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A 30-GHz Scale-Model, Pyramidal, Horn-Reflector Antenna

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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 the 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.

Radio interference from adjacent paths limits the number of converging routes of a common carrier microwave radio system, and in recent years, demands have been made to improve the sidelobe performance of the pyramidal horn-reflector antenna. In response, blinders (metallic extensions to the sidewalls of the horn) have been developed[3] which provide a degree of far sidelobe reduction, i.e., sidelobes beyond 35 degrees from the axis of the main beam.

To continue the investigation for ways of reducing the sidelobe levels of this type antenna, a scale model was built. The model has a numerically-machined, precision reflector, and the scaling factor is 7.5, which means that measurements made at a frequency of 30 GHz will represent the performance of a full-size antenna measured at a frequency of 4 GHz. This paper presents and discusses the measurements made on the scaled model at 30 GHz. Comparisons are made with data obtained (at a frequency of 4 GHz) by others on full-sized antennas.[4]

In the discussion that follows, it should be remembered (from Ref. 4) 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 polarization and transverse plane indicate that the electric field in the aperture and plane of antenna rotation are perpendicular to the horn axis.*

II. DISCUSSION

A study of the historical data on the radiation characteristics of the horn-reflector antenna indicates that, since its inception in the 1940s, disagreements between measured data and theoretical values have existed. For example, in the transverse plane with longitudinal polarization, agreement between measured data and theoretical value exists only out to the first sidelobe. With transverse polarization, good agreement extends out to the fourth sidelobe.

Since the aperture of the horn-reflector antenna is illuminated with a dominant waveguide mode, the theoretically obtainable off-axis radiation levels[4] in both the transverse planes for transverse polarization are considerably higher than those obtained for longitudinal polarization in the transverse plane and transverse polarization in the longitudinal plane. For transverse polarization in the transverse plane, one has essentially the equivalent of an aperture with constant illumination across it. Hence, with the antenna mounted on its normal vertical position (i.e., the axis of the horn normal to the earth), the amplitude distributions across the aperture of the antenna are as follows: For longitudinal polarization, the electric field in the longitudinal direction is uniformly distributed across the aperture, and in the transverse direction the field is tapered to a low value at the edges; with transverse polarization, the electric field is uniform across the aperture in the transverse direction and is tapered to a low value at the edges in the longitudinal direction.

Of the many various possible contributors to high sidelobes, the two strongest contenders are: (*i*) higher-order modes being generated in the existing feedhorn, which was designed to accommodate the oversized circular waveguide† used in the system, and (*ii*) surface toler-

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

† Higher-order modes can be excited in oversized waveguide; hence to avoid this condition when obtaining radiation patterns, one uses a transition from feedhorn to waveguide transducer.

ances of the parabolic reflector. To examine the first contender, two feedhorns were made, one a scaled version of the existing system feedhorn and the second a new design. This new feedhorn terminates the taper of the horn into the walls of rectangular K-band waveguide, thus ensuring the presence of only the dominant mode. In a sense, this is achieved by opening the parallel walls of the waveguide at a constant angle and extending them until they form the square aperture needed to mate with the rest of the antenna. This, of course, requires that the walls normal to the electric field open first. Carefully machined mandrels were made of both feeds over which copper was electroformed to produce the final models. An examination of the radiation characteristics of the scale-model antenna obtained from using both feeds indicated that the characteristics were essentially identical. Hence, the characteristics contained in the figures to be discussed were obtained using the scale version of the system feedhorn. In the figures, the theoretical values[4] are shown by a dashed line, and the measured data of the full-sized horn-reflector antenna by a broken line. The measured data for the scale-model are shown by the solid line.

For the transverse plane, Figs. 1 and 2 show the measured characteristics for longitudinal and transverse polarizations, respectively. As indicated here, the agreement between scale-model measurements and theory is remarkably good. From these two figures, one can see the improvement in sidelobe level by comparing the results with the broken line curve which indicates the measured response for the full-sized antenna. For example, in Fig. 1 the improvement is about 8 dB and increasing in the region of the fourth sidelobe and beyond, i.e., beyond 8 degrees from the on-axis position. In Fig. 2, a similar comparison shows a 4-dB improvement beginning around 10 degrees.

