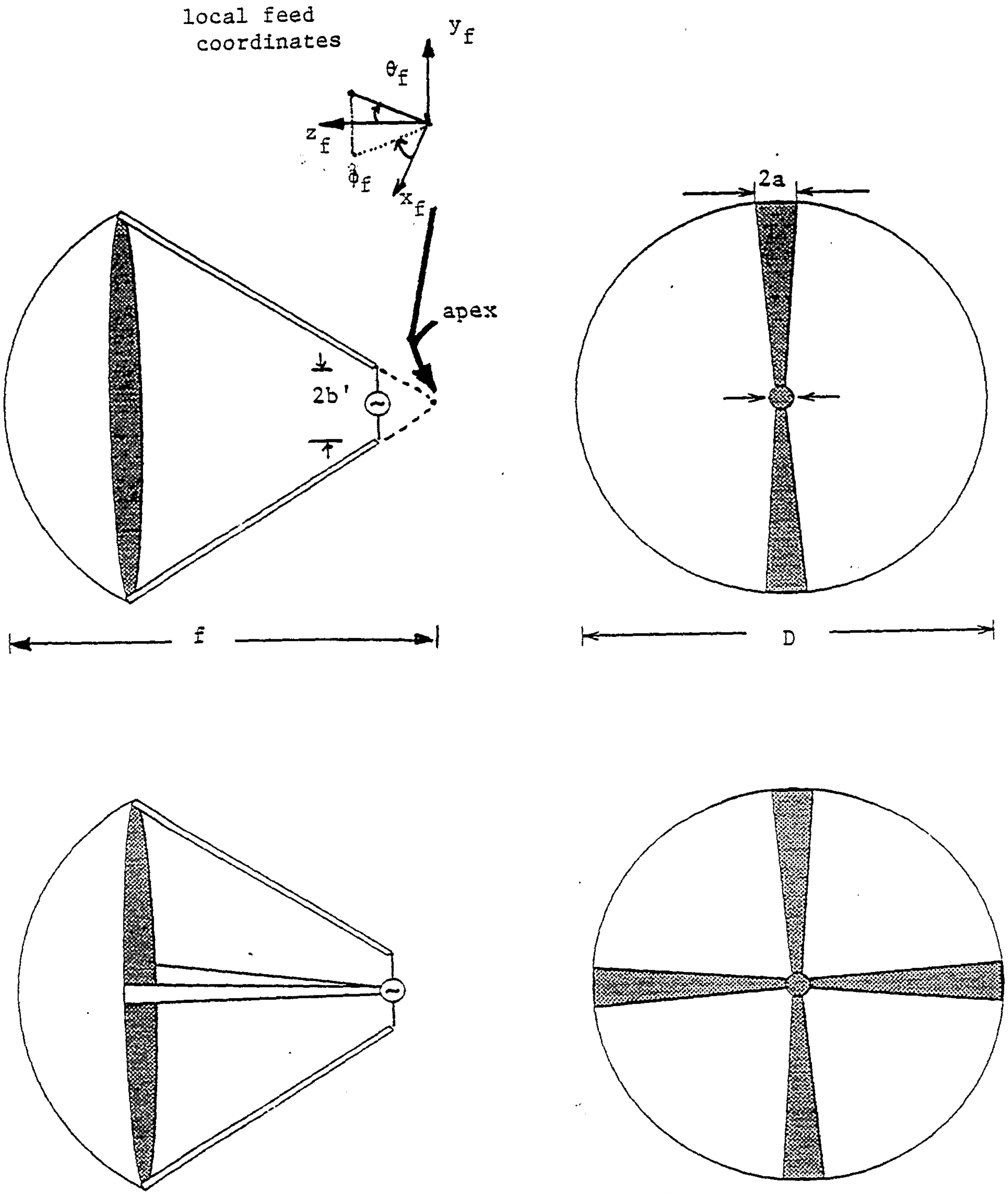

Figure 1 Antenna Configurations for two-arm and four-arm TEM-fed reflectors (e.g., D = 5m, f = 2m, 2a = 0.72m, 2b = D = 5m, 2b' = 0.1

