100-GHz Measurements of Two Astigmatic Launchers

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Astigmatic launchers that would permit a single earth station antenna to communicate with all the satellites along the geosynchronous arc have been fabricated and measured at a frequency of 100 GHz. Good agreement between measured data and calculated values has been obtained for astigmatic corrections required by feeds displaced 18 and 29 degrees from the focus.

I. INTRODUCTION

For high-capacity satellite communication systems, communication satellites are placed at different locations along the geosynchronous arc with the usual practice of using a separate earth station antenna to communicate with each satellite in the system. If both the satellites and earth stations are equipped with multiple-beam antennas, these high-capacity communication systems could be achieved by using a single earth station antenna and simultaneously communicating with all the satellites in the system.[1]

Measurements and theory have indicated that the geometry of an offset Cassegrainian antenna results in an ideal configuration[2-5] for both earth station and satellite antennas. Since the antenna aperture has no blockage, this significantly reduces the sidelobe levels and, in turn, reduces interference. However, since only one of the multiple beams can be aimed along the axis of the antenna reflector, the remaining beams must be displaced from the focus. The loss in
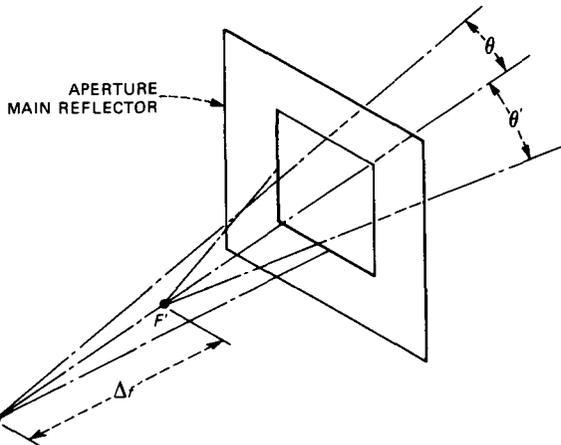
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Fig. 1—Astigmatic correction can be obtained by a feed with two different phase centers, F and F', in the two principal planes of its beam.

efficiency that these displaced beams exhibit is a function of the amount of astigmatism introduced as a result of the displacement from the focus. By using a feed with different phase centers in the two principal planes of its beam, shown in Fig. 1, one can eliminate the astigmatic loss.[6] For efficient operation over a wide band of frequencies, both the two phase centers (F, F') and the beamwidths in the two principal planes (θ, θ') must be frequency independent.

Earlier work by Dragone[7] and Chu[8] shows that frequency-independent astigmatic corrections can be obtained by combining a small horn with two cylindrical reflectors whose focal lengths are such that a magnified image of the feed horn is produced over the main reflector aperture.[9] However, this feed arrangement is not very suitable for an earth station antenna supporting multiple beams, since the distance between the two phase centers is fixed and cannot be varied after the feed is constructed. If one were to vary this distance, the beamwidths in the two principal planes would change, causing a reduction in aperture efficiency. This is an important restriction, for it implies that a given feed can only be used at certain locations in the vicinity of the focus; at other locations corresponding to other beam displacements, different feed parameters are required, necessitating the design of different feeds for different displacements. In addition, a large feed aperture is required, along with relatively large dimensions for one of the two reflectors.

II. DISCUSSION

Reference 6 describes a single launcher design that overcomes the above difficulties and permits the phase center separation to vary

while maintaining constant beamwidth in the two principal planes. Using the principles of Ref. 6, two launchers (one long and one short) were designed and fabricated for operation at 100 GHz.

The electroformed feed horn used with the launchers is shown in Fig. 2. To permit polarization rotation in the rectangular aperture of the feed horn, the horn was fabricated in two sections—one section tapering down to a square aperture and the second section tapering down to rectangular waveguide. The complete feed horn can be seen mounted together with the mixer on the short astigmatic launcher shown on the right of Fig. 3.

The long astigmatic launcher, shown without feed horn on the left of Fig. 3, has the top parallel plate removed to display the first reflector that would be illuminated by the feed horn. Both the short and long launchers shown here have identical pairs of reflectors; the only difference is the length of the parallel plates.

