NASA TM-85666

NASA Technical Memorandum 85666

NASA-TM-85666 19830025841

Preliminary Design Of 19-Element Feed Cluster For A Large F/D Reflector Antenna

M. C. Bailey

August 1983

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

PRELIMINARY DESIGN OF 19-ELEMENT FEED CLUSTER FOR A LARGE F/D REFLECTOR ANTENNA

M. C. Bailey

Introduction

This report describes the preliminary design of a 19-element cluster array and feed network for obtaining the proper array excitation coefficients to illuminate a reflector with a large F/D ratio. In particular, the design addresses the problem of spillover illumination of an adjacent reflector in a multiple aperture reflector system such as the hoop-column four-quadrant large space antenna design. The primary application being considered for the feed design is the UHF Land Mobile Satellite Service (LMSS); however, the design can be tailored for other applications as well by readjustment of the design parameters, such as frequency, element spacing and excitation coefficients.

Design Requirements

The immediate application for the design is a feed suitable for testing the 15-meter model of the hoop-column antenna; however, the ultimate potential application is a UHF feed for the Land Mobile Satellite Service. Therefore, this preliminary design will address those requirements associated with the ultimate intended application. The UHF frequencies being considered for communication are 821-831 MHz for the up-link and 866-876 MHz for the down-link. If the same feed is used for both up-link and down-link, then the feed must possess good impedance and pattern characteristics over a bandwidth of 6.5 percent centered at 848.5 MHz. In addition, the feed must be suitable for use in a multiple beam system for obtaining total coverage of the continental USA with high isolation between beams. The high degree of beam-isolation is generally obtained through a combination of frequency reuse, polarization diversity, and low-sidelobe beams. This isolation requirement dictates secondary pattern sidelobes of the order of -30 dB or lower and requires a primary feed pattern with a low edge illumination of the reflector. Since circular polarization is preferred, the feed must also be ammenable to excitation in either right-hand or left-hand circular polarization. At UHF frequencies, the physical size of the feeds becomes a major concern for an antenna system to be Shuttle compatable for a single launch. If the array is to be used as the feed in a multiple-aperture reflector system such as the hoop-column concept, the feed pattern spillover onto the adjacent reflectors must be reduced in order to prevent a potentially unacceptable lobe due to the spillover illumination. The level of this secondary beam from the adjacent reflector (sometimes referred to as a parasitic sidelobe) will depend to a large degree upon the level of the sidelobe of the feed pattern; therefore, in order to satisfy the beam-isolation requirement, the sidelobes of the feed pattern should also be of the order of -30 dB or lower.

Cluster Design

The cluster design is illustrated in figure 1. The radiating aperture consists of 19 circular microstrip patches on a dielectric honeycomb substrate material (dielectric constant of 1.15). The design of circular patch microstrip arrays is described in reference 1. A substrate thickness of 0.07 wavelengths is selected in order to achieve the LMSS bandwidth needed for both up-link and down-link. With a substrate thickness of 0.07 wavelengths and dielectric constant of 1.15, the circular patches are resonant at a diameter of 0.433 wavelengths.

In the design of the feed array, the spacing and excitation distribution for the patch cluster is adjusted for the proper reflector illumination while maintaining a low spillover onto the adjacent reflector. After examination of several potential excitation distributions, the one in figure 2 was selected for the preliminary design. The element excitation in figure 2 approximates a (cos)**1.5 amplitude distribution and gives similar results obtained when attempting to approximate a -40 dB sidelobe Taylor distribution. It should be noted that the excitations in figure 2 have not been fully optimized and a fine adjustment of the coefficients may be performed later for the final design; however, the present coefficients are adaquate for describing the concept and presentation of initial results.

The calculated radiation pattern for an element spacing of 0.9 wavelengths with the distribution of figure 2 is presented in figure 3. Note that the sidelobes of the feed cluster are well below -30 dB in all planes. A contour plot of the radiation pattern is presented in figure 4 over a 120-degree angular sector using 5 dB increments for the contours. A six-fold symmetry can be observed in the first sidelobes, which is characteristic of the hexagonal geometry of the feed cluster. Figures 5-7 give a 3-dimensional view of the feed cluster radiation pattern over different angular sectors about the beam center. The 3-dimensional representations illustrate the sidelobe structure above the -40 dB level. The far-out sidelobes in figure 7 are due to grating lobes which are beginning to appear in the visible space because the element spacing is approaching a full wavelength. Note also the six-fold symmetry of the grating lobes.

When the present array cluster design is used as the primary feed for a reflector with an F/D of 1.53 the edge illumination taper would be about -14 dB, resulting in a secondary radiation pattern as calculated in figure 8 for a paraboloidal reflector with a circular aperture. The projected apertures of the hoop-column antenna design are not circular, but are each a quadrant of a circle. Figure 9 presents the principal plane patterns which were calculated for an offset "PIE" shaped aperture representing one quadrant of the 15-meter hoop-column antenna design at the LMSS scale frequency of 7.67 GHz with the present feed cluster design.

In order to further assess the applicability of the present feed cluster design concept as a feed for the hoop-column reflector configuration, the secondary radiation pattern from an adjacent quadrant, due to the feed spillover, was calculated and is compared in figure 10 with the radiation pattern of the primary illuminated quadrant. The radiation patterns in figure 10 were calculated in the 45-degree plane since this is the plane where the maximum of the "parasitic" sidelobe is expected to occur. The main lobe and the parasitic sidelobe are separated by several degrees because each quadrant of the hoop-column reflector is a portion of an identical paraboloid but with its vertex displaced from the other quadrants; thus, the parasitic sidelobe is scanned away from boresite since the feed is displaced from the focal point of the "parasitic" quadrant. The composite radiation pattern for two quadrants of the hoop-column configuration is shown in figure 11. Note that all sidelobes (including the parasitic lobe) are below the -30 dB criteria that was selected in the requirements section.

Distribution Network Design

Once an acceptable array excitation distribution is determined, a network must be designed that is practical to implement with the array configuration. Figure 12 shows schematically one method of obtaining the tapered excitation of a 19-element array. The symbols at the 3-way junctions represent unequal power dividers and figure 13 shows one branch of the distribution "tree" with the power divisions necessary to obtain the array amplitude excitations of figure 2. The element numbering notation for figures 12 and 13 is illustrated in figure 14 for the array cluster.