In the longitudinal plane, the measurements for longitudinal and transverse polarizations were obtained for the scale-mode antenna but are not included here since these patterns, like those of the full-size antenna, are in very good agreement with theory. Similarly, the cross-polarization patterns obtained on the scale model were like those of the full-sized antenna and, since both agree well with theory, are also not included here.

It is evident from these figures that the scale-model measurements are in remarkable agreement with theory. The presumption that the high sidelobe levels of the full-size antenna were due in part to high-order modes being generated by the feedhorn is not valid. This is emphatically demonstrated by the agreement with theory which does not accommodate the presence of higher-order modes. The remaining strong contender for these high sidelobe levels is the accuracy of the full-size parabolic reflector surface. An examination of the full-size structure shows the surface to consist of two half skins fastened to parabolic back ribs by means of 262 (No. 14, Type B) sheet metal

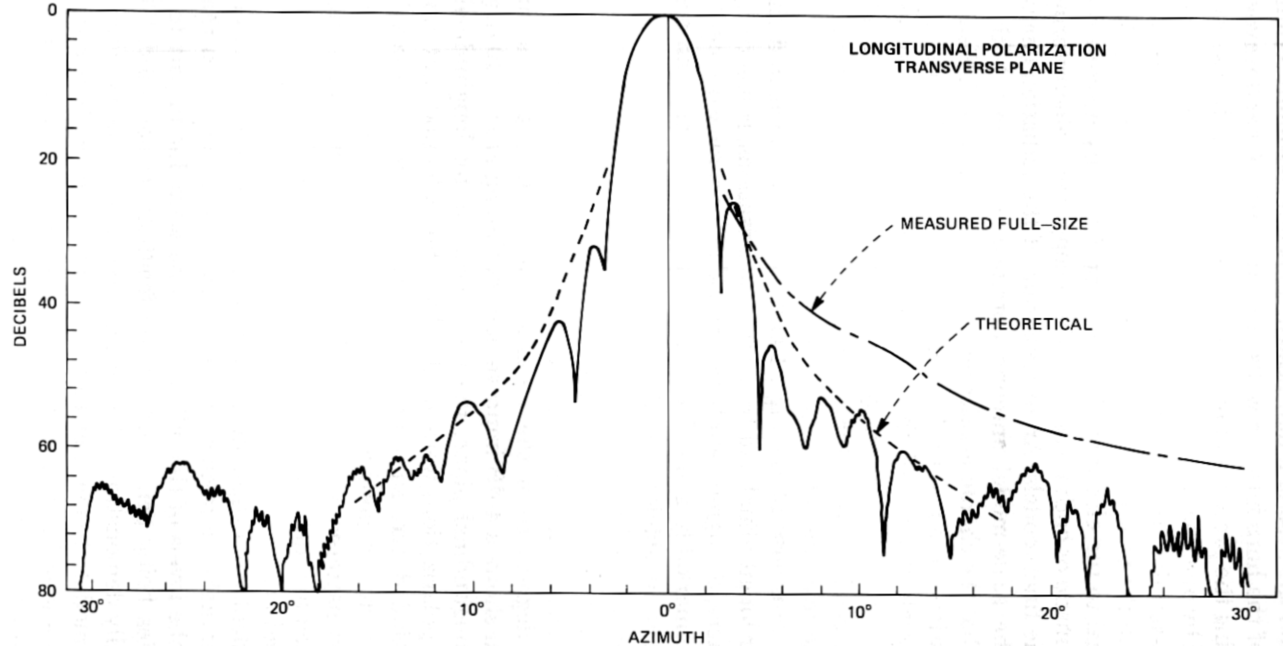

Fig. 1—Radiation pattern in the transverse plane for longitudinal polarization. The dashed line is theoretical, and the broken line represents measurements obtained on the full-size antenna.