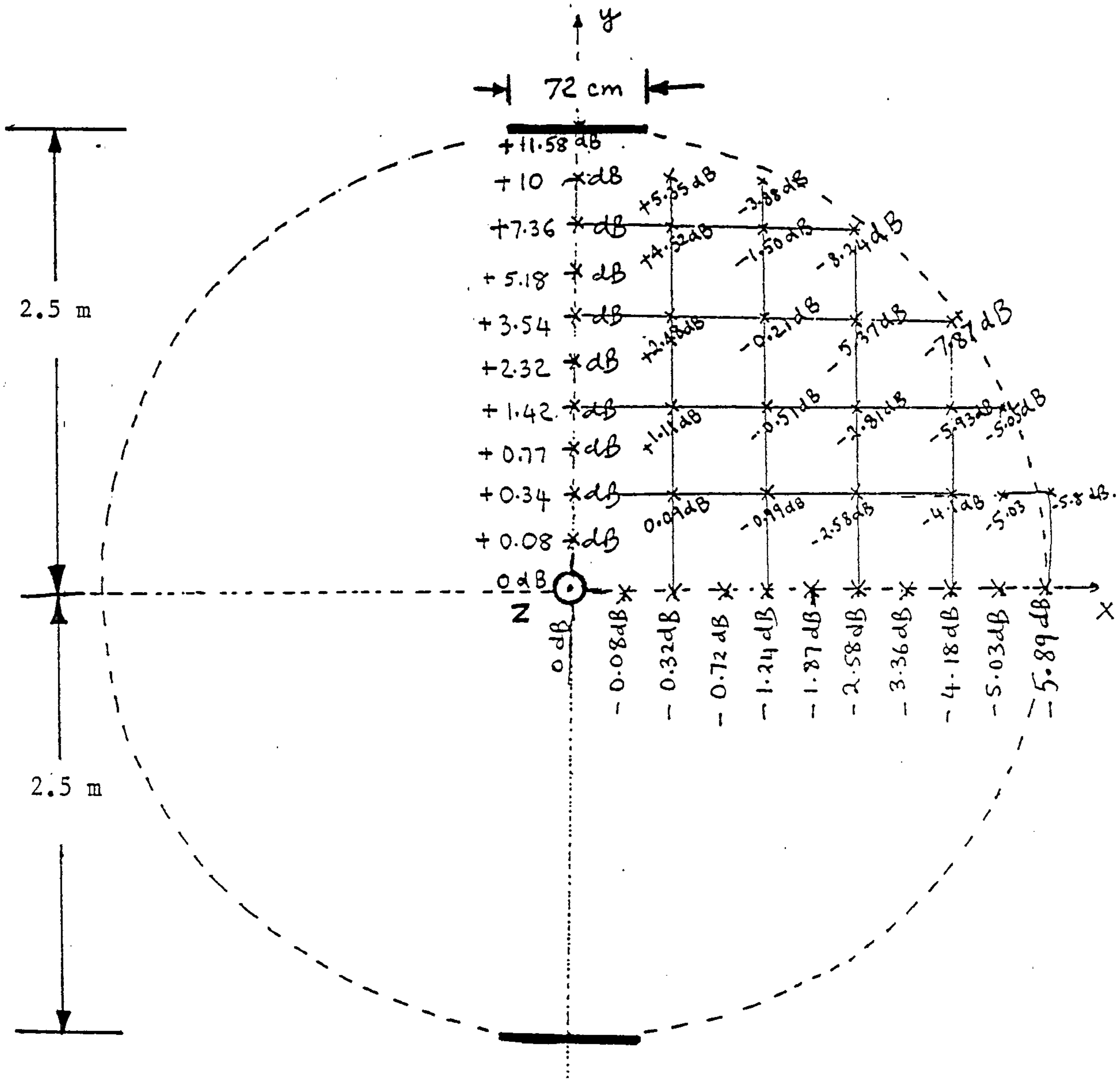

Fig. 2. Illumination amplitude field distribution by the TEM launcher

NOTE: The rectangular coordinates (x,y,z) shown above for the reflector is different from the local feed coordinates (x_f,y_f,z_f), in figure 1. The differences lie in the reversal of x and z coordinate directions.

analysis computer program, attempt was made to create a functional form for the amplitude distribution given in figure 2. As mentioned before, the wavefront is assumed to be spherical. The principal plane distributions were matched to appropriate functional distributions. After several attempts, the following functions were used to approximate the principal pattern distribution of figure 2. The mathematical expressions for these functional distributions are found to be

In xz plane:

$$P_H(\theta_f) = [\cos(\theta_f)]^{1.4} \tag{1}$$

In yz plane:

$$P_E(\theta_f) = 1 + 3.2 \exp - [1.9 \{\tan(\theta_f) - 1.45\}]^2 \tag{2}$$

The above functional distribution models are used as inputs in the computer programs dealing with the diffraction analysis of a reflector antenna. In order to demonstrate how well the functional forms agree with the TEM field distribution given in figure 2, plots were made to compare the two fields, as may be seen in figure 3. It is observed that the empirical fits represent the TEM fields well. These principal plane functional forms were then used to generate the complete illumination patterns from the feed in the local feed coordinates in the following fashion.

$$\vec{P}(\theta_f,\phi_f) = [\, P_H(\theta_f)\sin(\phi_f)\,\vec{1}_{\theta_f} + P_E(\theta_f)\cos(\phi_f)\,\vec{1}_{\phi_f} \,] \frac{\exp(-jkr_f)}{r_f} \tag{3}$$

As mentioned before, it is very important to realize that the feed illumination has vastly different characteristics in the two principal planes. In one plane, the illumination tapers down gradually, whereas in the other plane, it has an almost exponential growth characteristic.