A layout of the distribution network is shown in figure 15 for convenient excitation of the 19-element array cluster. The lengths of the lines in the network should be selected so as to present equal phase paths to each element of the array. In this configuration, there are no crossovers of the lines of the network. Figure 16 shows the network layout using stripline TEEs and simple unequal power dividers (reference 2) as an integral part of the network. This network requires only two transmission line widths throughout the circuit corresponding to 35.35 and 50 ohms, and the design also provides the capability for a wide range of excitation distributions by a simple adjustment of the "tap point" on the unequal power dividers. The entire distribution network can be fabricated from a single printed circuit board, thus eliminating the need for multilayered boards and interconnections. Figure 17 illustrates a wider bandwidth implementation of the network in which all TEEs and power dividers have been replaced by 1.5 wavelength in-phase hybrids with terminating loads. The unequal power split is obtained by the proper selection of transmission line impedances. Coupling factors of 3.00, 3.30, 3.65, 6.20, and 7.26 dB are needed for the excitation distribution of figure 2; therefore, the required line widths for the network of figure 17 are practical to fabricate in stripline.

The lengths of all lines in figures 16 and 17 are drawn approximately to scale assuming suspended stripline (air dielectric substrate), which may be desirable for a flight model in order to reduce network insertion loss and weight. Initial estimates indicate that sufficient surface area is available at UHF frequencies to avoid excessive interference coupling between lines using suspended stripline with 1.27 centimeter ground plane spacing and at L-band with 0.635 centimeter ground plane spacing. At frequencies above L-band, it may be necessary to use denser dielectric substrates and smaller ground plane spacings in order to avoid excessive line coupling within the stripline distribution network.

Conclusion

A preliminary design of a low sidelobe 19-element microstrip array and its distribution network is described. The applicability of the array as a feed for the hoop-column reflector antenna is demonstrated through calculations of the secondary radiation patterns using the radiation pattern of the array as the reflector illumination function. A practical implementation of the array is presented which requires only one printed circuit board for the distribution network. The basic design can be easily tailored to meet other performance requirements than those selected for this conceptual design.

References

1. M. C. Bailey and F. G. Parks: Design of Microstrip Disk Antenna Arrays, NASA Technical Memorandum, TM-78631, February 1978.

2. M. C. Bailey: A Simple Stripline Design for Uneven Power Split, NASA Technical Memorandum, TM-81870, August 1980.

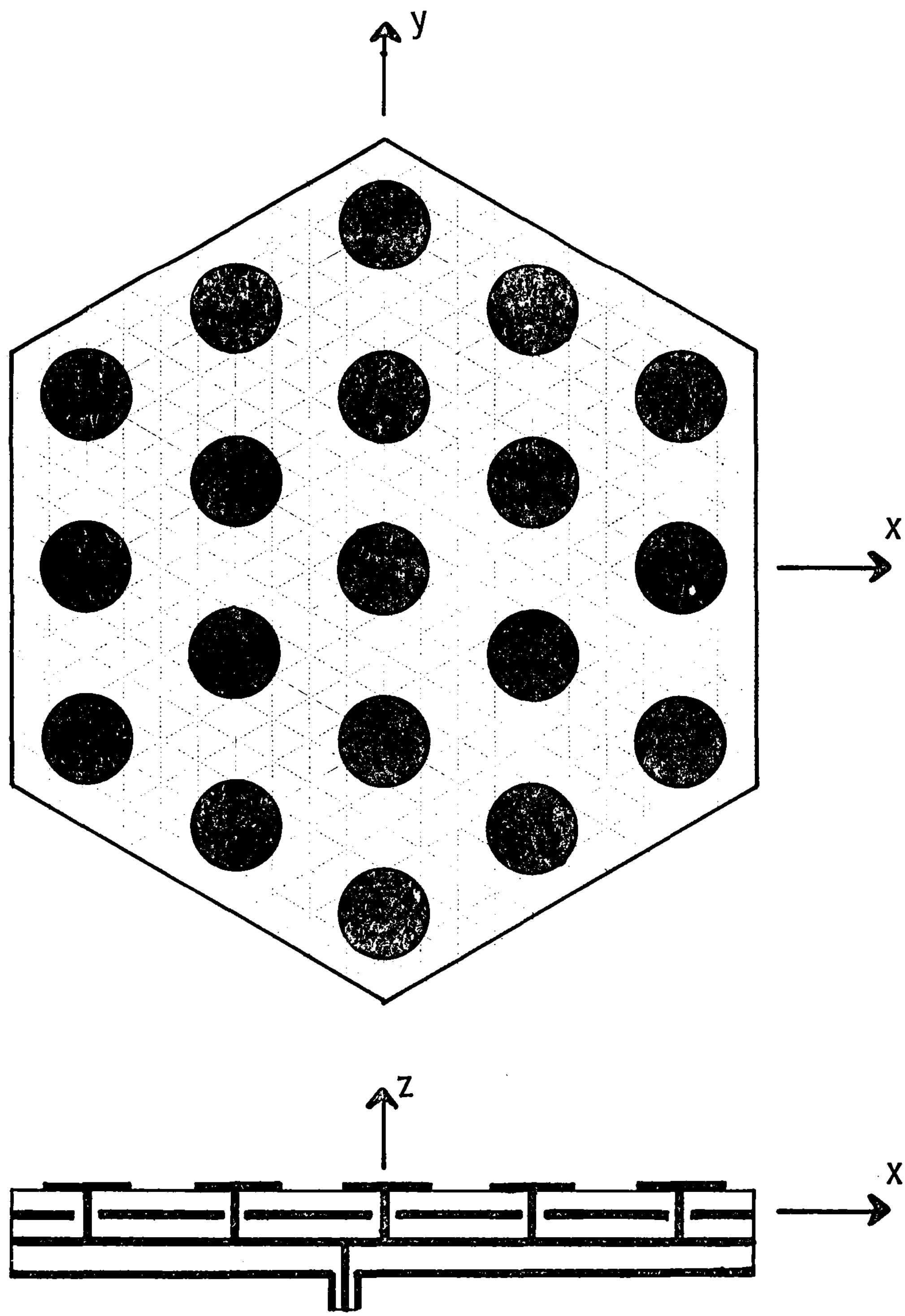

Figure 1. Geometry of microstrip patch cluster.

