THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 60, No. 6, July–August 1981
Printed in U.S.A.

Three-Dimensional Radiation Characteristics of a Pyramidal Horn-Reflector Antenna

By P. E. BUTZIEN

(Manuscript received January 29, 1981)

A widely used Bell System pyramidal horn-reflector antenna, used in terrestrial radio relay systems, has been characterized over all space. We give the dB contours for principal (as opposed to cross-polarized) measured radiation patterns and compare them to contours of calculated patterns for this antenna at 4 GHz. In addition, we present the contours for 6-GHz measured principal patterns, describe the measurement method, and discuss the causes of departure of the measured from the calculated patterns.

I. INTRODUCTION

Since its conception in the late forties[1] and its implementation in the fifties,[2,3] thousands of pyramidal horn-reflector antennas have been installed in terrestrial radio systems. The antenna is a broadband device currently used in the 2-, 4-, 6-, and 11-GHz common-carrier bands. Antenna dimensions are given in Fig. 1, along with coordinates as used below. Discussion of its performance will be limited in this paper to the 4- and 6-GHz bands which constitute the major usage.

Although the performance of this antenna is well known in the xz and in the yz planes (see Fig. 1), its exact performance in directions other than these principal planes was unknown until the measurements reported here were made. The three-dimensional responses are of interest in any case where an interfering signal impinges upon the antenna outside of these planes, e.g., direct interference from other terrestrial stations or satellites, or reflections from buildings or the ground.[4] Calculated three-dimensional responses based on aperture fields have been reported for small angles from the main beam.[5] Here, we also include calculated three-dimensional responses for the 4-GHz band out to angles of 30° from the main beam.

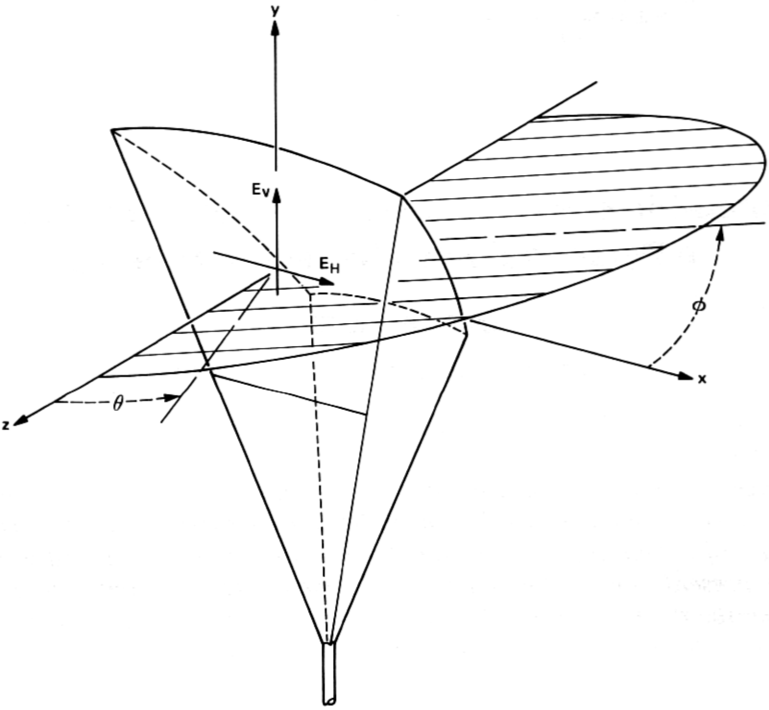

Fig. 1—Pyramidal horn-reflector antenna with coordinate system. Aperture dimensions are: height in center of aperture 2.7 m, width in center of aperture 2.4 m. Apex half-angle is 14°31′.