The cylindrical wave radiated by the feed horn positioned at the focus of the first reflector is guided to the first reflector by the parallel plates. After being reflected, the wave is again guided by the parallel plates in the direction of the second reflector. After some distance the parallel plates are truncated and the aperture illuminated by the reflected cylindrical wave is defined by this truncation. The width of
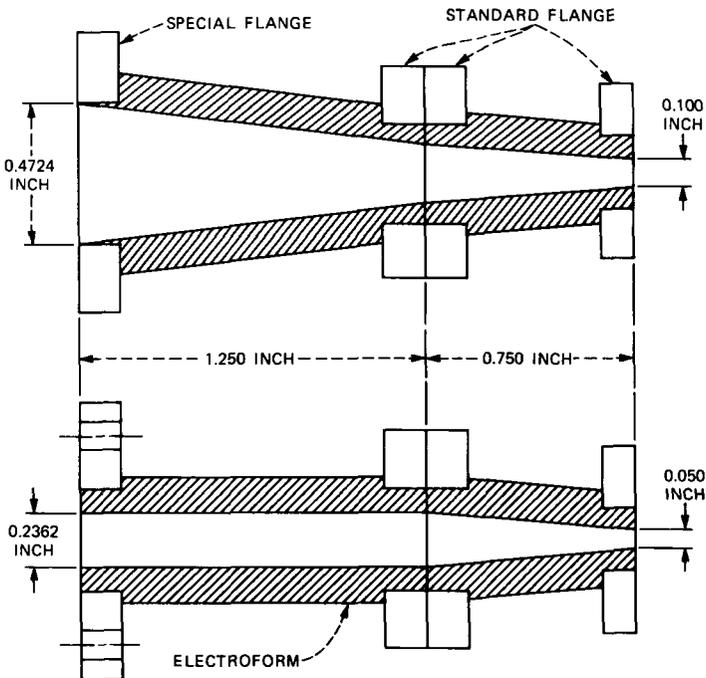

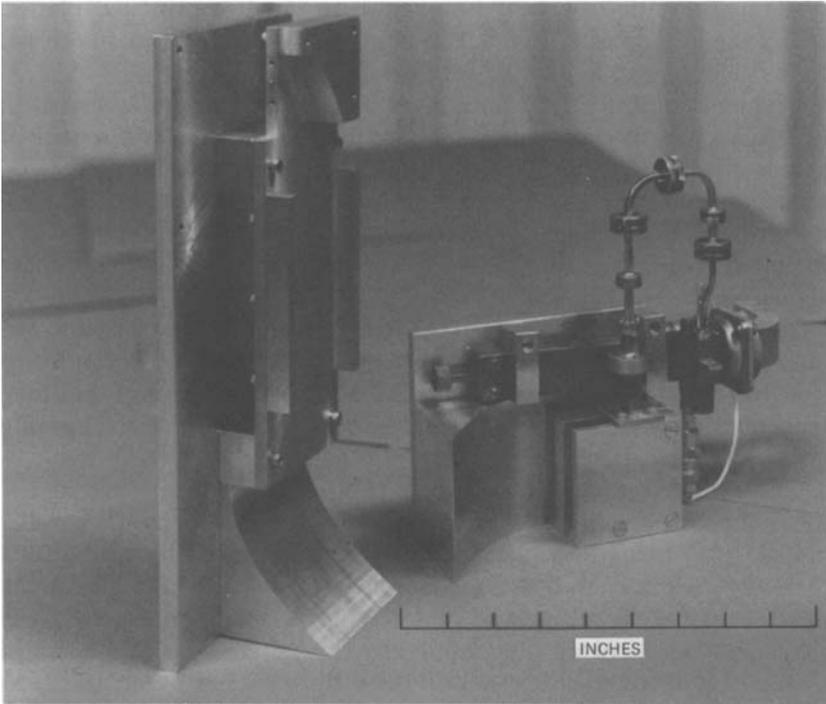Fig. 2—100-GHz feed horn used with the astigmatic launchers.

Fig. 3—The short astigmatic launcher (right) and the long astigmatic launcher (left).

the aperture is defined by the spacing between the two parallel plates; the wave radiated by this aperture illuminates the second cylindrical reflector.

To produce an image of the feed horn aperture over the aperture of the main reflector, the distances of the phase centers of the feed horn and the truncated parallel plate aperture must satisfy the optical thin lens equation.[6]

III. ASTIGMATIC LAUNCHER MEASUREMENTS

Using the newly constructed anechoic chamber at the radio range facilities at Holmdel, New Jersey, measurements were made of the radiation characteristics of the two 100-GHz astigmatic launchers depicted in Fig. 3. The measured data,* both amplitude and phase, are presented in Figs. 4 through 7 for both launchers and are shown by the solid curves. The dashed curves are the calculated theoretical values.

