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SCANNING PROPERTIES OF A 7-METER OFFSET CASSEGRAINIAN ANTENNA

T. S. Chu and R. W. England
Bell Laboratories
Crawford Hill Laboratory
Holmdel, N. J. 07733

Multiple-beam antennas can greatly increase the capacity of a satellite communication system. This prospect motivated considerable exploratory studies in this subject during the past decade. Large lenses were found to be either very heavy or narrow in bandwidth. The symmetrical reflector configuration encounters intolerable aperture blocking due to a large number of feeds or the subreflector. The offset front-fed reflector is often handicapped by excessive coma phase aberration due to the relatively small effective f/D ratio. These considerations led to an offset cassegrain with oversized subreflector[1] as the most promising multiple-beam antenna for both satellite and earth station. This paper will describe the measurements of off-axis beams of a recently constructed 7-meter offset cassegrainian antenna[2] and discuss their comparison with previous calculated[3] and measured data[4,5].

The Crawford Hill 7-meter antenna as sketched in Fig. 1 was built for propagation measurements with the COMSTAR beacons at 19 and 28.5 GHz, and for radio astronomy at frequencies from 70 to 300 GHz. The main reflector has a focal length of 6.57m. The subreflector is a 1.2m by 1.8m oval portion of a hyperboloid and gives a magnification ratio of six. Measured low side-lobe level ($\leq$ -40 dB) at one degree off the main beam and measured low cross polarization ($\leq$ -40 dB) throughout the main beam were achieved using a quasi-optical 19/28.5 GHz dual polarization feed system. The prime-focus gain measurement at 99.5 GHz found the difference between the measured and calculated gains to be (0.79 ± 0.45) dB which is consistent with the expected rms surface error ($\sim$0.1 mm). Multiple beam operation is accomplished by installing on-axis feeds for millimeter-wave radio astronomy and operating the 19/28.5 GHz beacon receiver feed for a beam at 0.5° off-axis in azimuth.

To demonstrate that low side-lobe and high gain efficiency can be obtained in an earth station antenna serving several satellites simultaneously, we have made beam scanning measurements of the 7-meter antenna by locating a 19/28.5 GHz vertically polarized feed package at various off-axis points. A terrestrial source is located on a tower at 11 km from the antenna. The feed package as shown in Fig. 2 consists of a quasi-optical frequency separator, two pairs of offset paraboloid and corrugated horn, and an adjustable mirror.

Radiation patterns were first optimized and gain was then measured at each location of the feed. Fig. 3 shows three 28.5 GHz elevation patterns which are on axis, 4 beamwidths below axis and 5 beamwidths above axis, respectively. These patterns indicate little change over the scanning range. Fig. 4 shows three 28.5 GHz azimuth patterns which are on axis, 3 beamwidths and 9 beamwidths off axis in azimuth, respectively. It is seen that the pattern of 3 beamwidths off-axis is essentially the same as that of on-axis, whereas the pattern of 9 beam-widths off-axis, which keeps the same half-power beamwidth, shows the merging of the first side-lobe with the main lobe. The scanning is currently limited to the vertex room window which gives the farthest beam about 10 beamwidths at 28.5 GHZ (1° in azimuth and 0.5° in elevation) from the on-axis direction. The gain measurement made use of the COMSTAR beacon receiver feed as the reference beam. Measured gain reductions relative to the on-axis gain for all off-axis beams within the aforementioned scan limit are less than (0.3 ± 0.1) dB at 28.5 GHz and (0.1 ± 0.1) dB at 19 GHz. At 0.5° off-axis in either azimuth or elevation, the scan loss at both 19 and 28.5 GHz appear to be less than or about the measuring error of 0.1 dB.

Our experimental results agree within measuring error with the results of a numerical analysis of multiple-beam offset cassegrainian antenna.[3] They are also consistent with the measured results on azimuth scanning of a 100 GHz exploratory model.[4] The scan loss reported here at a given number of beamwidths is much less than those of another recent experiment[5] which employs an offset cassegrain of smaller magnification ratio. The price to pay for the low-loss scanning capability is the narrow feed pattern which can be provided by an offset reflector.