II. MEASUREMENT SYSTEM

A computer-controlled measurement system was designed by the author to deal with the extensive data involved in these measurements. The signal level was measured accurately to 60 dB below the main beam, using a pulse technique (using pulses of less than 50-ns effective length) to exclude reflections from objects adjacent to the antenna range. Linear polarizations depicted by E_V and E_H in Fig. 1 were recorded as principal patterns simultaneously with their respective cross-polarized components (cross-polarized patterns), using two receivers covering a range of 360° in θ in each of 91 cuts defined by 1° intervals in ϕ. Symmetry of the antenna about the yz plane obviates the necessity of changing ϕ by more than 90°. In all cuts, the antenna range source was copolarized with either E_V or E_H, as the case may be, when θ was zero. This measurement method has the distinct advantage of each cut going through the main beam so that the effects of drifting signal levels or other anomalies can be eliminated.

III. SPATIAL CONTOURS

We give the measured and calculated three-dimensional responses of the pyramidal horn-reflector antenna in the form of contour maps, using 10-dB contour intervals with the exception of 3 dB near bore-

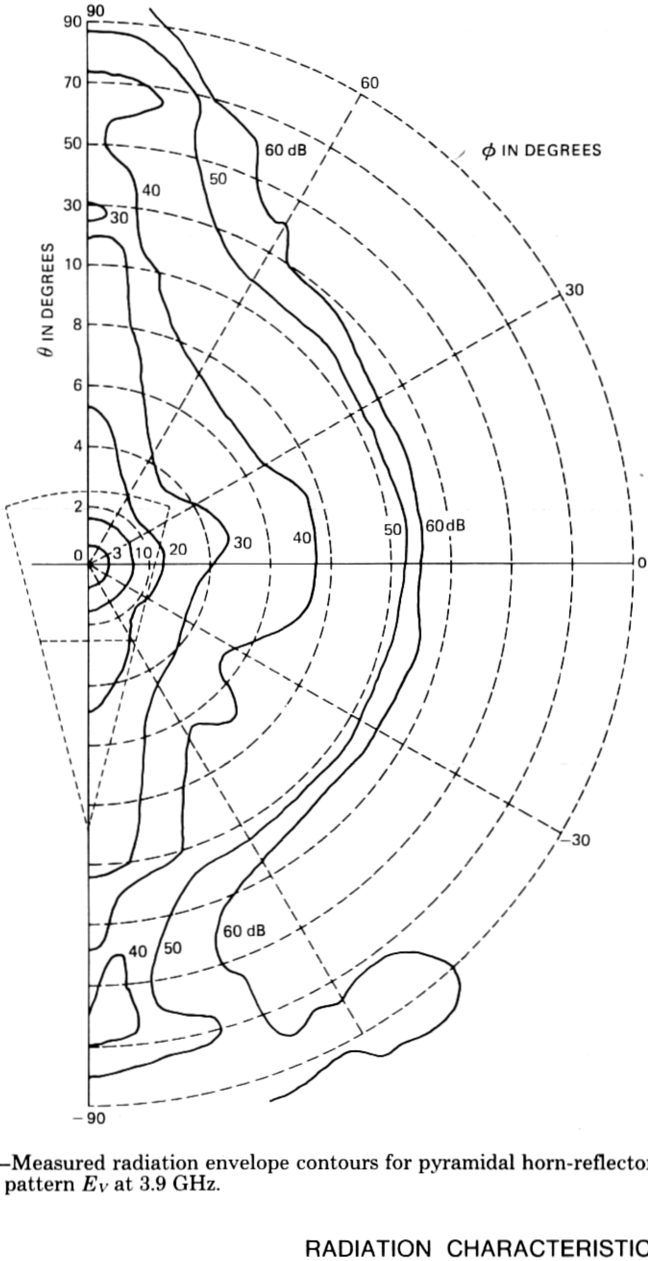

Fig. 2—Measured radiation envelope contours for pyramidal horn-reflector antenna. Principal pattern E_V at 3.9 GHz.

