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Hybrid-Mode, Shielded, Offset Parabolic Antenna

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In this paper measurements are presented for both a hybrid-mode feed having corrugations in two opposite walls and a modified scale-model pyramidal horn-reflector antenna using this feed. Comparisons of the measured and theoretical data for the hybrid-mode shielded offset parabolic antenna with the theoretical data for the standard pyramidal horn-reflector antenna show that a net improvement can be obtained in sidelobe level of about 4 dB in the transverse polarization in the transverse plane and 4 to 13 dB in the longitudinal polarization in the longitudinal plane.

I. INTRODUCTION

In most respects, the standard pyramidal horn-reflector is an excellent antenna. It is a combination of a square pyramidal horn and a reflector that is a section of a paraboloid of revolution whose focus coincides with the apex of the square horn. Its geometry provides a shielded offset parabolic antenna that is broadband with good front-to-back discrimination and good return loss. However, inherent in the design of the pyramidal horn-reflector antenna is a problem that results from illuminating the reflector with a dominant waveguide mode.[1] The theoretically obtainable off-axis radiation levels for transverse polarization in the transverse plane and longitudinal polarization in the longitudinal plane are considerably higher than those obtained for longitudinal polarization in the transverse plane and transverse polarization in the longitudinal plane, i.e., the former are essentially the equivalent of an aperture with constant illumination, whereas the latter aperture field distributions are tapered to zero at the edges.

In the discussion of the horn-reflector antenna, it should be remembered that longitudinal polarization and longitudinal plane indicate that the electric field in the aperture and the plane of antenna rotation (for radiation measurements) are aligned with the pyramidal horn axis, whereas transverse polarizations and transverse plane indicate that the electric field in the aperture and plane of antenna rotation are perpendicular to the horn axis.

As used in microwave radio-relay systems, the horn-reflector antenna is mounted with the axis of the horn normal to the earth's surface. Hence, longitudinal and transverse polarizations could be called vertical and horizontal, respectively. However, the aperture field distribution for each polarization is different. Moreover, when the antenna is used as an earth station antenna for satellite communications, or as a radiometer, or simply to obtain radiation characteristics in the longitudinal plane, the antenna is mounted on its side, i.e., the longitudinal axis of the horn is parallel with the earth's surface, and aperture field distributions for so-called vertical and horizontal polarizations are now interchanged. To avoid this ambiguity, longitudinal and transverse polarizations are referred to the axes of the horn.

Radio interference from adjacent paths limits the number of converging routes of a common-carrier microwave radio system. In recent years, demands have been made to improve the sidelobe performance of the pyramidal horn-reflector antenna. The use of blinders[2] (extensions to the side walls of the antenna aperture) provides a degree of far sidelobe reduction, i.e., lobes beyond 35 degrees from the axis of the main beam. A method now exists for eliminating the troublesome reflections from the flat weather cover of the horn-reflector antenna by using a focused weather cover.[3]

As used in terrestrial microwave radio systems, the horn-reflector antenna is mounted with the axis of the pyramidal horn normal to the earth's surface. Therefore, to address the problem of obtaining improvement in the sidelobe structure, primary consideration should be given to those sidelobes produced by transverse polarization in the transverse plane. Hence, one needs to consider those special feeds[4,5] that would decrease the field intensity at the two side walls.

In Section II a discussion of the design and radiation measurements of a 30-GHz, two-wall, hybrid-mode feed is presented; in Section III the radiation measurements obtained in both the transverse and longitudinal planes when this feed is used on a 30-GHz, scale-model, horn-reflector antenna are discussed;[6] and in Section IV the conclusion is made that the antenna as modified is no longer the familiar horn-reflector antenna, but a shielded, hybrid-mode-fed, offset paraboloid.

II. TWO-WALL HYBRID-MODE FEED

The hybrid-mode feed fabricated for this experiment was designed at a frequency of 30 GHz as a 6-inch-square aperture with two opposite walls corrugated. The design of the corrugations at this frequency requires a tooth and groove width of 0.020 inches (0.508 mm) and a tooth height or groove depth of 0.0997 inches (2.532 mm). These dimensions present a formidable machining task. Hence, other methods for fabrication were considered. As shown in Fig. 1, the approach used for this feed consisted of stacking alternating 0.020-inch- (0.508-mm) thick strips of brass and aluminum, with the height of the brass strips twice that of the aluminum strips. The assembly of alternating strips was electroformed and then machined to obtain the proper tooth height. The aluminum was chemically removed to provide the grooves. The rest of the fabrication proceeded along normal lines.