In conclusion, our measured data confirmed the wide scanning capability of an offset cassegrainian antenna with moderate magnification. Measured radiation patterns at 5 beamwidths off-axis in elevation or azimuth remain essentially the same as those of on-axis beam. Measured scan loss at 10 beamwidths off-axis remains only 0.3 dB which agrees within measuring error with theoretical prediction.

REFERENCES

1. E. A. Ohm, "A Proposed multiple-Beam Microwave Antenna for Earth Stations and Satellites," B.S.T.J., Vol. 53, pp. 1657-1665, October 1974.

2. T. S. Chu, R. W. Wilson, R. W. England, D. A. Gray and W. E. Legg, "The Crawford Hill 7-Meter Millimeter Wave Antenna," B.S.T.J., May-June 1978.

3. E. A. Ohm and M. J. Gans, "Numerical Analysis of Multiple-Beam Offset Cassegrainian Antenna," AIAA Paper No. 76-301, AIAA/CASI 6th Communication Satellite Systems Conference, Montreal, Canada, April 5-8, 1976.

4. R. A. Semplak, "100 GHz Measurements on a Multiple-Beam Offset Antenna," B.S.T.J., Vol. 56, pp. 385-398, March 1977.

5. K. C. Lang and B. J. Forman, "Experimental Study of Scanning Characteristics of an Offset Cassegrainian Reflector Antenna," 1977 IEEE/AP-S Symposium Digest, pp. 545-548.

