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Horn-Reflector Antenna—Eliminating Weather-Cover Reflections

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This paper discusses measurements of flat and focused weather covers made on a scale-model, horn-reflector antenna (scaling factor 7.5). A focused weather cover eliminates the reflection lobes produced from the flat weather cover currently installed on the horn-reflector antenna. These antennas have extensive use in the Bell System microwave common-carrier radio relay network.

I. INTRODUCTION

In the early 1940s, the pyramidal horn-reflector antenna was invented[1] at Bell Laboratories, Holmdel, New Jersey. It is now in extensive use in the Bell System 4-, 6-, and 11-GHz transcontinental microwave, common-carrier, radio-relay network.[2] This antenna is a combination of a square electromagnetic horn and a reflector that is a section of a paraboloid of revolution. The apex of the square horn coincides with the focus of the paraboloid. The antenna is essentially a shielded, offset, parabolic antenna, so that very little of the energy incident on the reflector is reflected back into the feed to produce an impedance mismatch.

As used in system applications, the longitudinal axis of the antenna is normal to the earth's surface. This mounting position is shown in Fig. 1a. To prevent the entry of rain, snow, and other various foreign bodies into the antenna aperture and hence flowing down the waveguide transmission line, the aperture is covered by an essentially flat piece of glass fiber fabric (weather cover, Fig. 1a). The application of the weather cover was highly successful in excluding the elements. However, for microwave radio systems, the Bell System would like to have sidelobes down 40 to 50 dB or more. This has generally been obtained for far-out sidelobes except for those lobes associated with reflections from the weather cover. These weather-cover reflection

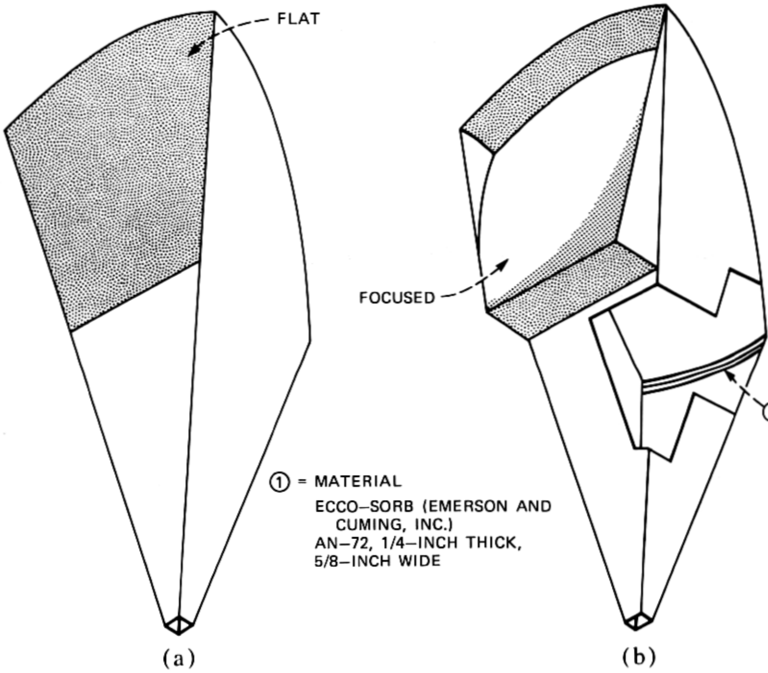

Fig. 1—Perspective views of horn-reflector antenna. (a) With flat weather cover. (b) With focused weather cover.

lobes occur as downward-looking lobes in the vertical plane of the antenna and reduce discrimination in that plane.

In the discussion that follows, it should be remembered that longitudinal polarization and longitudinal plane indicate that the electric field in the aperture and the plane of antenna rotation, respectively, are parallel to the pyramidal horn axis, whereas transverse polarization and transverse plane indicate that the electric field in the aperture and the plane of antenna rotation, respectively, are perpendicular to the horn axis.*

During a recent investigation for ways of reducing the near-in sidelobe levels of the horn-reflector antenna, using a scale model

* As used in the microwave radio relay system, 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 distributions for each polarization are different, and when the antenna is used as an earth station antenna for satellite communications, as a radiometer, or simply to obtain radiation patterns in the longitudinal plane, the antenna is mounted on its side, and the aperture field distributions for so-called vertical and horizontal are now interchanged. To avoid this ambiguity, longitudinal and transverse polarizations are used referred to the axis of the horn.