2.3 Antenna Patterns With and Without Blockage Effects

Using the above feed illumination pattern, diffraction analyses were performed to determine the radiation characteristics of the reflector antenna at several frequencies. The geometrical parameters are summarized below:

the reflector diameter $D = 5$m ; focal length $f = 2$m ; $f/D = 0.4$
TEM impedance $Z_c = 400$ Ohms ; plate width $2a = 0.72$m ;
plate separation $2b = 5$m ; width / separation = 6.99

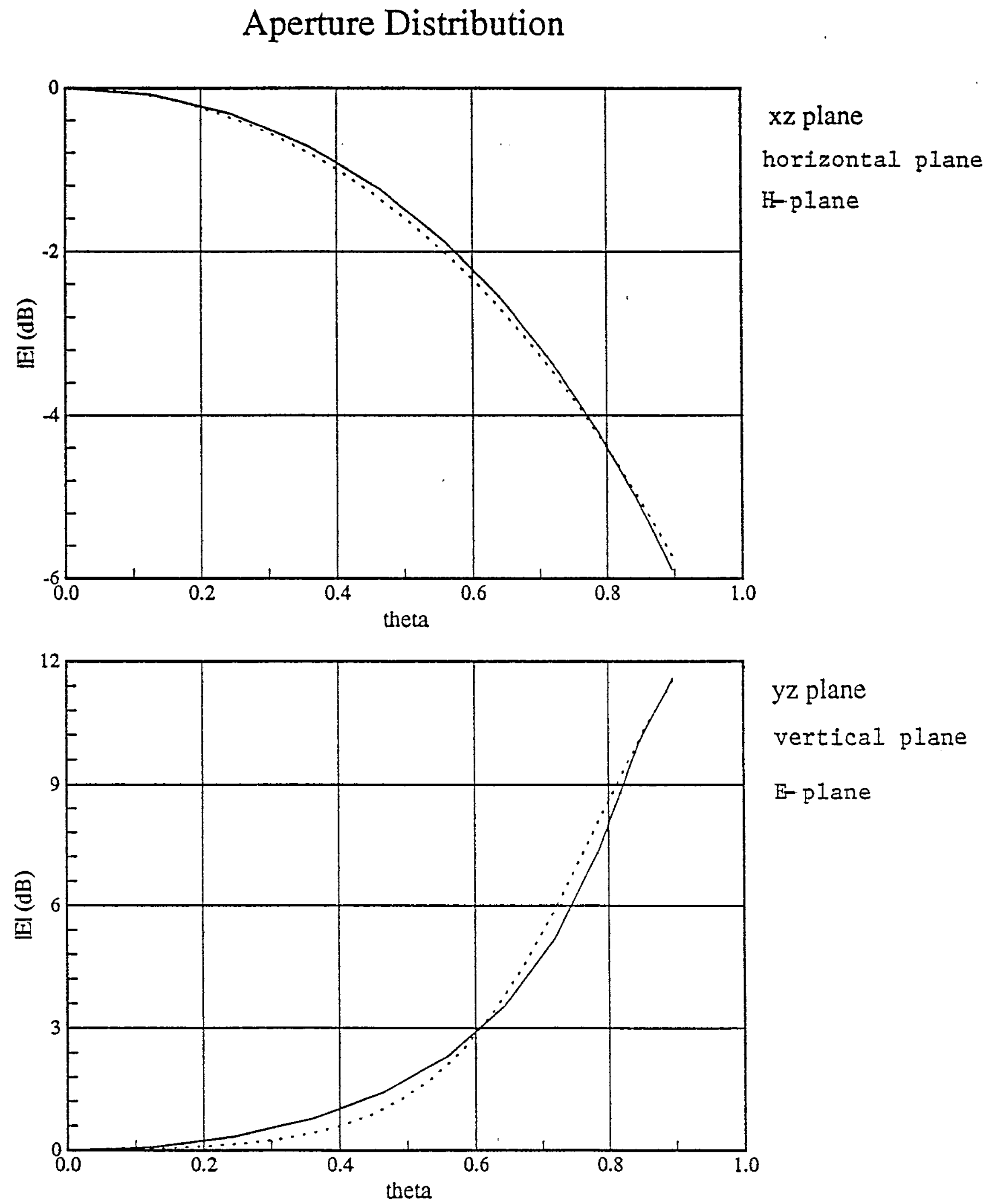

Fig. 3. Comparison between the TEM amplitude distributions (solid line) and the ones obtained using the functional forms (dashed lines).