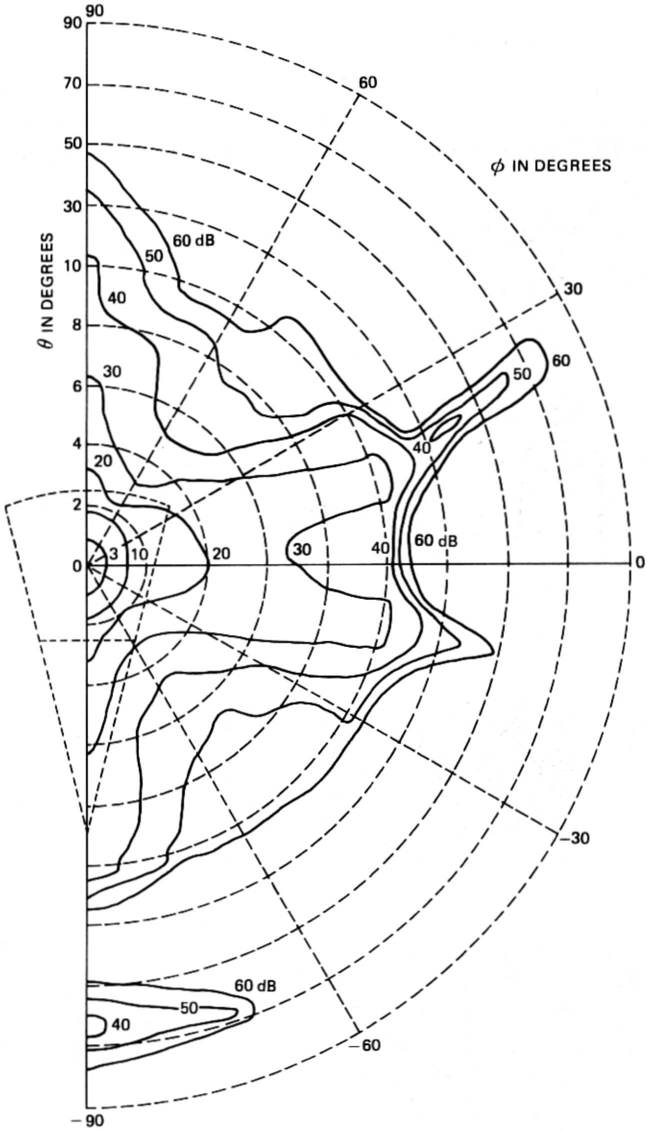

Fig. 3—Measured radiation envelope contours for pyramidal horn-reflector antenna. Principal pattern E_H at 3.9 GHz.

sight. Isometric plots of the measured data have been published for the 4-GHz band.[4] The 6-GHz three-dimensional patterns are quite similar but with narrower lobes. In Figs. 2 through 7, we show the contour maps for the principal patterns at 4 and 6 GHz. Notice that a scale change is implemented at 10° in θ to give more detail near boresight. Data for the rear hemisphere of the antenna is not shown since only the 4-GHz vertical polarization has any contours below 60 dB in that space. Both the top ($\phi = 90°$) and the bottom ($\phi = -90°$) exhibit levels between 50 and 60 dB for a small angular region behind the antenna at 4 GHz (vertical polarization) only. Figures 2 and 3 depict the radiation contours of measured performance in the 4-GHz