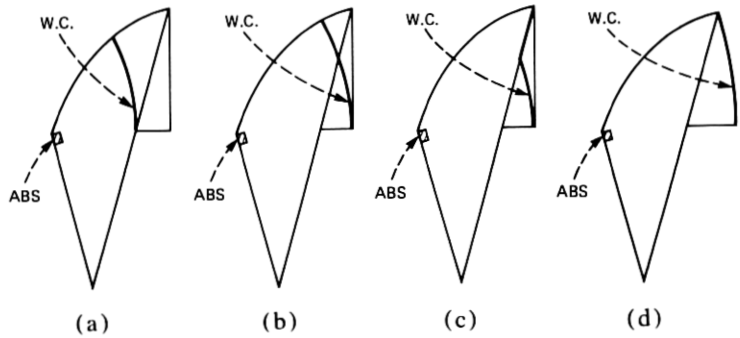

Fig. 2—Cross-sectional views of the horn-reflector antenna showing the four weather-cover configurations considered in this study.

antenna[3] (scaling factor of 7.5*), it was determined (by experiments) that a linear piece of microwave absorbing material of uniform width placed at the intersection between the paraboloidal reflector and the rear wall of the horn had little effect on the radiation characteristics of the antenna.

With the line of absorbing material inside the antenna aperture and the fact that a cylindrical paraboloid produces a line focus, one has the combination for eliminating reflections from the weather cover. That is, by using a weather cover shaped into the simple single curved surface of a cylindrical paraboloid, all reflections from this weather cover can be made to focus into the absorbing material on the back wall of the horn instead of scattering out into the radiation pattern, as now occurs with the flat weather cover. (See Fig. 1b.)

As shown by the cross-sectional views of Fig. 2, four positions for the cylindrical paraboloidal weather cover were initially considered. For simplicity, in the discussions that follow, the cylindrical paraboloidal weather cover is referred to as a focused weather cover. In the first cross-section (Fig. 2a), the vertex of the focused weather cover is at the aperture of the antenna. Here, all the weather cover material is within the antenna. Figure 2b shows the vertex of the focused weather cover at the edge of the sidewall blinders.[4] As seen in this figure, a small portion of the weather cover still remains inside the antenna. This small portion is folded out in Fig. 2c to become a flat section. In Fig. 2d, the vertex of the focused weather cover is positioned such that

* With the model horn-reflector antenna scaled to 7.5, measurements made at a frequency of 30 GHz will represent the performance of a full-size antenna measured at a frequency of 4 GHz.

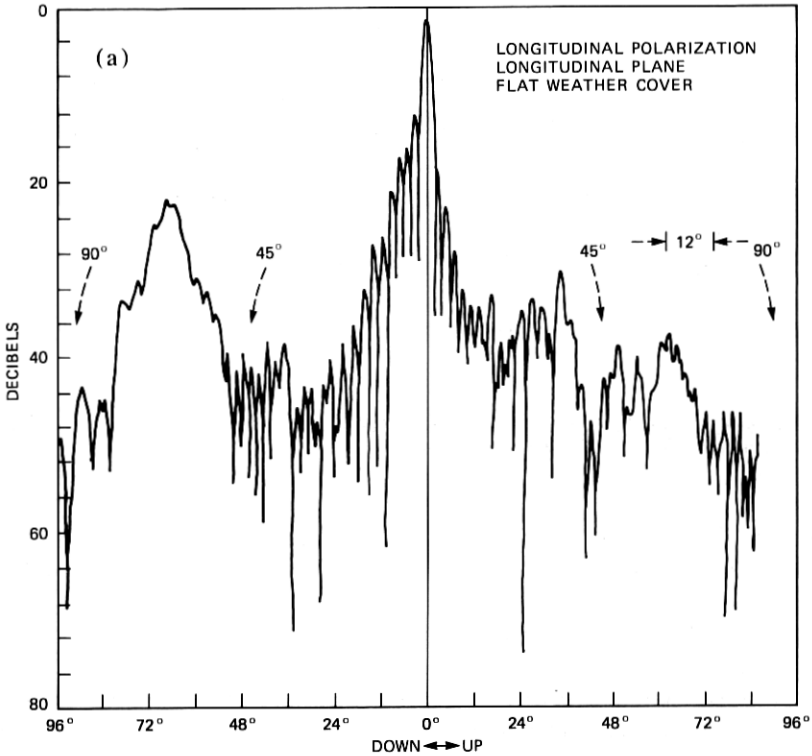

Fig. 3—Radiation characteristics of the scale model in the longitudinal plane for longitudinal polarization using (a) Flat weather cover. (b) Focused weather cover. (c) Comparison of the envelope of peaks from Figs. 3a and 3b.