In all cases, the results of the diffraction analysis are shown for the two situations of blockage and no blockage. Each pattern is normalized to the 0 dB level for the situation of no blockage. In this fashion, the reader can easily evaluate the effects of blockage on the far field patterns. As may be expected, the gain loss due to the blockage effect (geometrical shadowing), was approximately the same, i.e.,

$$\text{Gain loss} = 1.57 \text{ dB}$$

It is noted that the above gain loss is more than the previously reported (0.9 dB) for the cases of uniform tapers of 10 dB and 1 dB. The reasons for this additional gain loss lie in the nature of the illumination fields. The antenna far field patterns are shown in figures 4 - 7 for frequencies ranging from 0.2 GHz to 3 GHz. What we observe is that the radiation pattern in the horizontal or the H-plane (xz plane) is more affected than the radiation pattern in the vertical or the E-plane (xy plane). The side lobes in the H-plane are much smaller than the side lobes in the E-plane. The effect of the blockage is to take energy away from the main lobe and the side lobes in the E- plane and divert it to the boost the side lobes in the H-plane. This also suggests that if symmetric (in E and H planes) radiation pattern is of interest, one has to employ 4 feed arms (i.e., 2 pairs). Such calculations can be repeated for other parameters of IRA, such as f / D values, impedances etc., if needed.

3. Summary

In this note, we have estimated the effects of aperture blockage in the case of TEM horn- fed parabolic reflector, which is at least 3 wavelengths in diameter. A realistic TEM field formed by two-parallel plates is used as the illuminating field. This illuminating field falls off in the transverse direction, but increases in the direction along which the principal electric field is oriented. It is found that in the horizontal or the H-plane (xz plane), the side lobe patterns are significantly affected by blockage effects. Illustrative example calculations are performed for the case of f / D = 0.4 and a TEM impedance of 400 Ohms, for 4 spot frequencies. The reflector diameter is at least 3 wavelengths long at the lowest frequency.

In order to completely characterize the time domain response of the reflector antenna fed by a TEM launcher, it will be useful to evaluate the antenna performance at yet lower frequencies. A good technique for this is to use surface patch method of moment integral equation approach. This can be done in a systematic fashion by using a symmetric configuration such as the one shown in figure 8. Additionally, this integral equation solution will allow one to properly assess the usefulness of the physical optics based models at lower frequencies.

References

[1] Y.Rahmat-Samii, "Analysis of Blockage Effects on TEM-fed Paraboloidal Reflector Antennas," Sensor and Simulation Note 347, 5 October 1992.

[2] C.E.Baum, D.V. Giri and R.Gonzalez, "Electromagnetic Field Distribution of the TEm Mode in a Symmetrical Two-Parallel-Plate Transmission Line, " Sensor and Simulation Note 219, 1 April 1976.