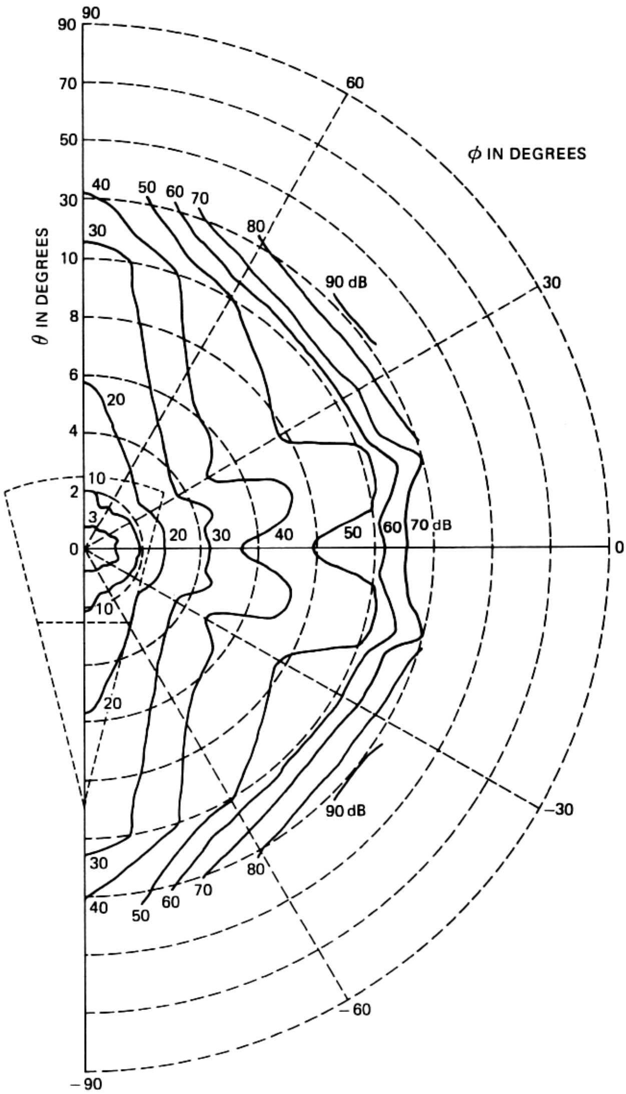

Fig. 4—Calculated radiation envelope contours for pyramidal horn-reflector antenna. Principal pattern E_V at 3.9 GHz.

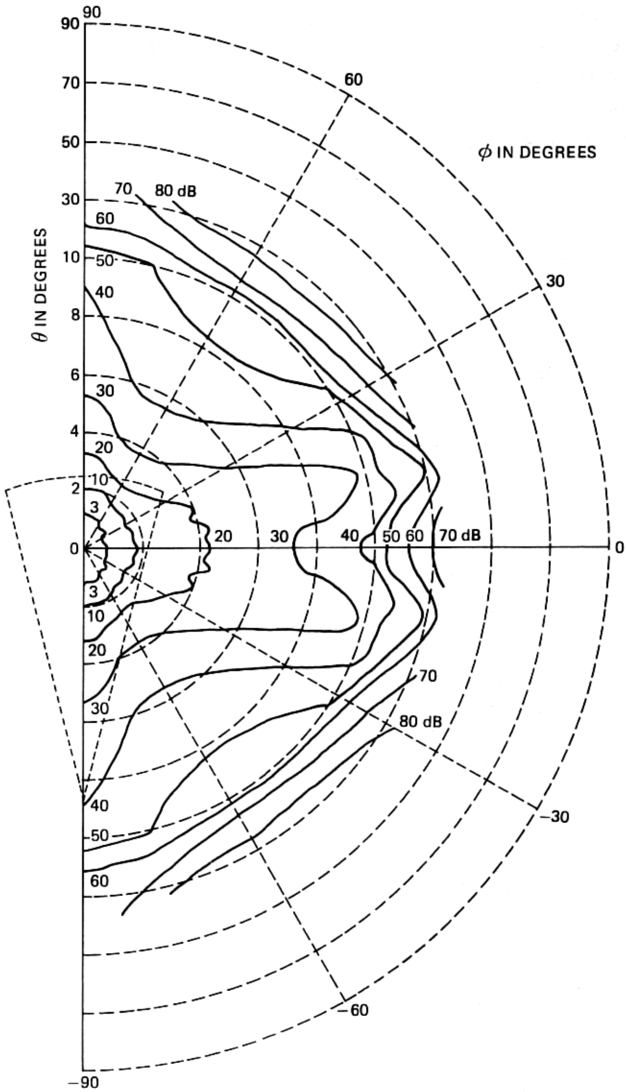

Fig. 5—Calculated radiation envelope contours for pyramidal horn-reflector antenna. Principal pattern E_H at 3.9 GHz.

band. These contours represent the envelope of the rapidly oscillating sidelobe structure where the envelope is always greater than or equal to the actual sidelobe levels. Envelopes are formed by going through the sidelobe peaks with smoothed interpolation. Thus, some very low-level lobes may be masked by larger lobes on each side. The contours may be thought of as giving the worst case response of the antenna at any three-dimensional point. Since the envelope changes vary slowly with frequency, only one measurement frequency was chosen in the middle of each band.