The measured vertical and horizontal polarization radiation characteristics for the two-wall hybrid-mode feed are shown in Figs. 2 and 3, respectively. The position of the two corrugated walls with respect to the electric field is indicated on the insert in each figure. For vertical polarization (Fig. 2), the corrugated walls are parallel to the electric field, whereas for horizontal polarization (Fig. 3) the two corrugated walls are normal to the electric field. An examination of these two figures indicates that, except for a few minor differences, the two patterns are essentially equal and symmetric. The dashed lines on these two figures indicate the respective cross-polarized response of the feed. From Fig. 3, we can conclude that the two-wall hybrid-mode feed provides a tapered field distribution for the transverse polarization in the transverse plane of the horn-reflector antenna. By rotating the hybrid-mode feed 90 degrees the same tapered field distribution can be provided for the longitudinal polarization in the longitudinal plane.

III. MODIFIED HORN-REFLECTOR ANTENNA

3.1 Transverse polarization, transverse plane

Using the radio range facilities at Holmdel, New Jersey, measurements were made of the far-field radiation characteristics of a 30-GHz,

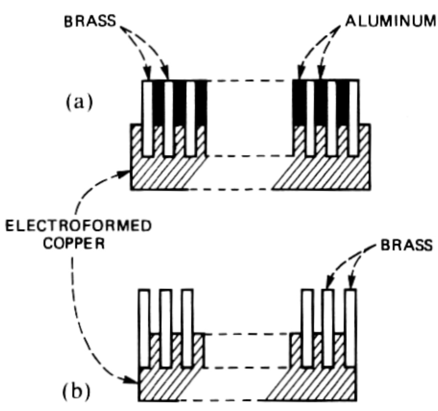

Fig. 1—(a) An assembly of alternating brass and aluminum strips used to achieve a corrugated wall. (b) The finished wall.

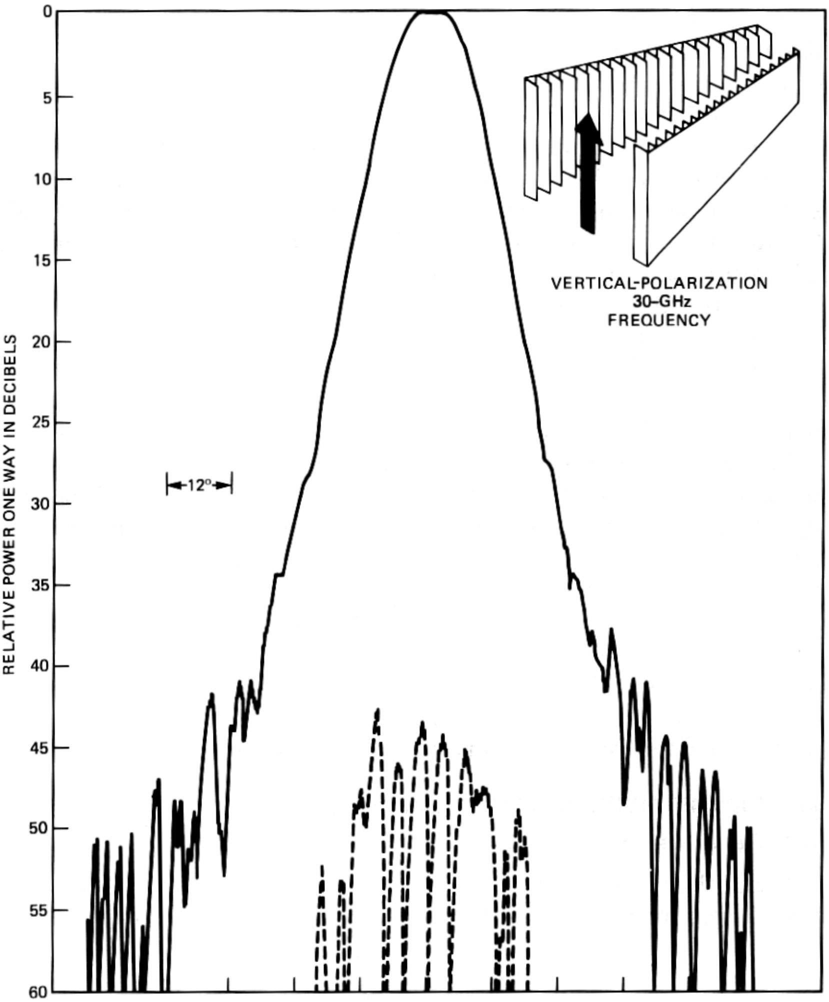

Fig. 2—The polarized radiation characteristics of the two-wall corrugated feed measured vertically are shown by the solid curve. The dashed curve shows the cross-polarized response. As depicted in the insert, the corrugated walls are parallel to the electric field.