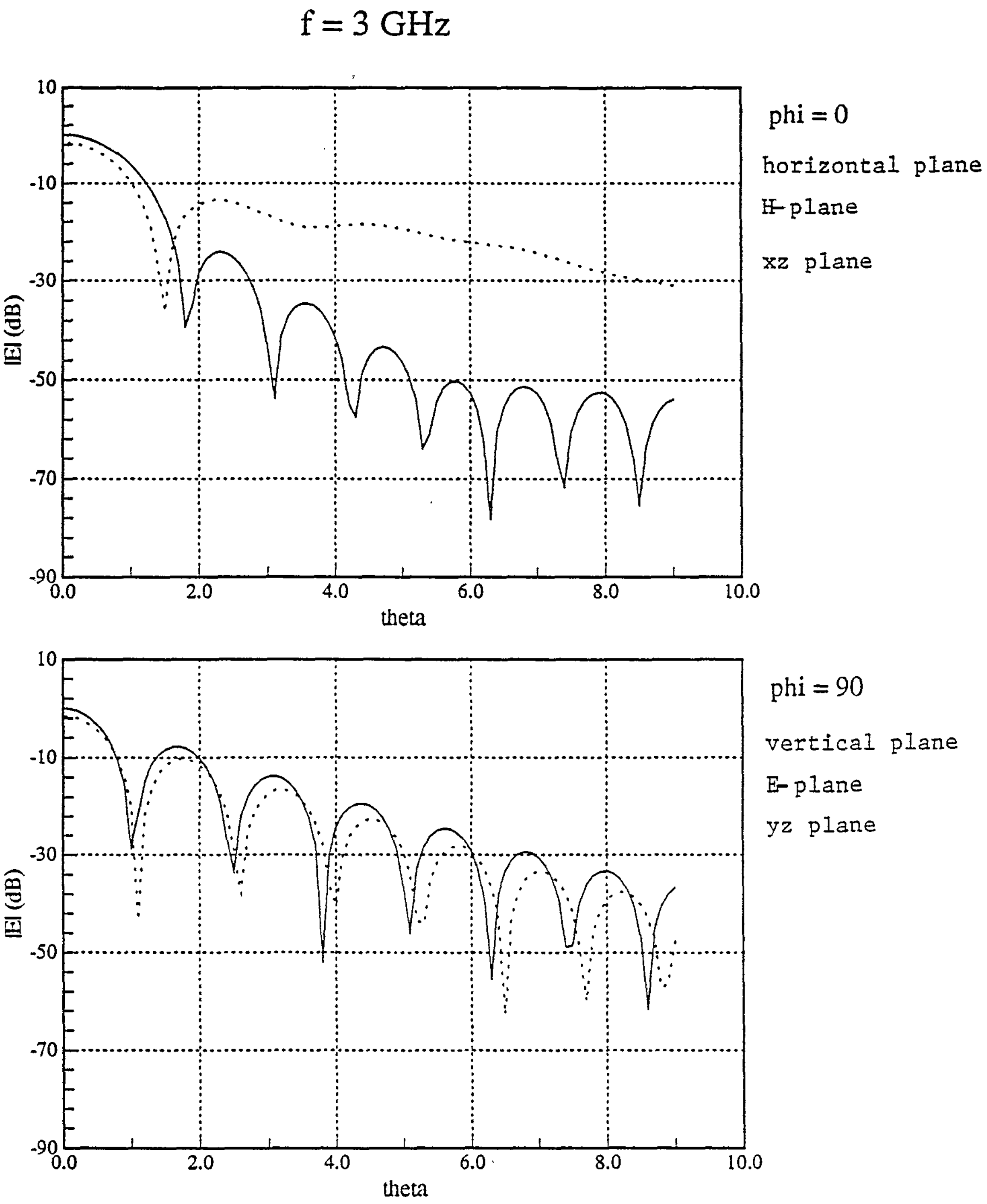

Fig. 4. Normalized antenna far field patterns for without (solid line) and with (dashed line) blockage cases (Freq. = 3.0 GHz)