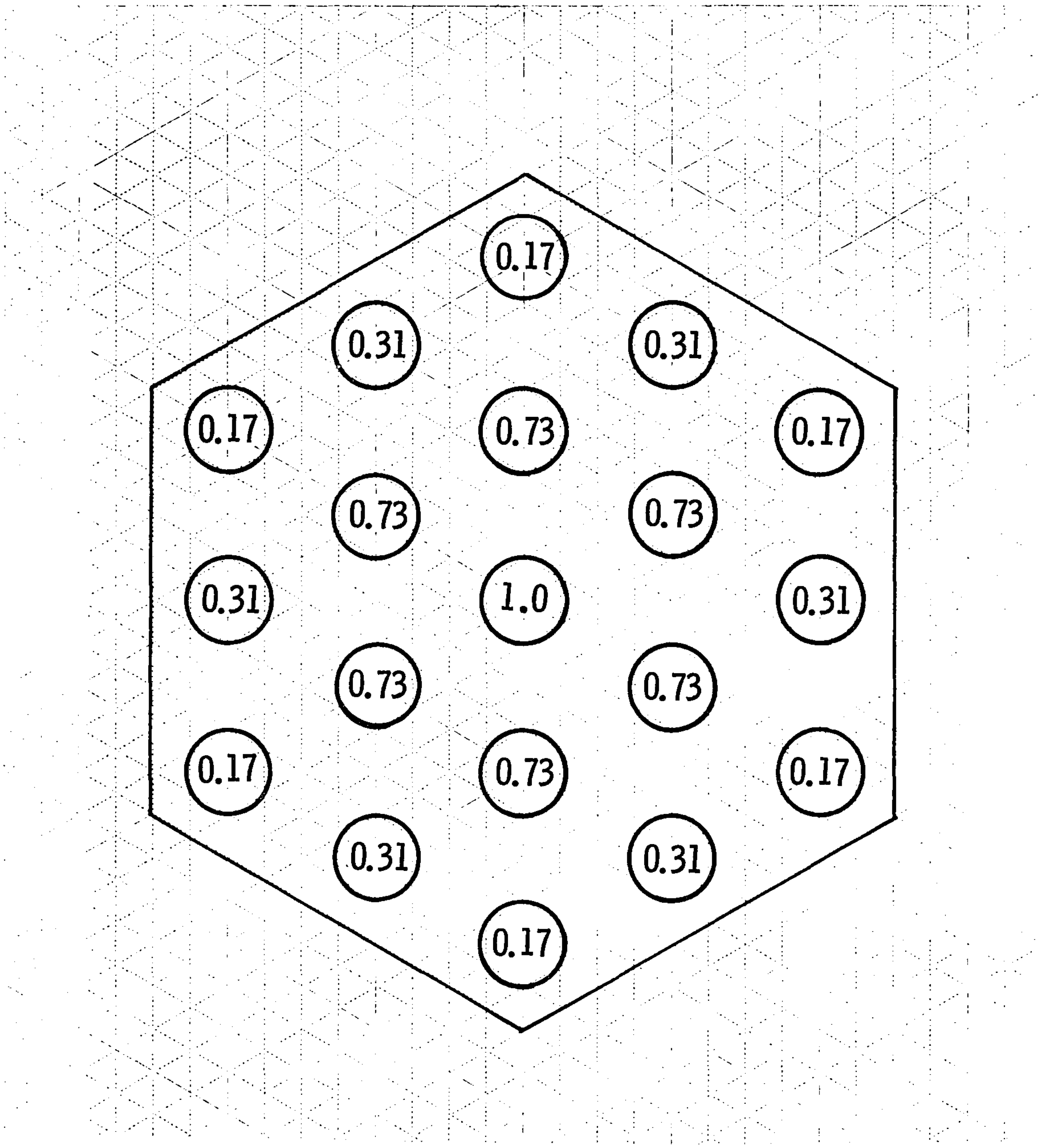

Figure 2. Amplitude excitation for microstrip patch cluster.