the entire weather cover is outside the aperture. Obviously, this position increases the wind loading on the antenna by extending the side blinders. Since the blinder size would be increased, one must examine, by experiment, the antenna far-sidelobe structure to determine any undesirable changes in level.

II. DISCUSSION

The material used for the weather cover in these investigations is identical to that in the central portion of the full-size horn-reflector antenna, i.e., 40-mil glass fiber fabric.* Since the same 40-mil material is used for both the flat and focused weather covers on the scale-model

* Attempts to scale the 40-mil weather cover material (used on the full-sized antenna) to 5.3-mil were not successful. Therefore, the 40-mil thickness was used and produced a transmission loss of 1.6 dB.

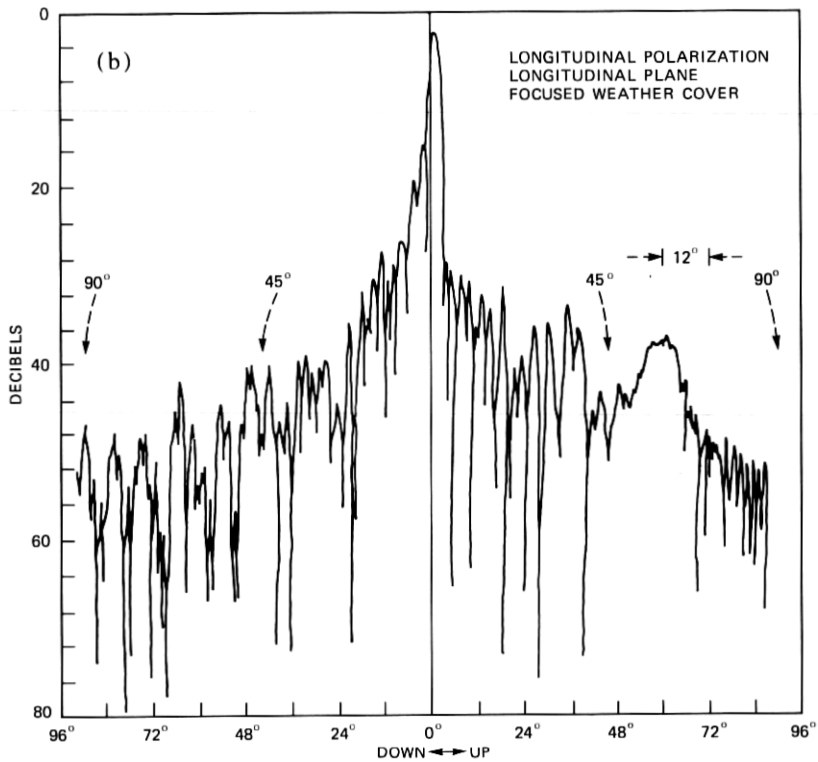

Fig. 3 (*continued*)

antenna, one can simply make an A-B type comparison to determine whether the reflection lobes produced by the flat cover are improved with the focused cover.

The first focused weather cover to be studied was totally within the antenna, as shown in Fig. 2a. Here, Plexiglas* (⅛-inch thick) forms were cut to the proper parabolic curvature and fastened inside the antenna on the sidewalls of the horn with nylon screws. The flat weather cover material was cut to fit inside the antenna and fastened to the two parabolic forms with nylon screws, thus producing the desired cylindrical paraboloid. Radiation characteristic measurements for this arrangement indicate the elimination of the weather cover reflection lobes. However, the presence of the dielectric material (plastic paraboloid sides and weather cover) totally within the antenna increased sidelobe levels, out to about 45 degrees from the main beam,

* Trademark Rohm & Haas Co.