scale-model, horn-reflector antenna[6] illuminated by the two-wall hybrid-mode feed discussed above. The solid line of Fig. 4 is the far-field radiation characteristic of this antenna for transverse polarization in the transverse plane. Recall that the two corrugated walls of the feed are normal to the transverse field. In Fig. 4, the dashed curve indicates the calculated envelope of peaks for the hybrid-mode antenna with ideal dual-mode excitation. Comparison of these two curves reveals good agreement over the main beam and first sidelobes but increasing disagreement for the sidelobes that are further out.

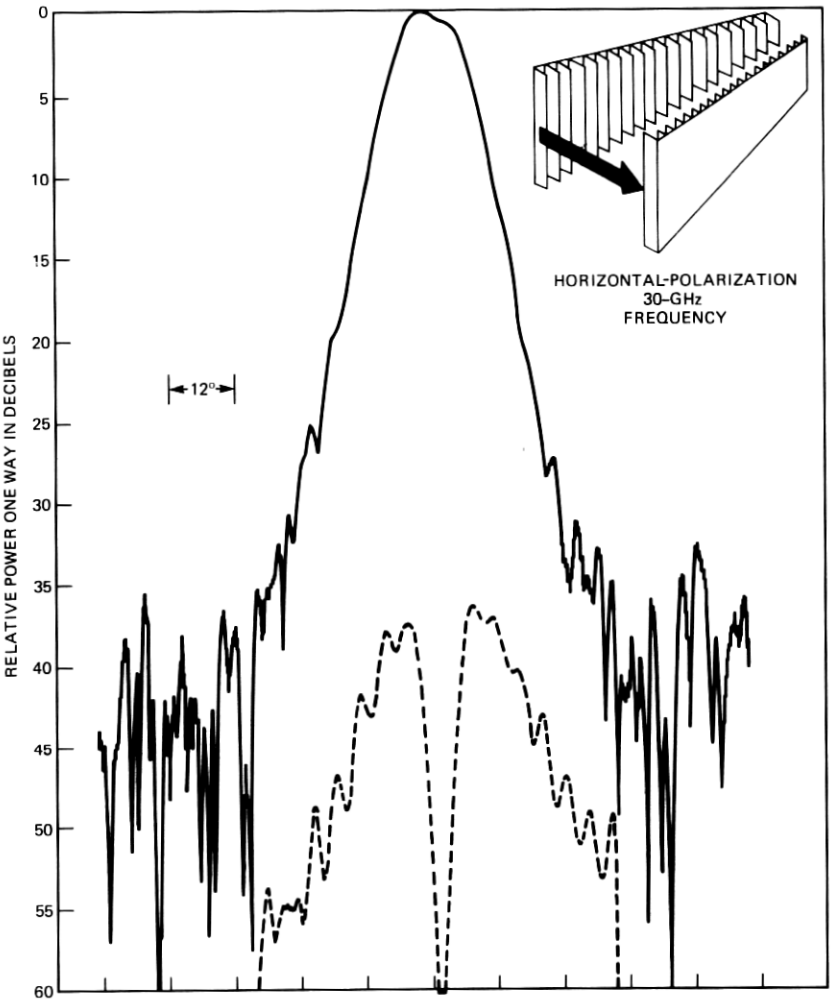

Fig. 3—The polarized radiation characteristics of the two-wall corrugated feed measured horizontally are shown by the solid curve. The dashed curve shows the cross-polarized response. As depicted in the insert, the corrugated walls are normal to the electric field.