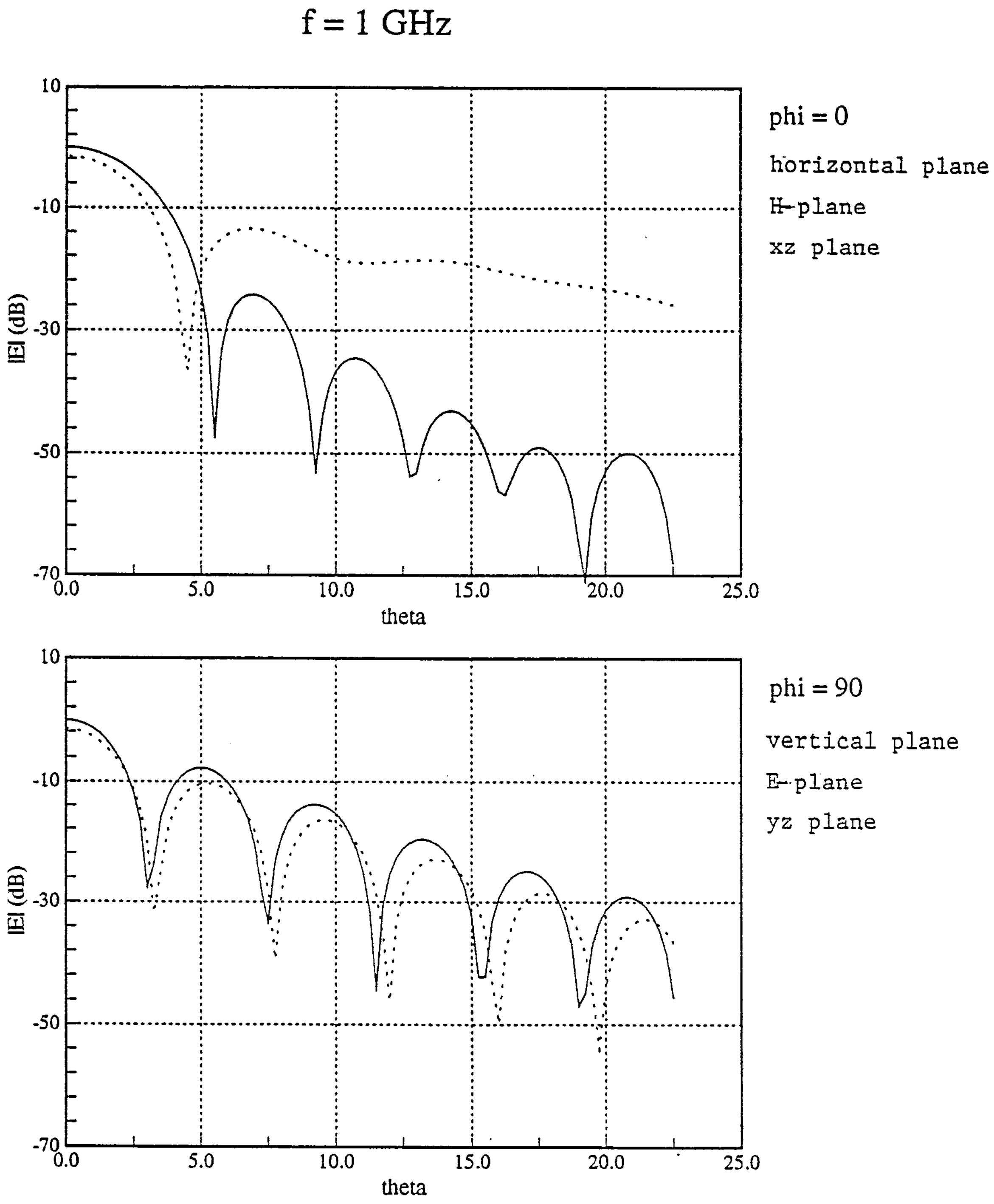

Fig. 5. Normalized antenna far field patterns for without (solid line) and with (dashed line) blockage cases (Freq. = 1.0 GHz)