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* These data were obtained at a distance equivalent to that of the main reflector of an offset Cassegrainian Antenna, i.e, the data represent the actual illumination at the aperture of the main reflector.
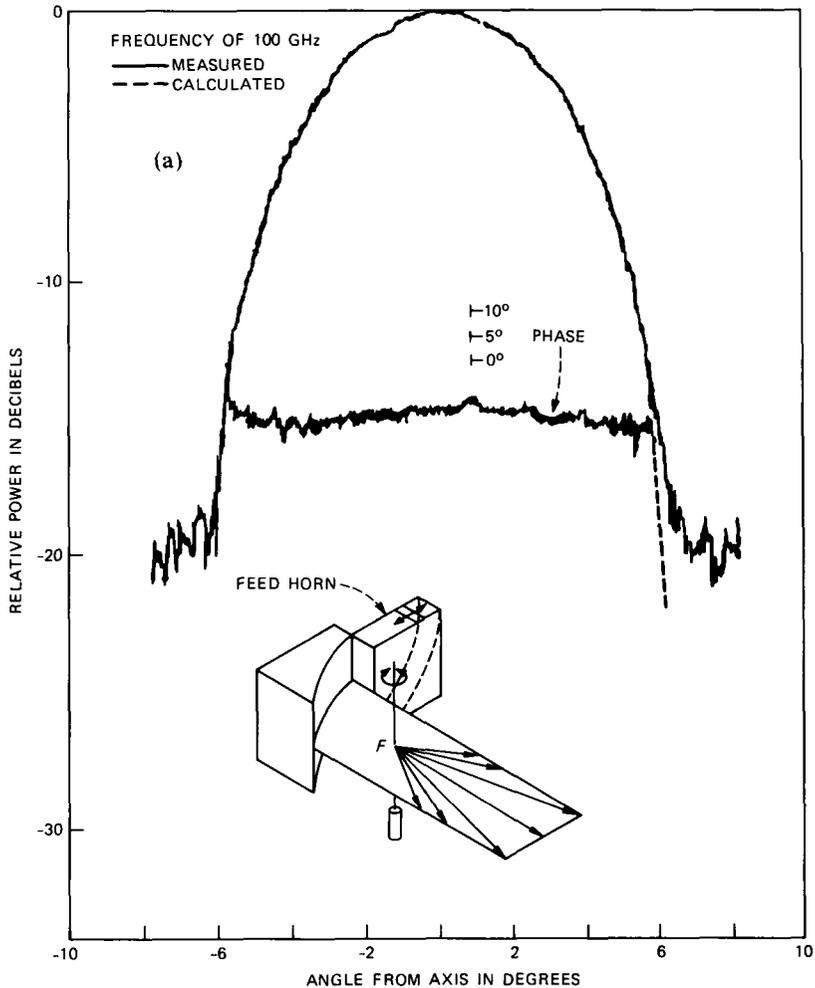
Fig. 4—(a) Measurements for an electric field parallel to the plates of the short launcher, and the theoretical amplitude distribution. The phase center lies in front of the aperture. (Cont.)

To avoid any difficulty in visualizing the polarization of the electric field, the electric field will always be referred to the plane of the parallel plates. Therefore, the electric field will be either parallel to or orthogonal to the plates. Further, the insert in each of these figures shows the position of the launcher with respect to the plane of measurements. The location of the phase center is also shown on the insert.