A more extensive comparison is presented in Fig. 5. In this figure, the curves represent the characteristics obtained for transverse polarization in the transverse plane for the following: the broken curve is the theoretical response for the standard pyramidal horn-reflector antenna;[6] the dashed curve represents the theoretical response for the hybrid-mode antenna with ideal dual-mode excitation; and the solid curve is the measured data for the hybrid-mode antenna. An examination of the two theoretical curves indicates the possible improvement

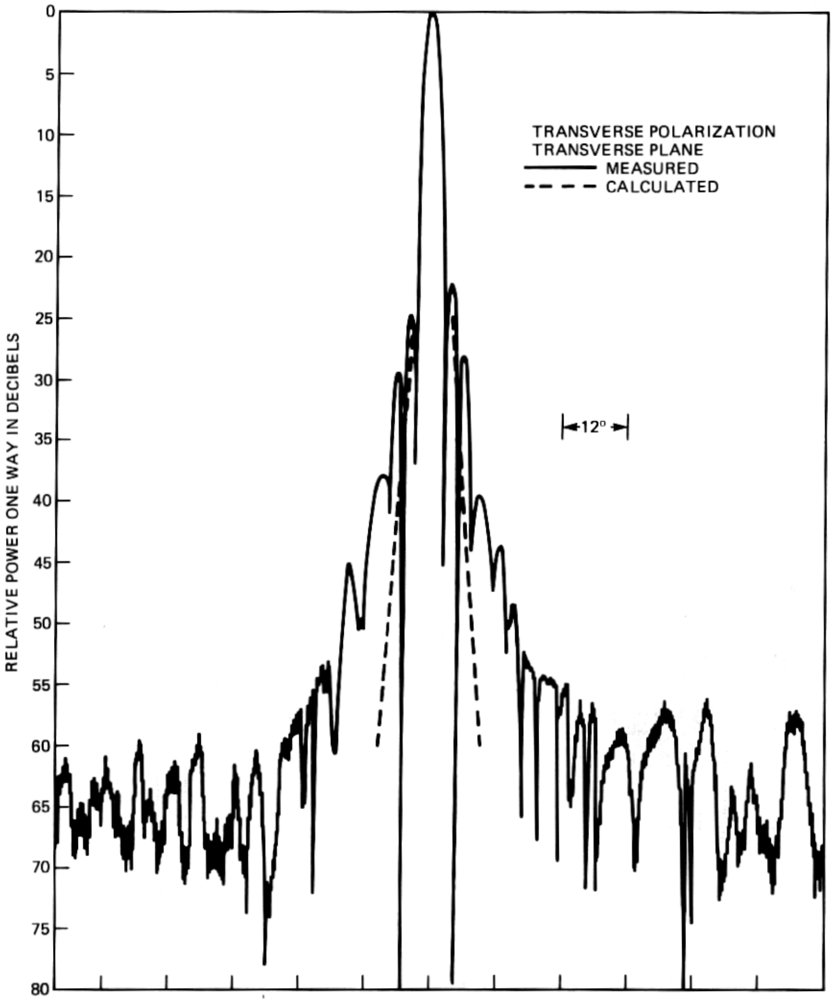

Fig. 4—The measured (solid curve) and calculated (dashed curve) radiation characteristics of the modified horn-reflector antenna for transverse polarization in the transverse plane.

in sidelobe structure that could be obtained by using the hybrid-mode feed instead of the standard horn feed of the standard horn-reflector. From comparison to the measured response (solid curve) one can see the actual improvement over that of the standard pyramidal horn-reflector antenna. However, the measured response is not quite as low as predicted by theory. The observed departure leads one to suspect that the two-wall corrugated structure used in these experiments may be flawed. By examining Figs. 2 and 3 more carefully, one observes regular small undulations in the radiation characteristics of the two-