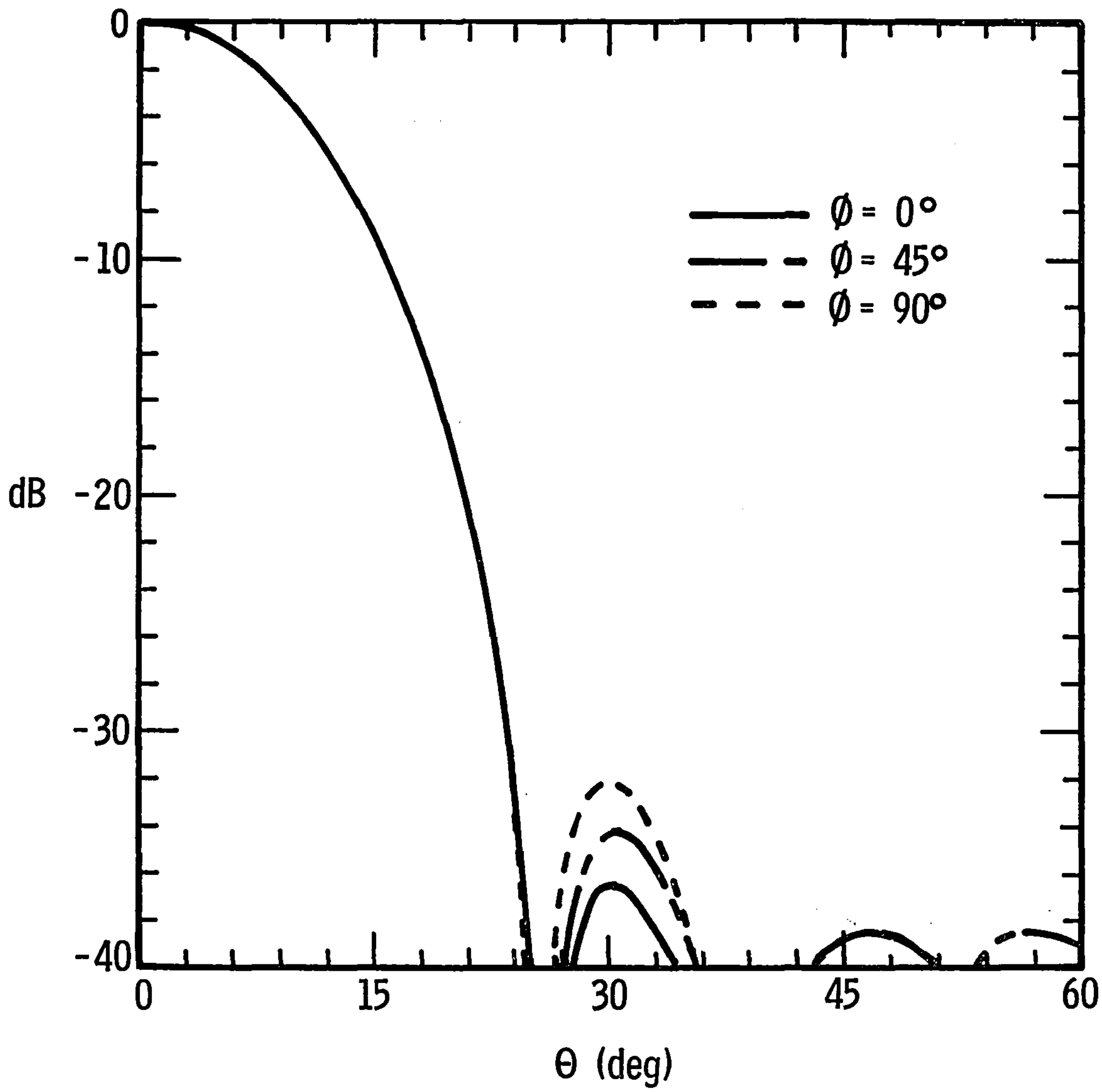

Figure 3. Radiation pattern for microstrip patch cluster.

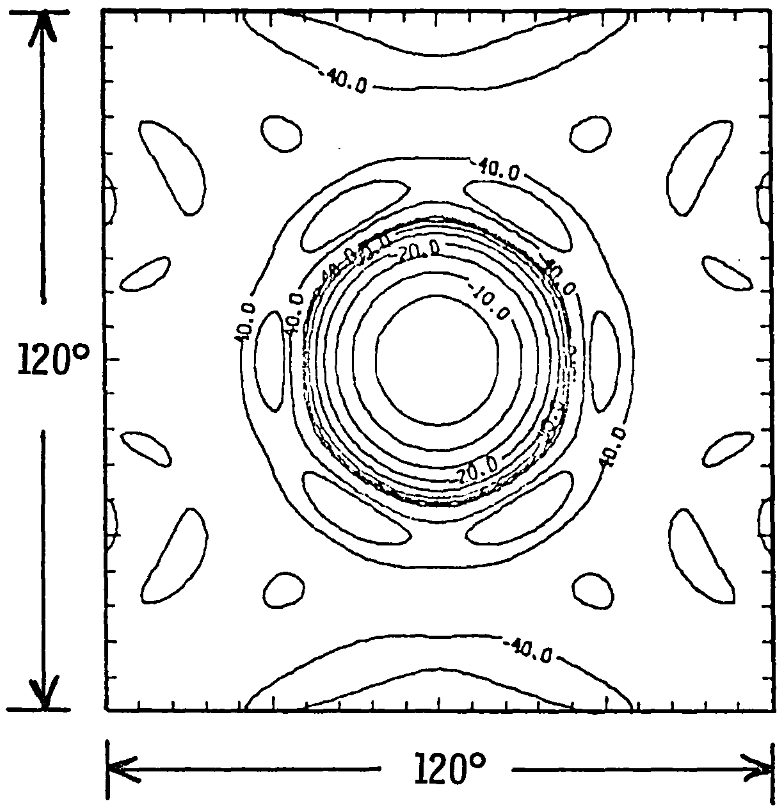

Figure 4. Contour plot of radiation pattern for microstrip patch cluster.

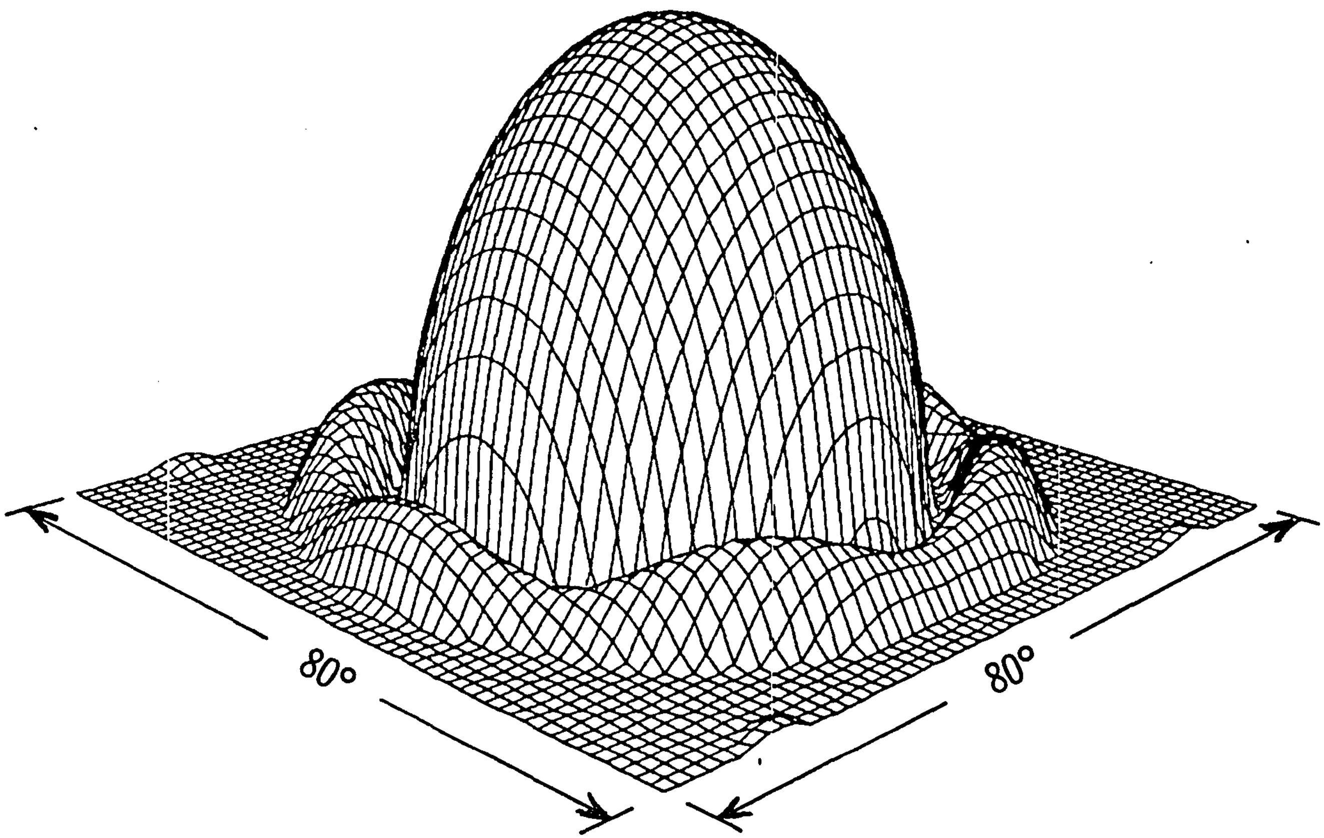

Figure 5. Three-dimensional plot of radiation pattern for feed cluster.