Figure 2 shows the measured principal pattern E_V. The cross-polarized pattern is not given, but may be found qualitatively in Ref. 4.

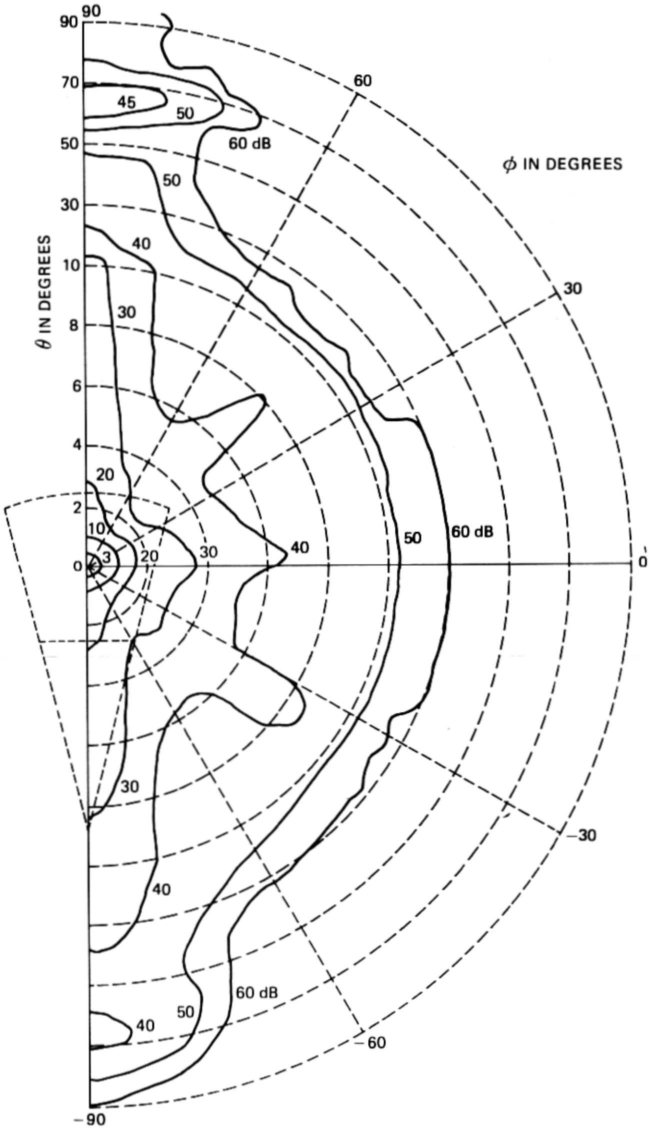

Fig. 6—Measured radiation envelope contours for pyramidal horn-reflector antenna. Principal pattern E_V at 6.175 GHz.