The amplitude measurements shown by the solid curve of Fig. 4a were obtained with the electric field parallel to the plates. The agree-
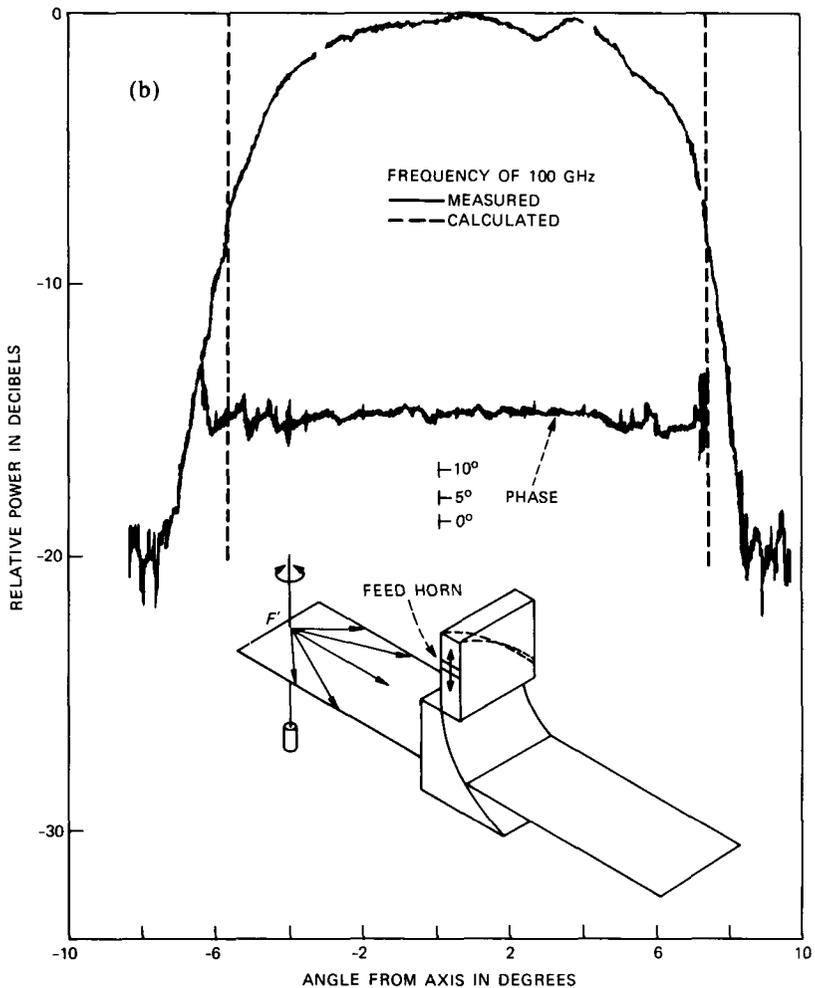
Fig. 4—(b) The electric field remains parallel to the plates, but the launcher is rotated 90 degrees. The phase center lies behind the aperture.

ment with the theoretical calculations is very good. An examination of the phase measurements shows a maximum phase variation of the order 6 degrees. Over much of the aperture, the phase is essentially constant.

For the amplitude data shown by the solid curve of Fig. 4b, the electric field is still parallel to the plates. As shown by the insert on this figure, the launcher is rotated 90 degrees. The dashed curve is that for a uniformly illuminated aperture. The measured data, given by the solid curve, are in good agreement. From the phase data shown here, one sees that the phase change over the aperture is of the order
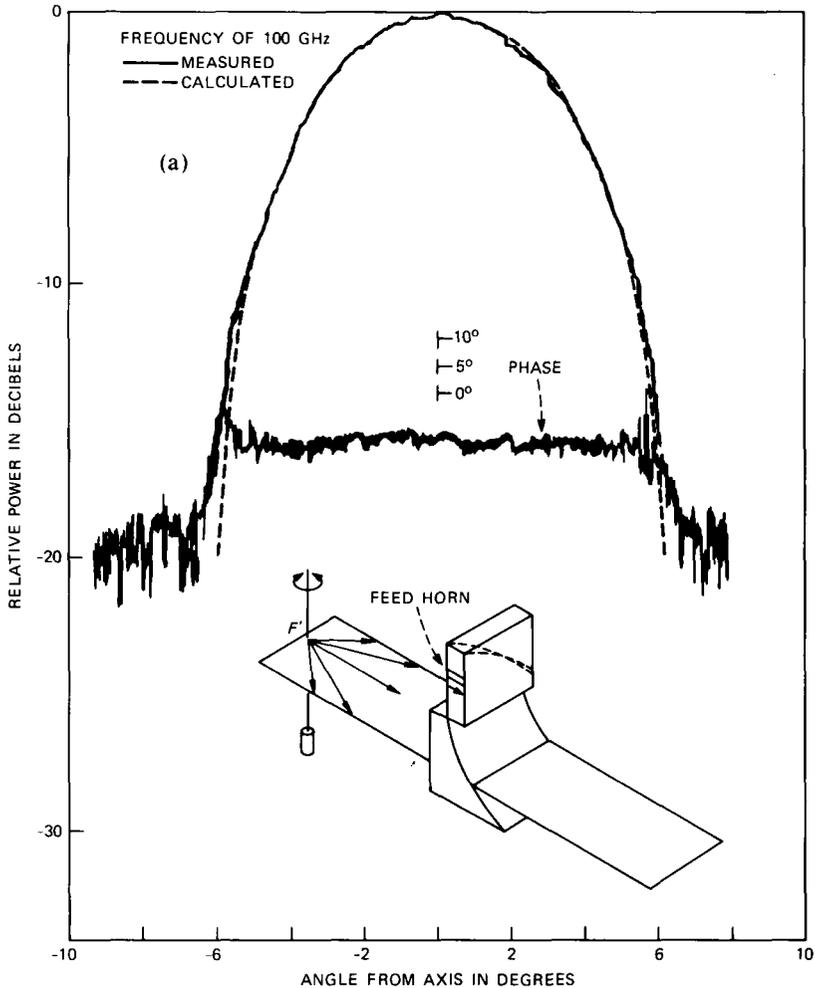
Fig. 5—(a) Measurements for an electric field orthogonal to the plates of the short launcher, and the theoretical amplitude distribution. The phase center lies behind the aperture. (Cont.)