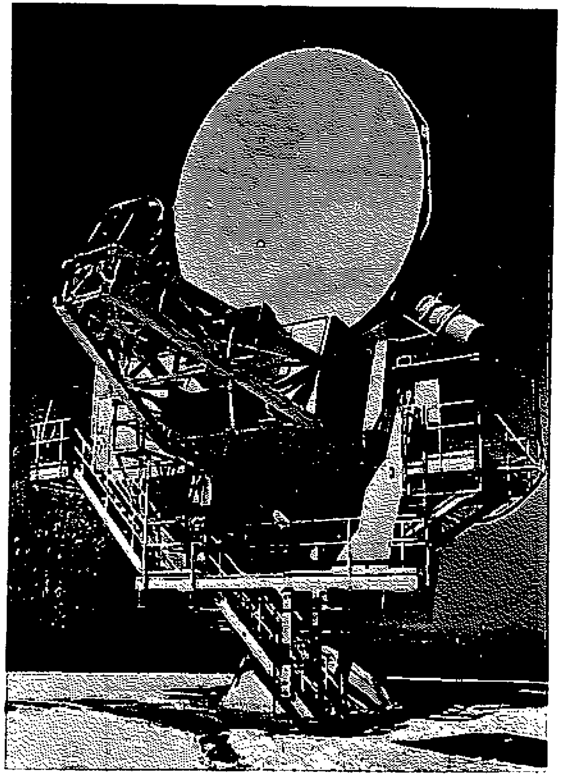

FIG.1 THE CRAWFORD HILL 7-METER OFFSET CASSEGRAINIAN MILLIMETER WAVE ANTENNA

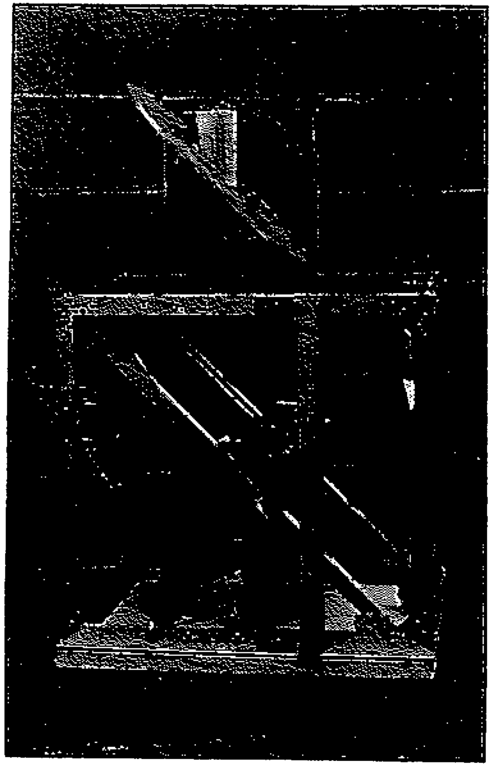

FIG.2 A 19/28.5 GHZ FEED PACKAGE

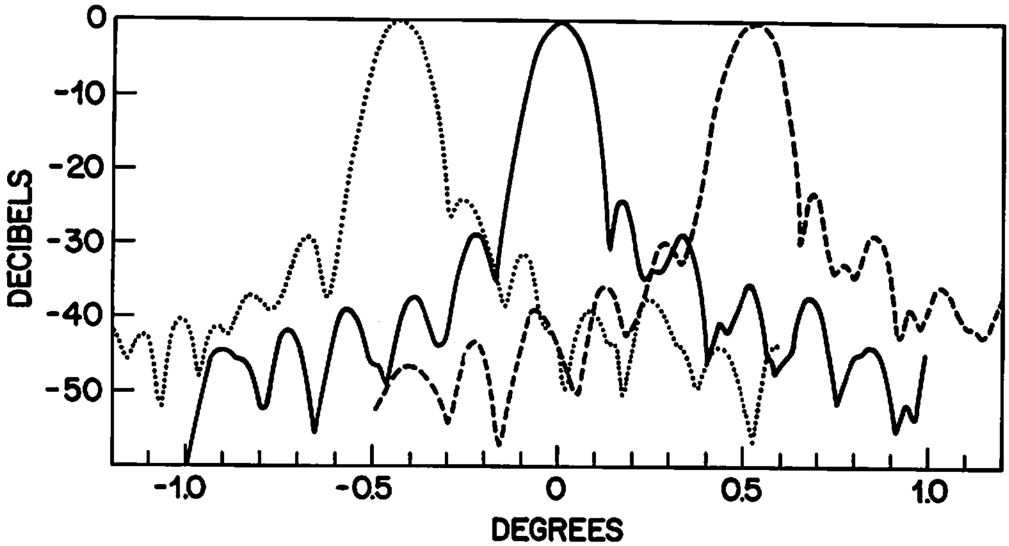

FIG.3 THREE MEASURED 28.5 GHZ ELEVATION PATTERNS;
——— ON AXIS, - - - 5 BEAMWIDTHS ABOVE AXIS,
------ 4 BEAMWIDTHS BELOW AXIS.

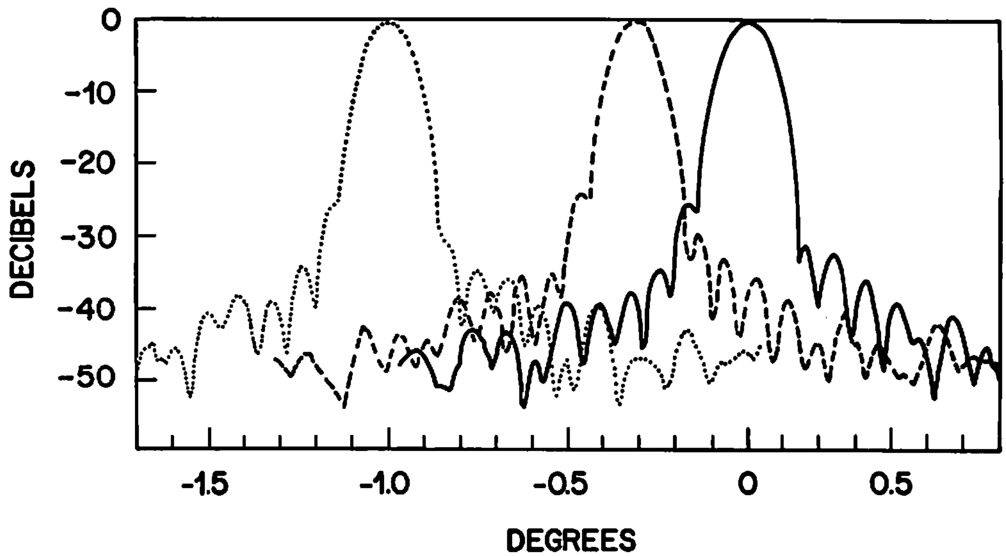

FIG.4 THREE MEASURED 28.5 GHZ AZIMUTH PATTERNS;
——— ON AXIS, - - - 3 BEAMWIDTHS OFF AXIS,
------ 9 BEAMWIDTHS OFF AXIS.