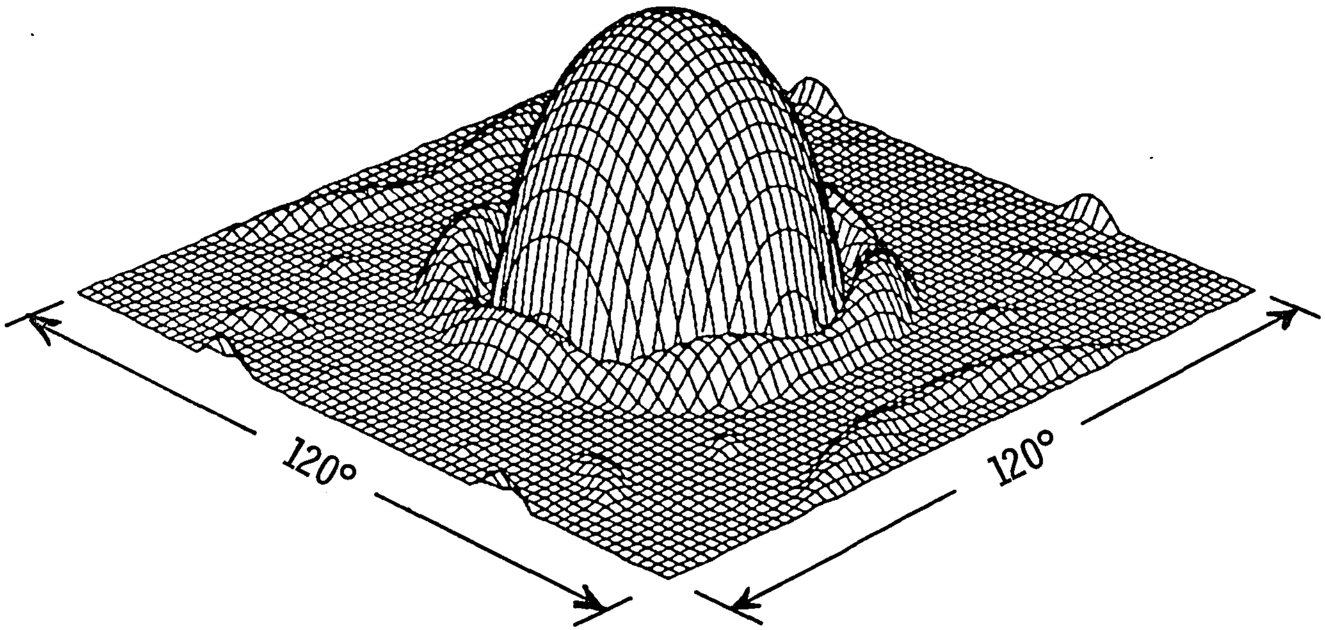

Figure 6. Three-dimensional plot of radiation pattern for feed cluster.

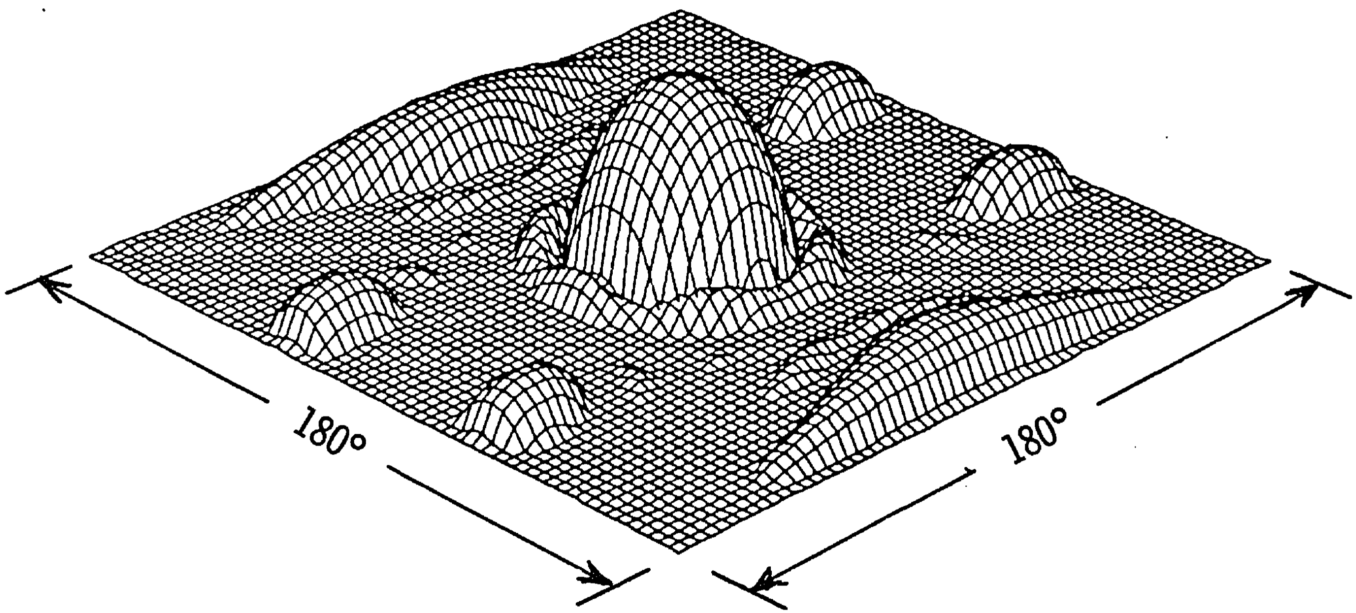

Figure 7. Three-dimensional plot of radiation pattern for feed cluster.