8 degrees. However, over most of the aperture the phase is essentially constant.

Measurements made with the electric field orthogonal to the plates are shown in Figs. 5a and b. As shown here by the dashed curves, the agreement between the calculated values and the measured data is very good. From the phase measurements shown on these figures, one can see that the phase is essentially constant across the aperture. The two pairs of measured data shown by Figs. 4 and 5 are essentially identical.
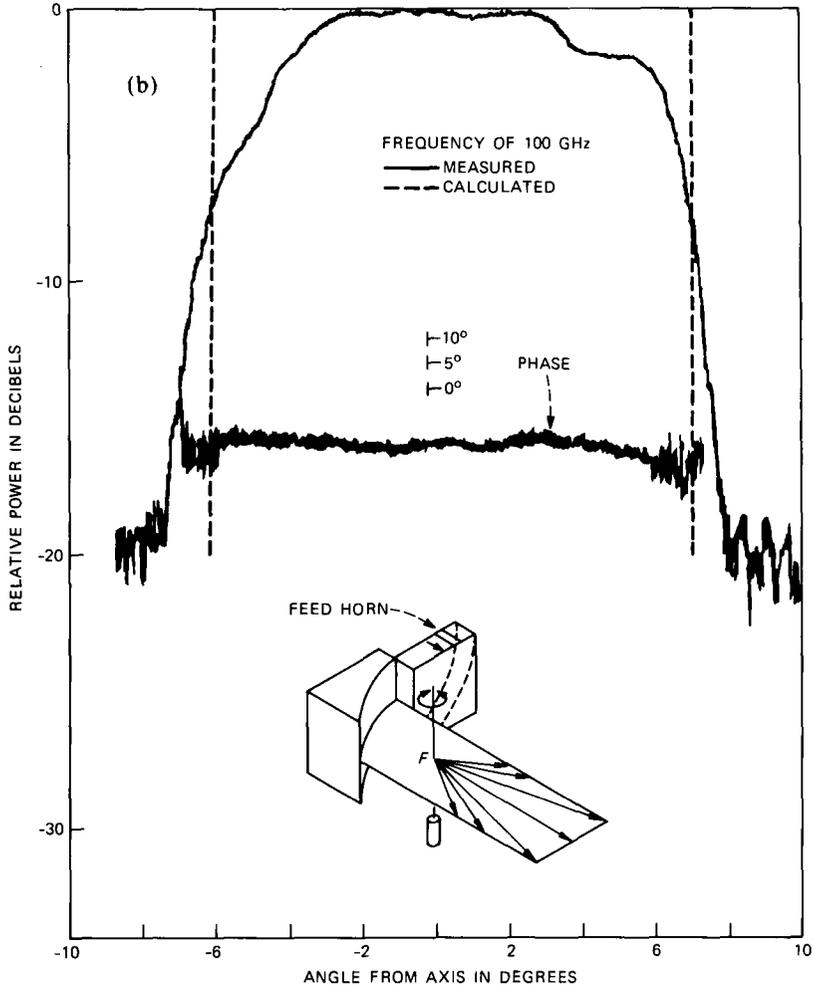
Fig. 5—(b) The electric field remains orthogonal to the plates, but the launcher is rotated 90 degrees. The phase center lies in front of the aperture.