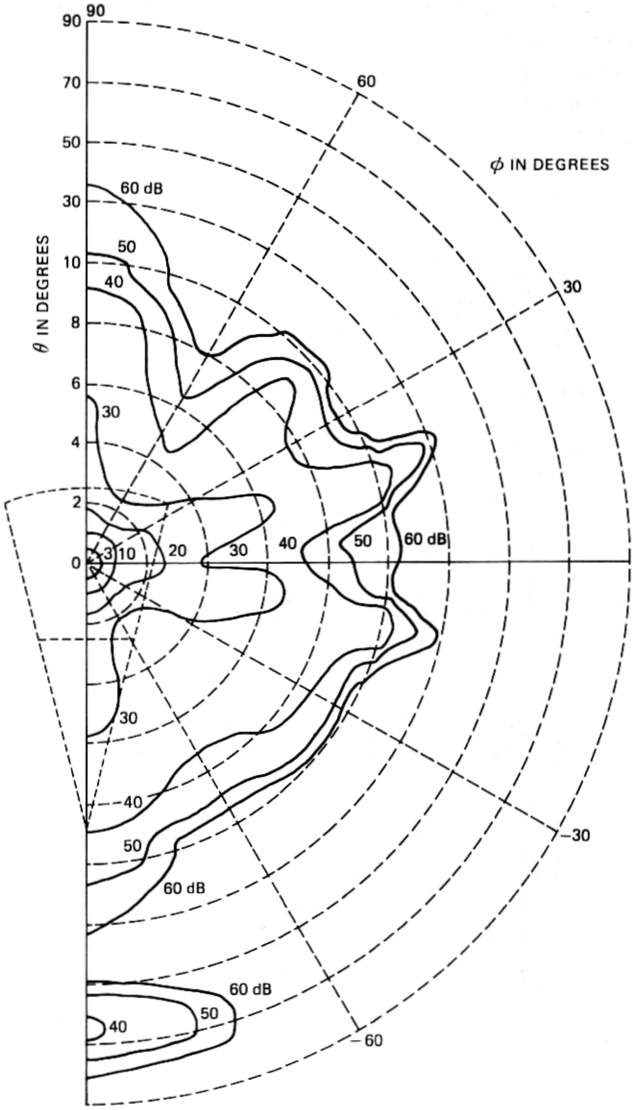

Fig. 7—Measured radiation envelope contours for pyramidal horn-reflector antenna. Principal pattern E_H at 6.175 GHz.

Figure 4 is the calculated response of the same antenna, with the same polarization used in Fig. 2, again, depicting the envelope of the response. The calculation is based on the electric-field aperture distribution resulting from the dominant mode launched by the antenna feed. Responses measured and calculated near the main lobe (θ near zero) and near the horizontal plane (ϕ near zero) are in quite good agreement. Notice, however, that in the vertical plane (ϕ near $\pm 90°$) broad lobes of approximately 40 dB level at their peak exist in both the upper and the lower regions of the measured, but not the calculated, data. The upper lobe, around $\theta = 70°$, is caused by spillover from the pyramidal feed and the lower lobe is caused by reflections from the flat weather cover. The "spillover lobe" is especially strong for vertical polarization, but the "weather cover lobe" is almost independent of polarization. A bottom edge blinder consisting of a flat (1.784 × 1.626 m) aluminum plate attached to the bottom rim of the aperture is now available to eliminate the weather cover lobe. The principal response for the horizontal polarization is shown as measured in Fig. 3 and as calculated in Fig. 5. The agreement is, again, good except for the spillover region and the weather cover lobe. The pronounced ridges near ϕ angles of $\pm 15°$ are caused by aperture shape effects (Ref. 5).

Measured responses in the 6-GHz band are given in Figs. 6 and 7. The contours in general tend to be closer to the main beam and the main beam is smaller, as would be expected for the larger gain of the antenna at this higher frequency. Again, the spillover and weather cover effects are evident.

IV. SUMMARY

We have given contours of the measured three-dimensional principal responses of the Bell System pyramidal horn-reflector antenna in the two major usage bands of 4 and 6 GHz, along with contours of the calculated response at 4 GHz. These contours are useful in determining the magnitude of interfering signals at any direction.

V. ACKNOWLEDGMENTS

It is with pleasure that I acknowledge contributions of C. P. Bates, E. R. Fladager, A. J. Giger, M. J. Pagones, J. R. Richard, C. A. Siller, Jr., and H. C. Wang in this effort.

REFERENCES

1. H. T. Friis, "Microwave Repeater Research," B.S.T.J., *27,* No. 2 (April 1948), pp. 183–246.
2. A. T. Corbin and A. S. May, "Broadband Horn Reflector Antenna," Bell Labs Record, *33,* No. 11 (November 1955), pp. 401–4.
3. R. W. Friis and A. S. May, "A New Broad-Band Microwave Antenna System," AIEE Trans., Part I, *77* (March 1958), pp. 97–100.
4. P. E. Butzien, "Radio System Interference from Geostationary Satellites," IEEE Trans. Commun., *COM-29,* No. 1 (January 1981), pp. 33–40.
5. C. A. Siller, Jr., "The Influence of Aperture Shape on the Radiation Patterns of Horn-Reflector Antennas," IEEE Trans. Ant. Prop., *AP-27,* No. 3 (May 1979), pp. 435–8.