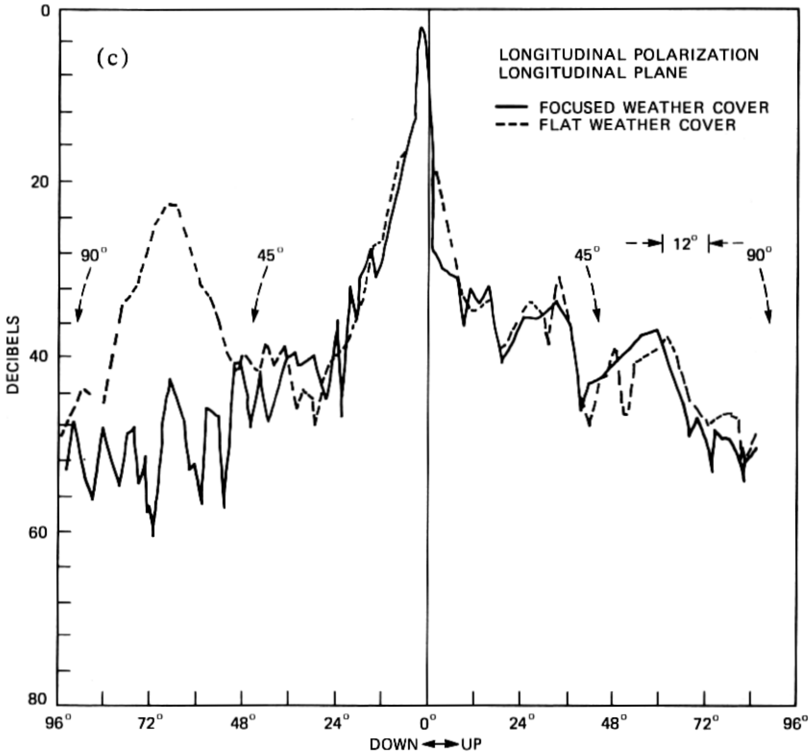

Fig. 3 (*continued*)

by an unacceptable amount. Hence, further studies with this particular configuration ceased, except to determine the minimum amount of microwave absorbing material* needed to eliminate the reflection lobes. This quantity of absorbing material, a strip ⅝-inch wide and ¼-inch thick, introduced a trivial gain loss of less than 0.2 dB.

The next configuration to be studied is shown in Figs. 1b and 2b, which are perspective and cross-sectional views, respectively. For this configuration, the radiation characteristics in the longitudinal plane for longitudinal polarization are shown in Fig. 3 for flat and focused weather covers. An examination of Fig. 3a shows the reflection lobes from the flat weather cover occurring in the vicinity of 65 degreees from the main beam, in the downward direction. These lobes, measured at a frequency of 30 GHz, are stronger by about 10 dB than those for the full-size antenna, measured at 4 GHz.† But recall that here one is

* ECCOSORB AN-72, a product of Emerson and Cuming, Inc.

† If the weather-cover material thickness were scaled, the amplitude of the reflection lobe for the model would be that for the full size antenna.