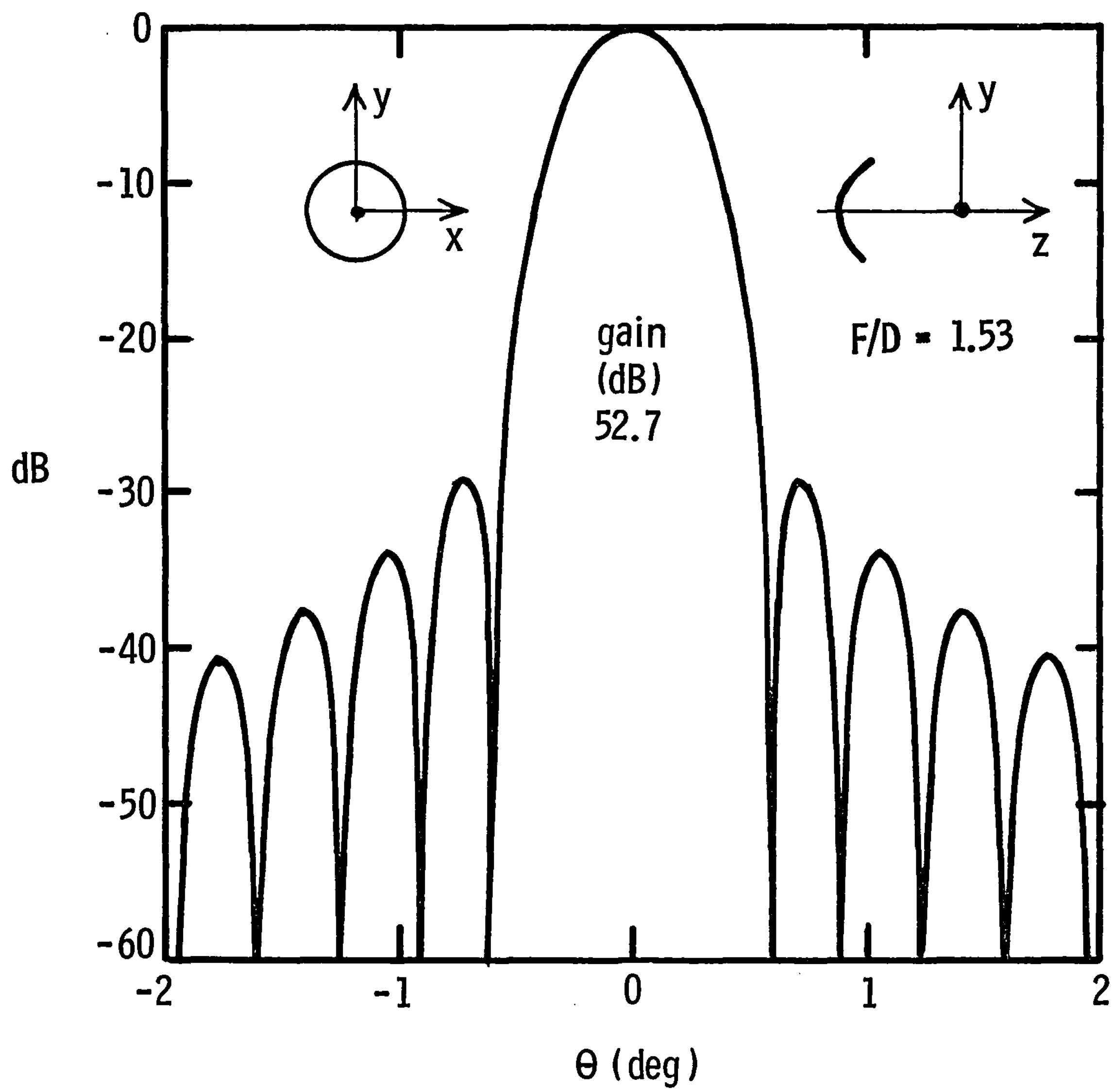

Figure 8. Radiation pattern for paraboloidal reflector with circular aperture.