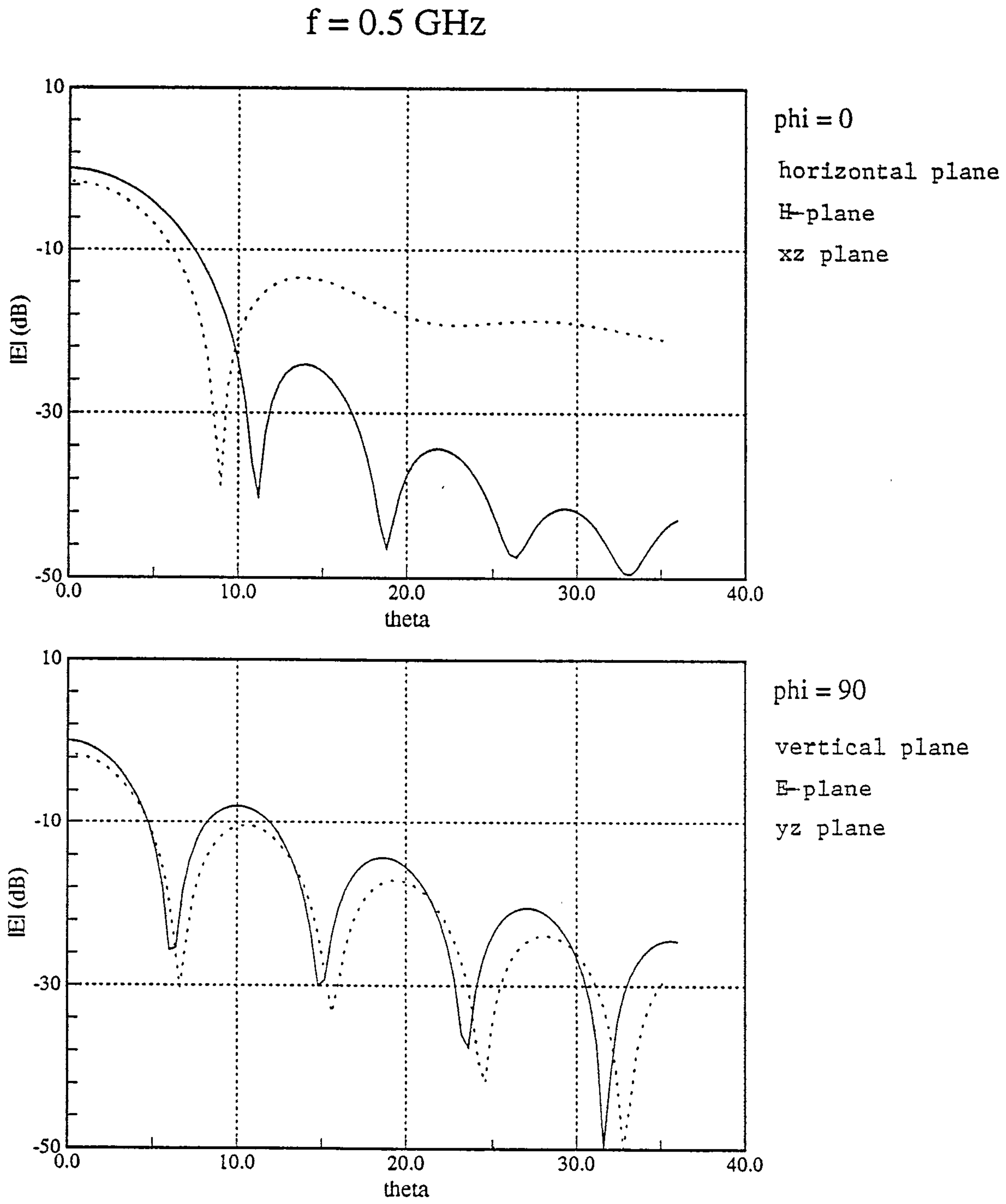

Fig. 6. Normalized antenna far field patterns for without (solid line) and with (dashed line) blockage cases (Freq. = 0.5 GHz)

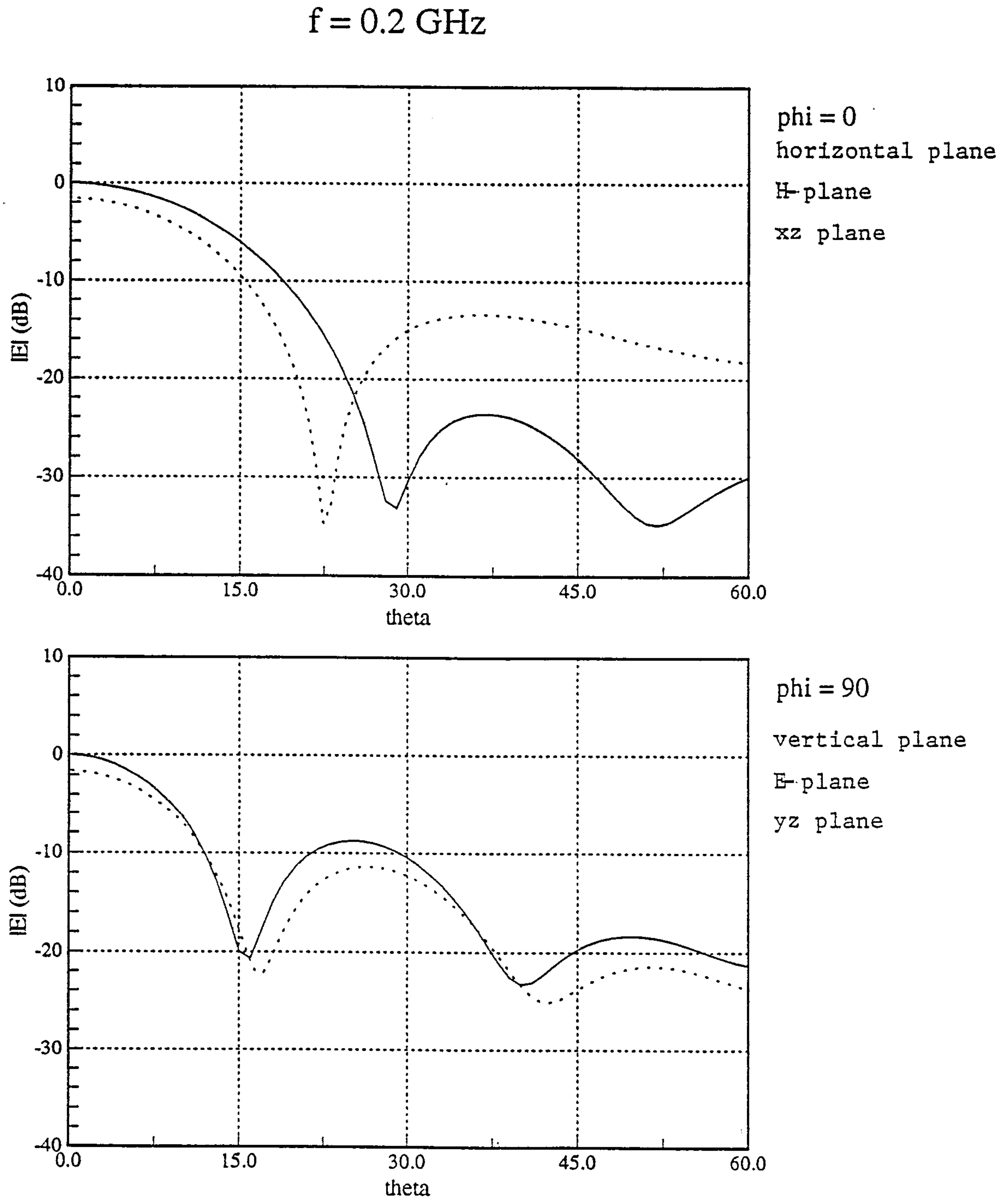

Fig. 7. Normalized antenna far field patterns for without (solid line) and with (dashed line) blockage cases (Freq. = 0.2 GHz)