The feed horn and mixer assembly were then transferred to the long astigmatic launcher shown at the left of Fig. 3. The amplitude and phase measurements obtained with the long launcher are shown in Figs. 6 and 7 by the solid curves. Again, the dashed curves are the theoretical calculations.

The data shown in Figs. 6a and b were obtained with the electric field parallel to the plates. As shown by the inserts on these figures, the launcher was rotated 90 degrees to obtain the second set of data. Here again, the measurements agree well with the calculated values. The phase deviations across the aperture are very small.
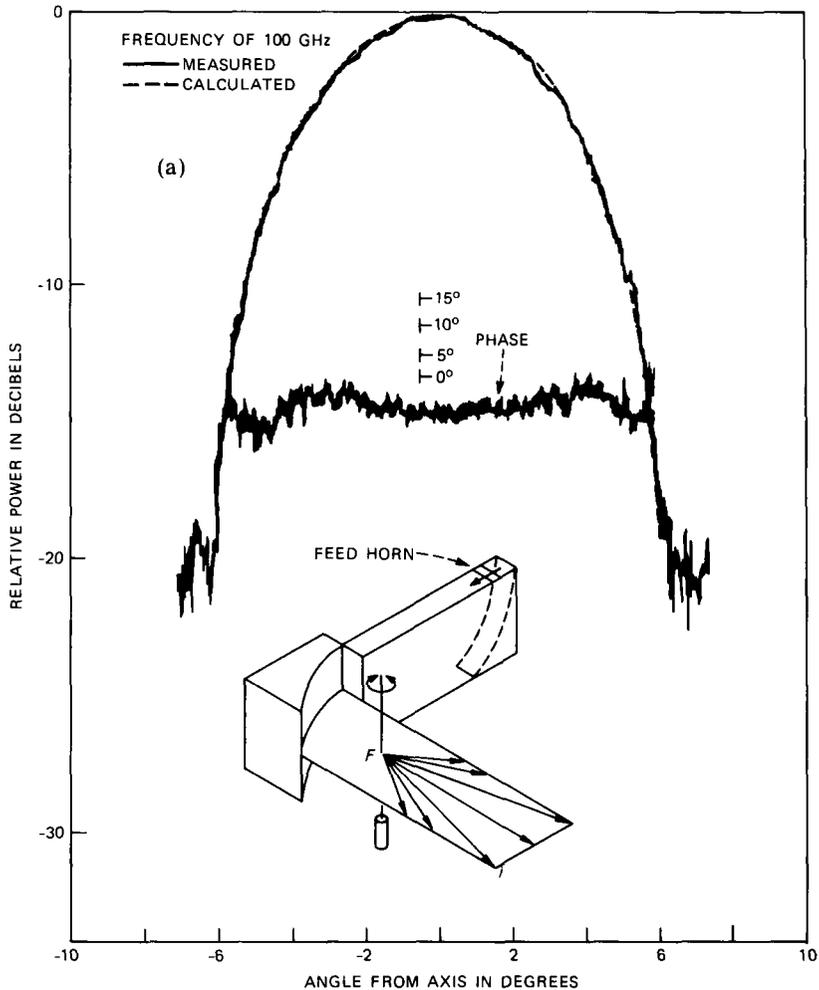
Fig. 6—(a) Measurements for an electric field parallel to the plates of the long launcher, and the theoretical amplitude distribution. The phase center lies in front of the aperture. (Cont.).

The data for the long launcher were completed with the measurements shown in Figs. 7a and b. For these data the electric field is orthogonal to the plates. Again, the agreement between amplitude measurements and theoretical calculations is very good and the phase variations across the aperture are small.