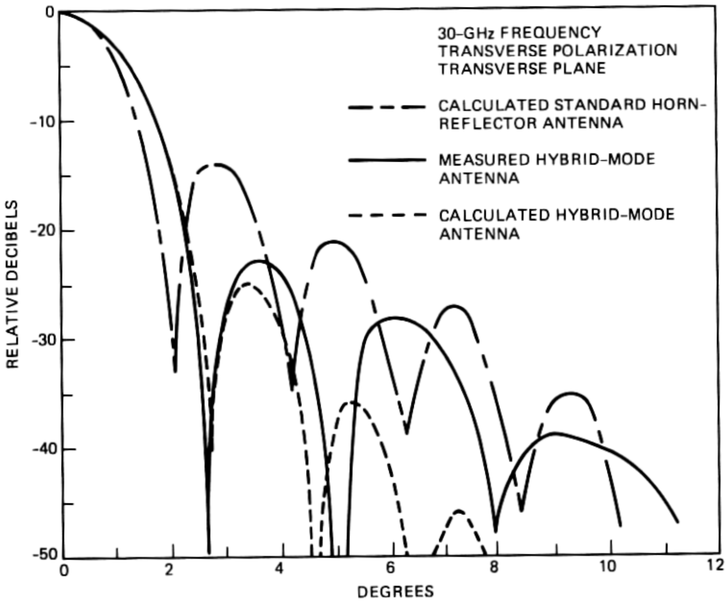

Fig. 5—Comparison of the measured response of the modified horn-reflector antenna (solid curve) with the theoretical response of the unmodified standard horn-reflector antenna (broken curve) and the theoretical response of the modified antenna (dashed curve).

wall corrugated feed that could indeed be indicative of the presence of modes other than the desired HE_{11} mode.

A comparison of the hybride-mode antenna measurements made for longitudinal polarization in the transverse plane with those of Ref. 6 indicate only minor differences and therefore are not included here.

3.2 Longitudinal polarization, longitudinal plane

To examine the possibility of improving radiation characteristics in the longitudinal plane, the hybrid-mode antenna is placed on the antenna positioner with its longitudinal axis parallel to the earth's surface. The two-wall hybrid-mode feed is rotated 90 degrees so that the corrugations are now on the front and back walls of the pyramidal portion of the antenna, i.e., the corrugations are now normal to the longitudinal field. The measured data obtained for this configuration are shown by the solid line in Fig. 6. The dashed line in this figure represents the calculated theoretical response for the hybrid-mode antenna with the ideal dual-mode excitation. Comparison of these two curves indicates good agreement.

A more extensive comparison is presented in Fig. 7. In this figure, the set of curves represents the characteristics obtained for longitudinal polarization in the longitudinal plane for the following: the broken

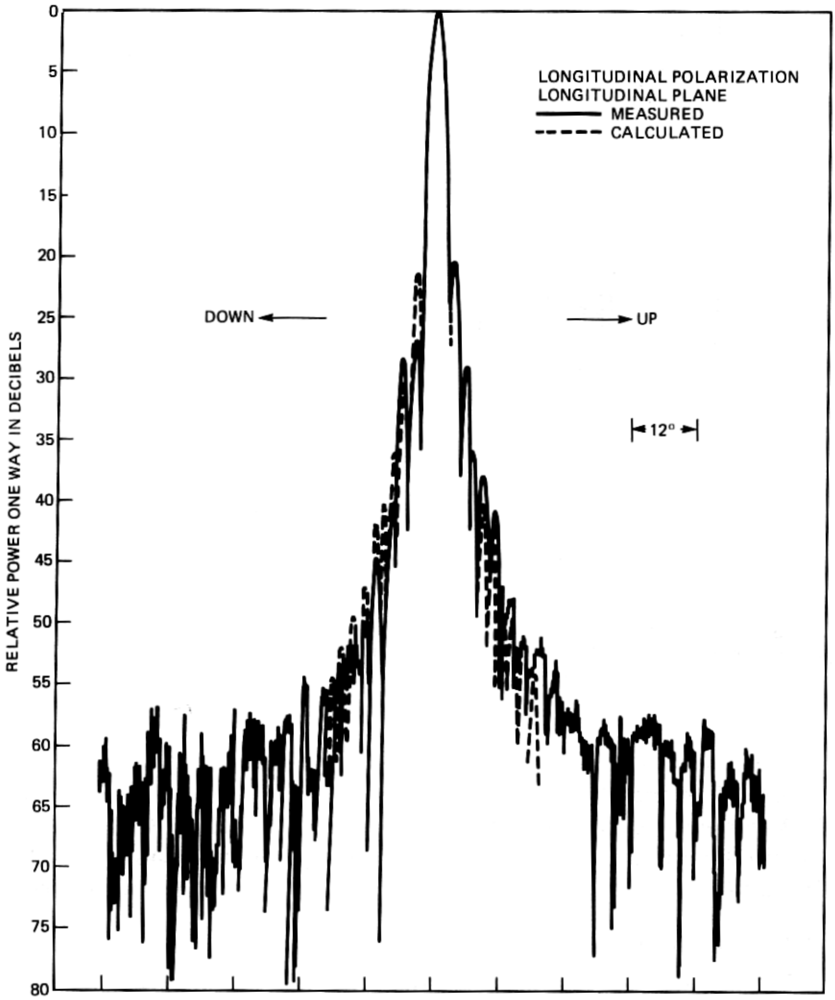

Fig. 6—The measured (solid curve) and calculated (dashed curve) radiation characteristics of the modified horn-reflector antenna for longitudinal polarization in the longitudinal plane.