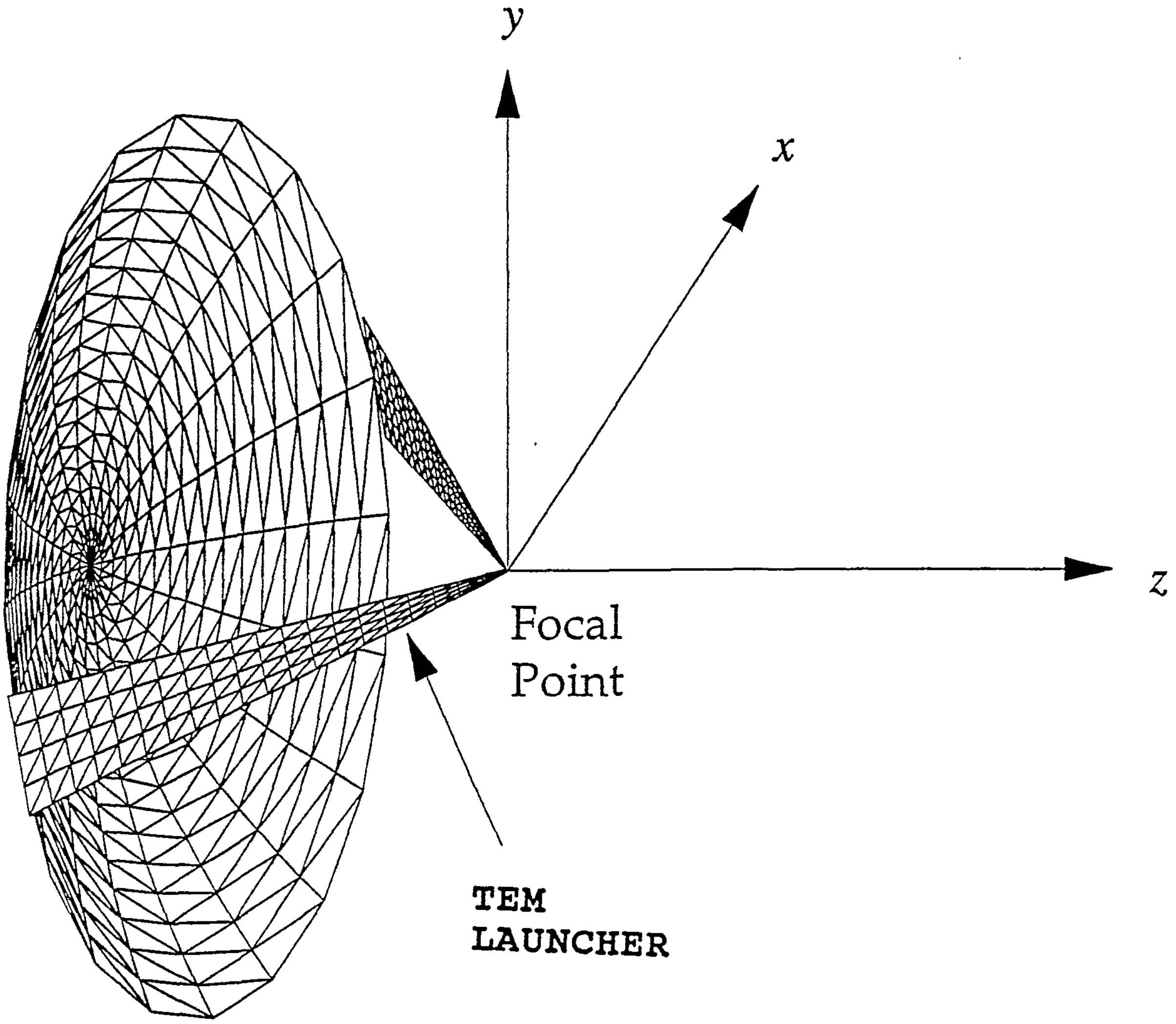

Fig. 8. Antenna performance evaluation using a surface-patch moment-method integral-equation approach.