A comparison of the data presented in Figs. 4 through 7 for both the short and long launchers confirms the fact that the phase center separation for this arrangement of launcher can indeed be varied and still maintain constant beamwidth in the two principal planes. The
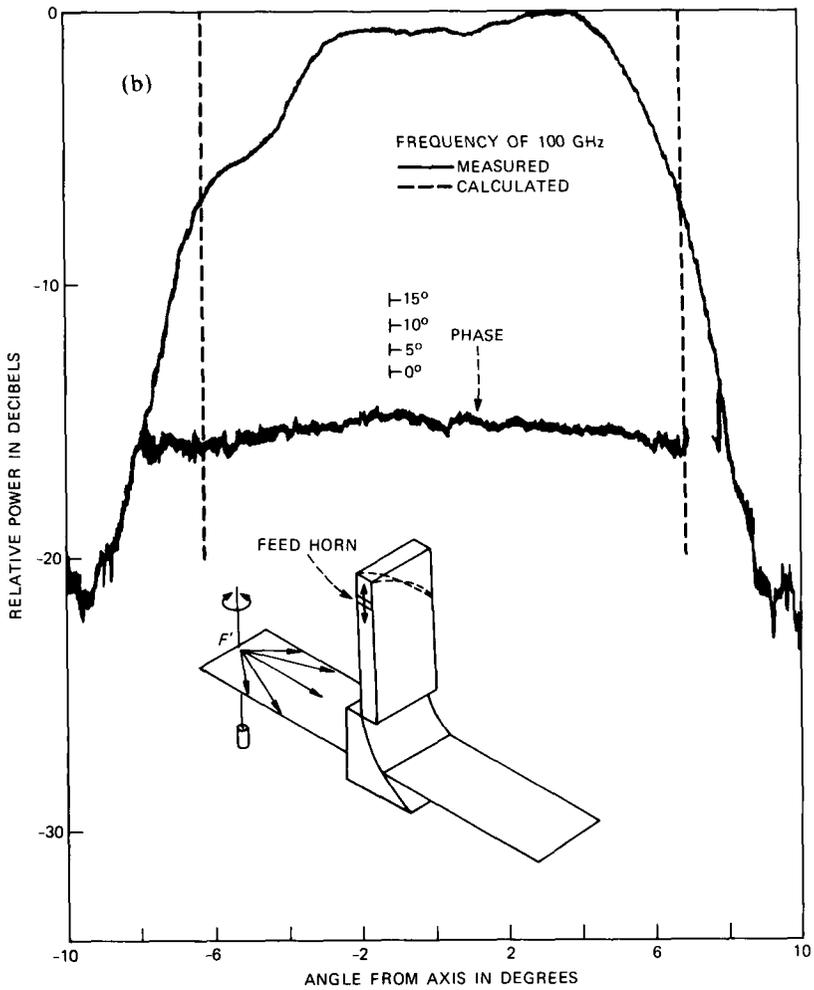
Fig. 6—(b) The electric field remains parallel to the plates, but the launcher is rotated 90 degrees. The phase center lies behind the aperture.
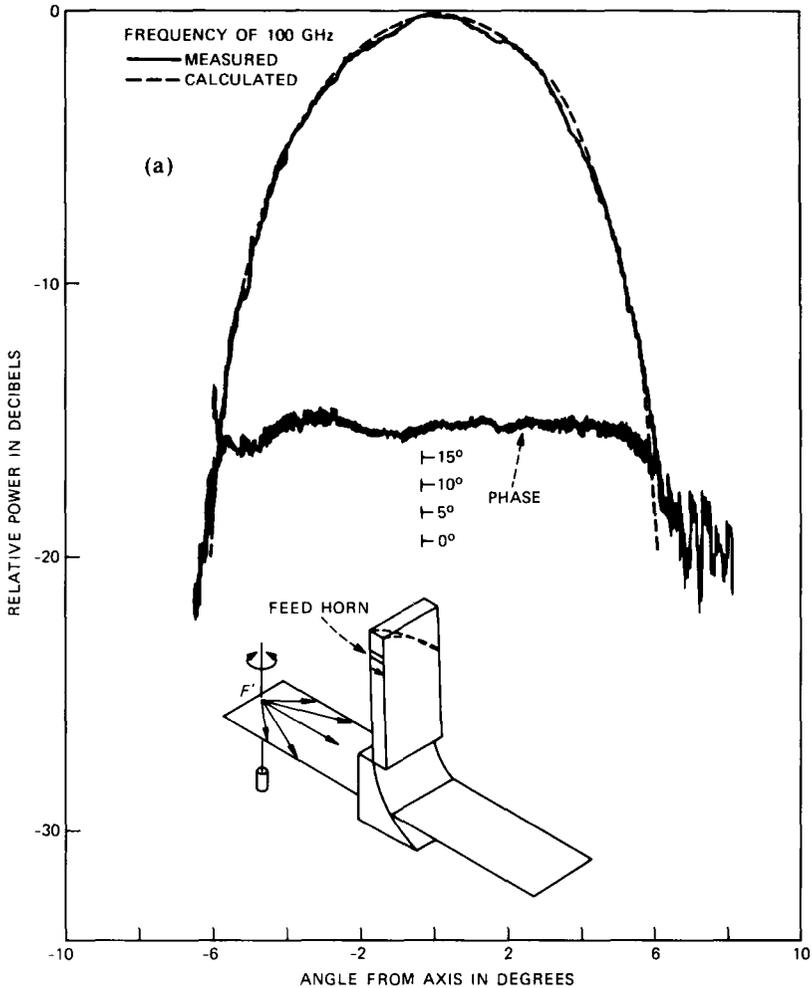
Fig. 7—(a) Measurements for an electric field orthogonal to the plates of the long launcher, and the theoretical amplitude distribution. The phase center lies behind the aperture. (Cont.)