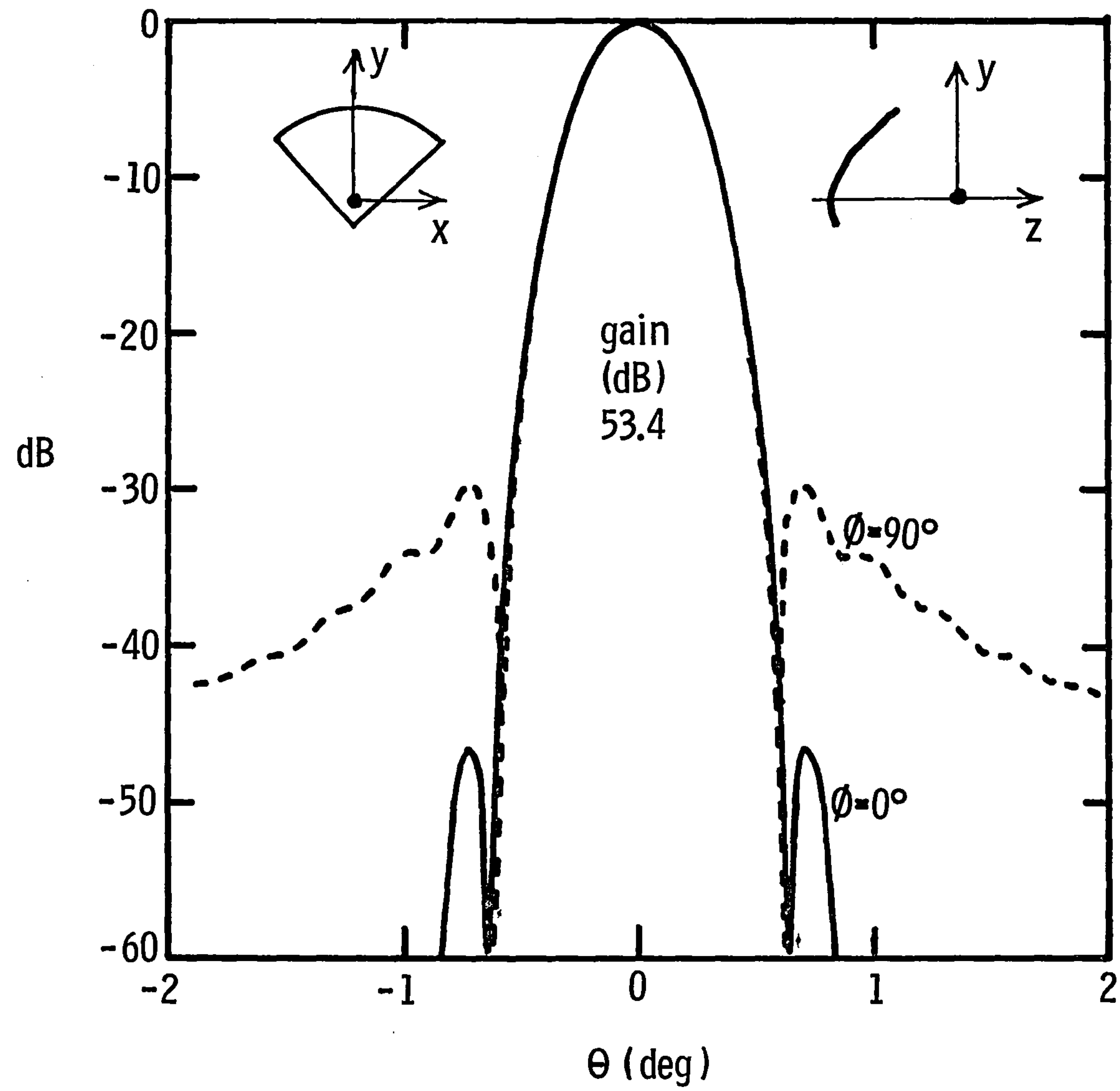

Figure 9. Radiation pattern for paraboloidal reflector with "PIE" shaped aperture.

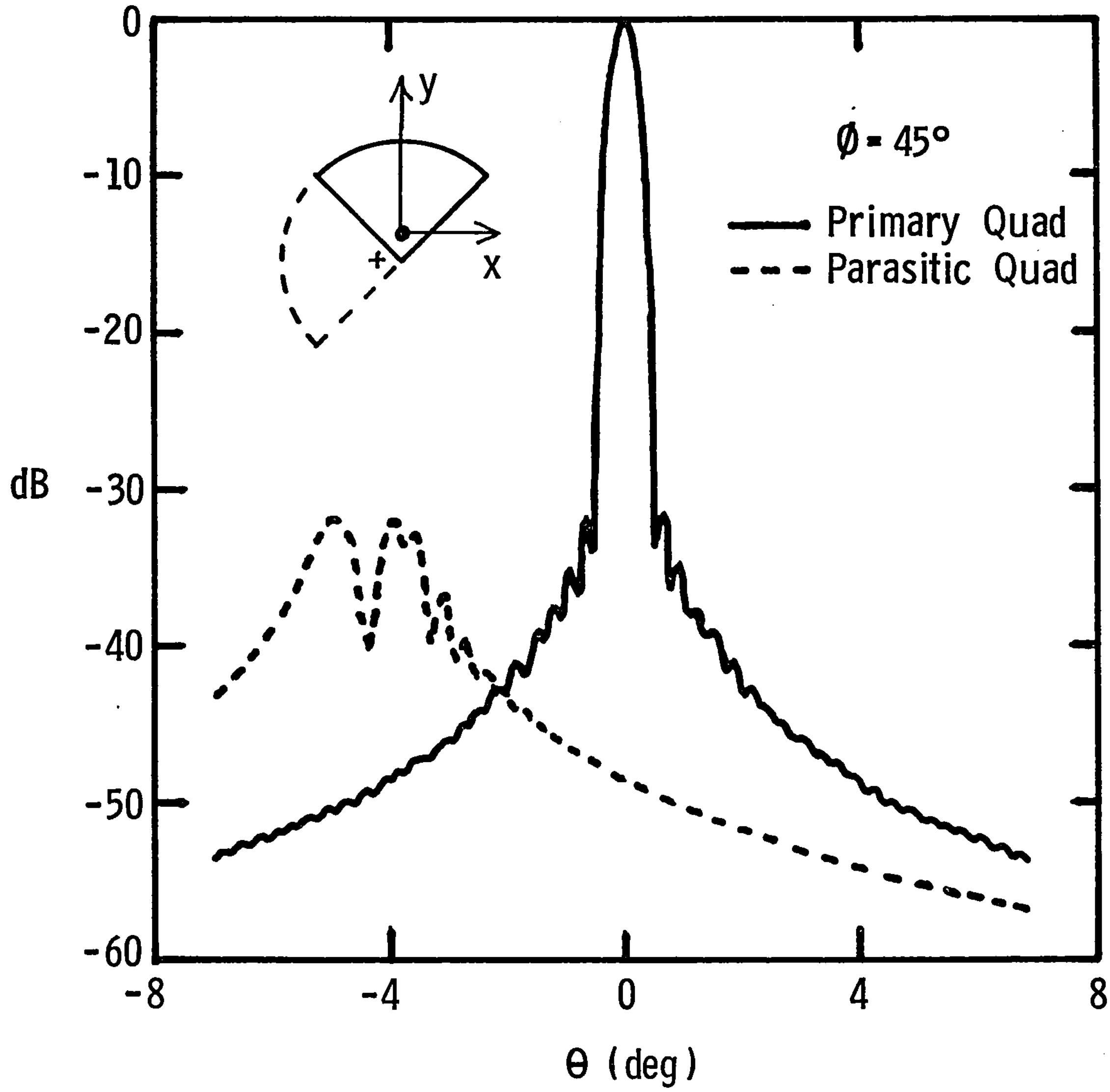

Figure 10. Radiation patterns for two quadrants of 15-meter model of hoop-column reflector antenna design.