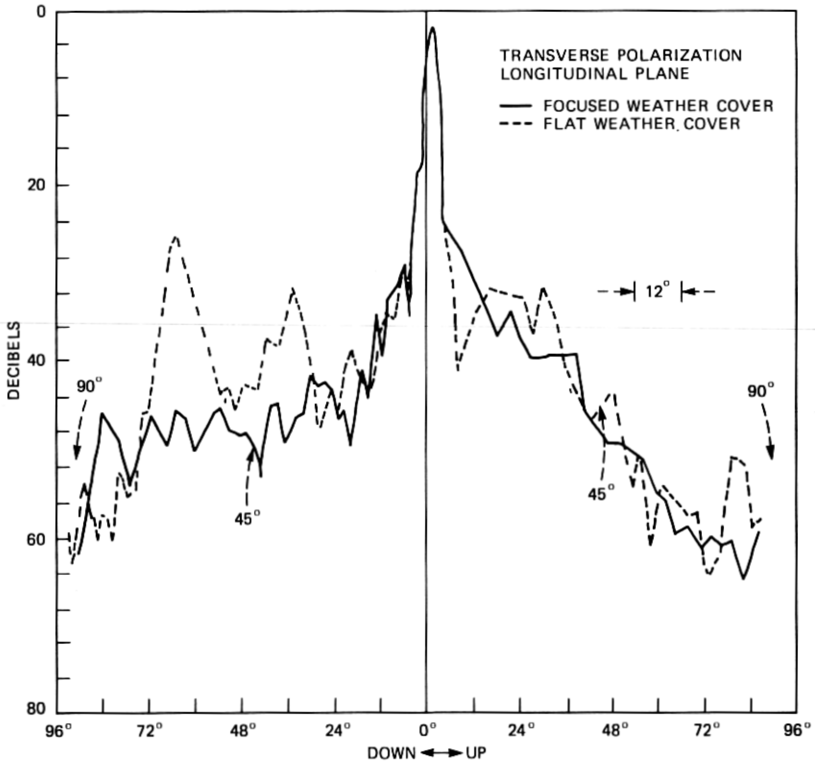

Fig. 4—Comparison of the envelope of peaks of the radiation characteristics of the scale model for both flat and focused weather covers in the longitudinal plane for transverse polarization.

simply comparing the results obtained from this material used both as a flat and then a focused weather cover. The results for the focused weather cover measured in the same plane and using the same polarization are shown in Fig. 3b. The absence of the reflection lobe is obvious. For ease of comparison between both the flat and focused weather covers, the envelope of the peaks of the radiation patterns are shown in Fig. 3c. From this comparison, the improvement obtained by using the focused weather cover becomes very clear.

Next, radiation characteristics were obtained using transverse polarization in the longitudinal plane. These are shown in Fig. 4. The characteristics for the flat weather cover are shown in Fig. 4 by the dashed line, and one again observes the presence of the reflection lobes in the vicinity of 65 degrees from the main beam in the downward direction. In addition, strong reflection lobes occur around 35 degrees in the same downward direction. The solid line of Fig. 4 also shows the

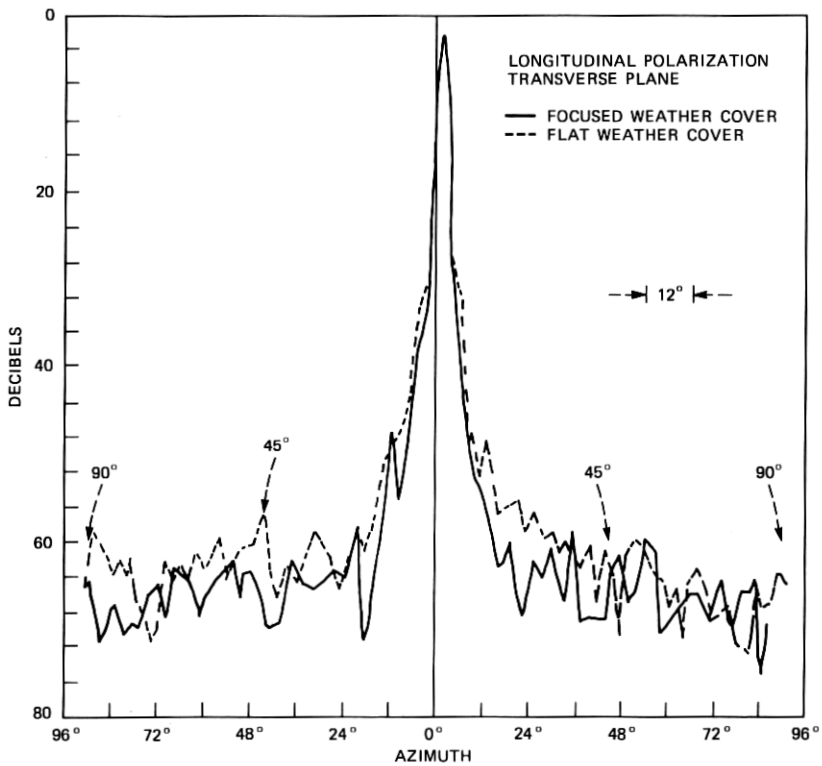

Fig. 5—Comparison of the envelope of peaks of the radiation characteristics of the scale model for both flat and focused weather covers in the transverse plane for longitudinal polarization.

radiation characteristics for the focused weather cover in this same plane, using the same polarization. Again, the absence of reflection lobes is made obvious by comparing the envelope of peaks for both weather covers as seen in Fig. 4.