curve is the theoretical response for the standard pyramidal horn-reflector antenna;[6] the dashed curve represents the theoretical response for the hybrid-mode antenna with ideal dual-mode excitation; and the solid curve is the measured data for the hybrid-mode antenna. Comparison of the two theoretical curves indicates the possible reduction in sidelobes that could be obtained by using a hybrid-mode-fed antenna. From the measured response (solid curve) one can observe the actual improvement over that of a standard pyramidal horn-reflector antenna and the good agreement with the theoretical values

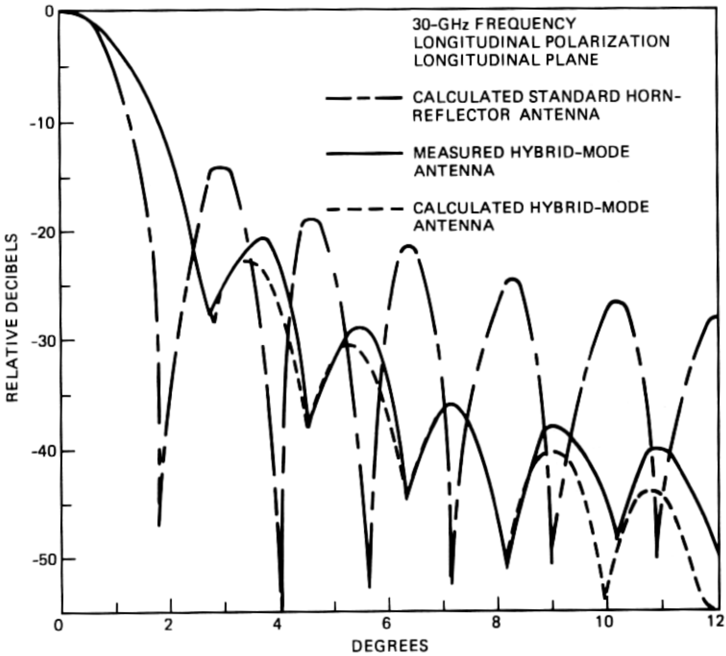

Fig. 7—Comparisons of the measured response of the modified horn-reflector antenna (solid curve) with the theoretical response of the unmodified standard horn-reflector antenna (broken curve) and the theoretical response of the modified antenna (dashed curve).

for the hybrid-mode antenna. The agreement here is better than that shown in Fig. 5, but one should recall that the pyramidal sidewalls contribute more to sidelobe structure than do the front and back walls. However, when compared to the transverse plane, the sidelobe structure in the longitudinal plane is, in general, higher. This can be attributed to the nearly parallel top and bottom edges of the antenna aperture.

A comparison of the hybrid-mode antenna radiation characteristics for transverse polarization in the longitudinal plane with those of Ref. 6 indicate only minor differences and therefore are not included here.

One should recall that, at present, the bandwidth of corrugated feeds is limited to less than two-to-one. This bandwidth limitation would tend to restrict the application of a two-wall corrugated feed to those system antennas where only two frequencies, i.e., 4 and 6 GHz, or 6 and 11 GHz were used. It should be noted that a two-wall hybrid-mode feed as discussed here will only reduce sidelobes in one plane; therefore one has the option when modifying existing antennas of applying the correction to that particular plane where interference in the near-in sidelobes is a problem. Of course, the use of a four-wall hybrid-mode feed reduces the sidelobes in both planes.

IV. CONCLUSIONS

Measurements for both a two-wall hybrid-mode feed and a modified scale-model horn-reflector using the hybrid-mode feed (a hybrid-mode, shielded, offset parabolic antenna) are presented and discussed. The high-sidelobe characteristics of a standard pyramidal horn-reflector antenna displayed in the transverse plane for transverse polarization and in the longitudinal plane for longitudinal polarization can be improved by modifying the antenna with a two-wall or four-wall hybrid-mode feed.

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