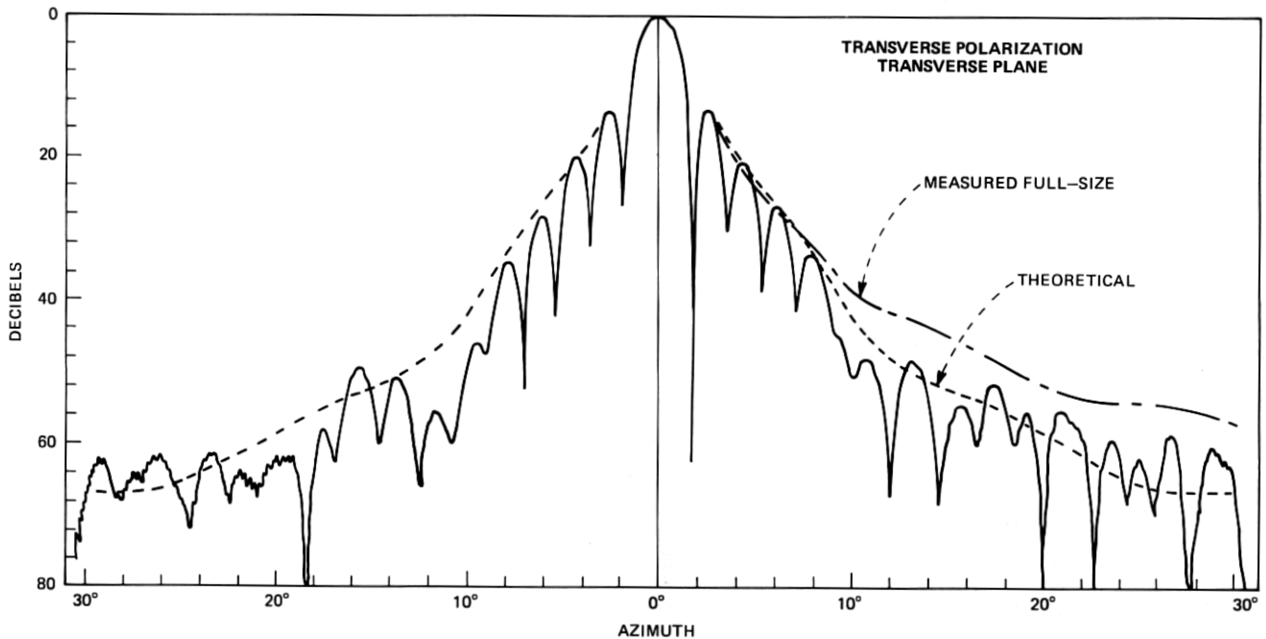

Fig. 2—Radiation pattern in the transverse plane for transverse polarization. The dashed line is theoretical, and the broken line represents measurements obtained on the full-size antenna.

screws and 120 (3/16-inch diameter Universal Head) rivets. Since these fasteners are distributed in a regular fashion, one could envision them as forming an array of scatterers which produce a low level, very broad beam and enhance the far sidelobe region. An investigation of this remaining aspect is not considered in the immediate future since it would entail a reproduction of these discontinuities on the precise surface of the scale-mode. Also, there are many interesting experiments waiting to be done on this scale model which can now serve as a test bed.

III. CONCLUSIONS

Data obtained on a scale-model version of the full-sized horn-reflector (used in the 4-, 6-, and 11-GHz microwave common-carrier, radio relay system) have been presented. From the data, one once again observes how well scale models depict the full-size world. But of most importance was the achievement of agreement between measurement and theory which produced the key finding that past disagreement between theoretical results and experimental data for a full-size antenna in the sidelobe region could not be due primarily to higher order modes being excited in the feedhorn, but could be attributed to surface imperfections of the reflector.

IV. ACKNOWLEDGMENTS

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