frequency independence of these launchers was checked over a 20-percent band with no discernible change in beamwidth.

Using the methods described in Ref. 10, the measured phase center separation of the short launcher would correct the astigmatism associated with a feed displaced about 18 degrees from the focus, whereas the long launcher would correct the astigmatism associated with a feed displacement of about 29 degrees.
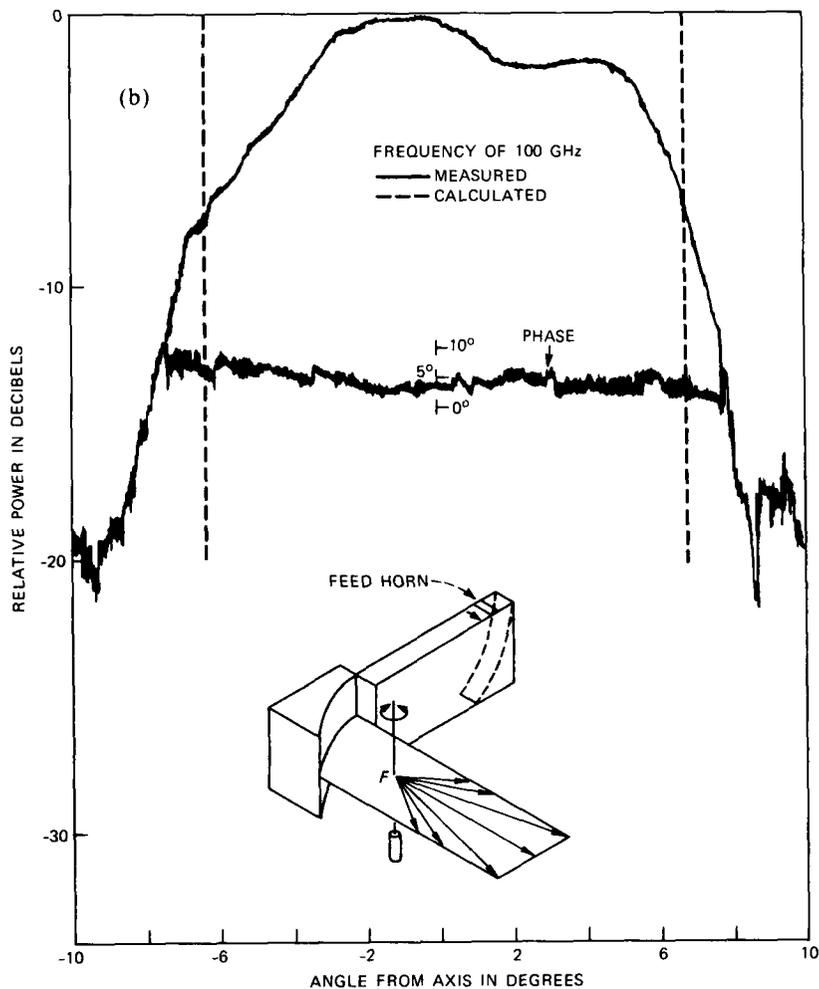
Fig. 7—(b) The electric field remains orthogonal to the plates, but the launcher is rotated 90 degrees. The phase center lies in front of the aperture.

IV. CONCLUSION

Based upon the data presented here, a multiple-beam earth station antenna equipped with launchers of the type described here (where only the separation of the phase centers needs to vary) can indeed communicate with all satellites along the geosynchronous arc.

V. ACKNOWLEDGMENTS

fabrication of the feed horn and launchers. The design discussions with C. Dragone are acknowledged.

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