Other than producing reflection lobes in the longitudinal plane, the use of the flat weather cover on the full size antenna had little effect on the far sidelobes in the transverse plane. Therefore, one would not expect the radiation characteristics made in the transverse plane of the scale model to deteriorate when using either a flat or a focused weather cover. However, to preclude any surprises, the antenna was re-positioned and radiation characteristics in the transverse plane were obtained. Using longitudinal polarization, Figure 5 shows by the dashed line the results obtained for the flat weather cover; the solid line, that obtained for the focused weather cover. From Fig. 5, one observes that the focused weather cover provides a slight overall improvement in the sidelobe levels.

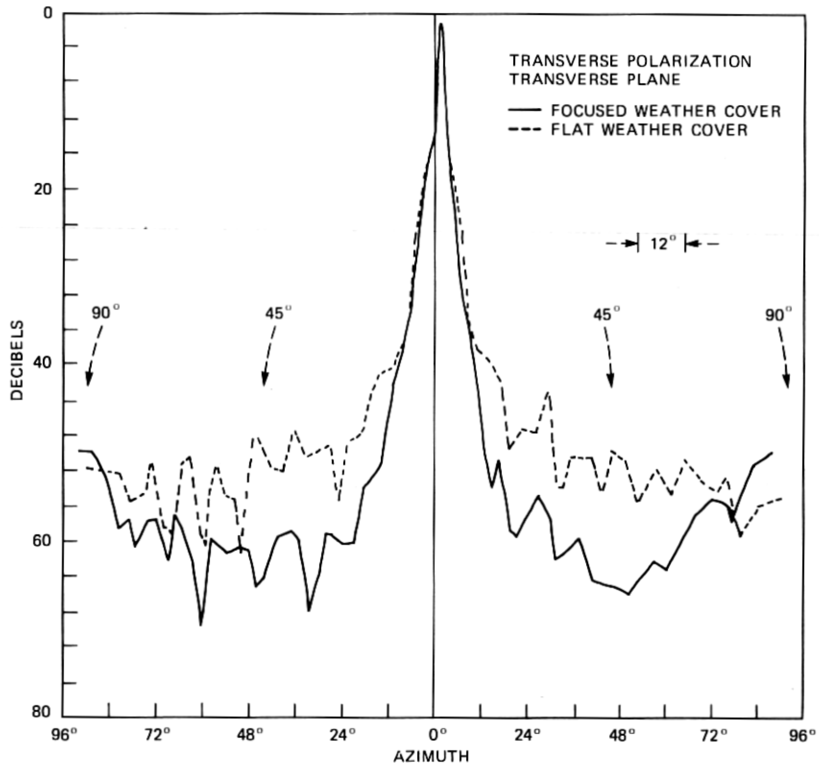

Fig. 6—Comparison of the envelope of peaks of the radiation characteristics of the scale model for both flat and focused weather covers in the transverse plane for transverse polarization.

The radiation characteristics using transverse polarization in the transverse plane are shown in Fig. 6. The characteristics for the flat weather cover are shown in Fig. 6, again by the dashed line and the focused weather cover by the solid line. At first glance, comparison of the two curves of Fig. 6 is rather startling. The flat weather cover produced an increase in the far sidelobe levels of the order 10 dB. This increase is easily explained when we recall that transverse polarization incident obliquely onto a flat surface produces the greatest amount of reflections from the surface.

As we discussed earlier, the weather cover material thickness was not scaled. Therefore, the amount of dielectric material has increased, and the results have been expected. Of greater importance, however, with the focused weather cover even these reflections are focused into the microwave absorber and are not radiated out into the environment to reduce the discrimination at the antenna.

In view of the results obtained with the weather cover configured as shown by Fig. 2b, it was decided that any additional improvements that might be obtained by using the configuration of Fig. 2d would in all likelihood be offset by the increase in wind loading on the antenna. Hence, no study was made for that configuration.

To determine whether or not one could replace that small section of the focused weather cover remaining within the antenna by a flat section, as shown in Fig. 2c, a new weather cover was made. Measurements obtained from this cover indicated that the flat section was sufficiently large to produce reflection lobes. These reflection lobes were lower in amplitude than those from the completely flat cover, but were still undesirable.

III. CONCLUSIONS

From the data obtained for both flat and focused weather covers, on a scale-model, horn-reflector antenna, it is apparent that the use of a focused weather cover eliminates the reflection lobes introduced by the presently used flat weather cover.

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