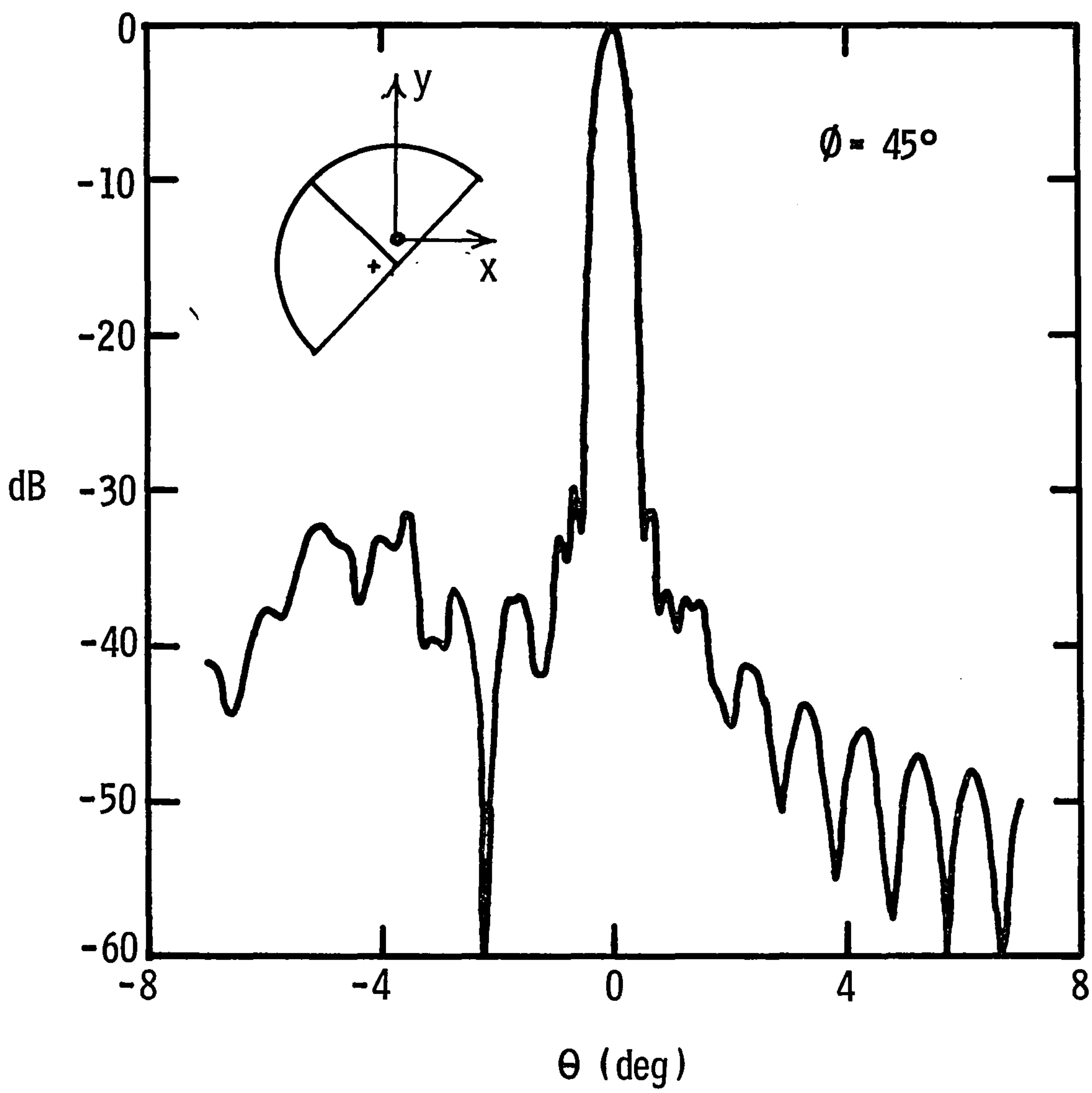

Figure 11. Composite radiation pattern for two quadrants of 15-meter model of hoop-column reflector antenna design.

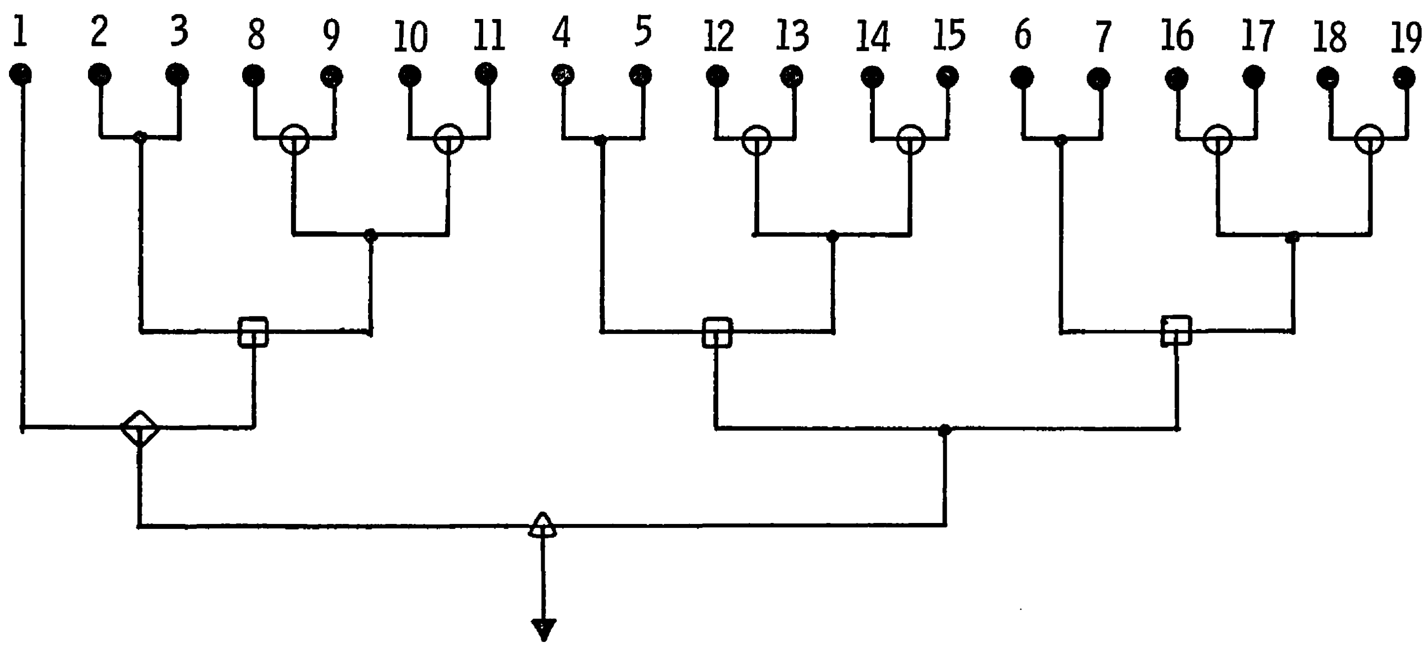

Figure 12. Schematic of 19-element feed network for tapered excitation.

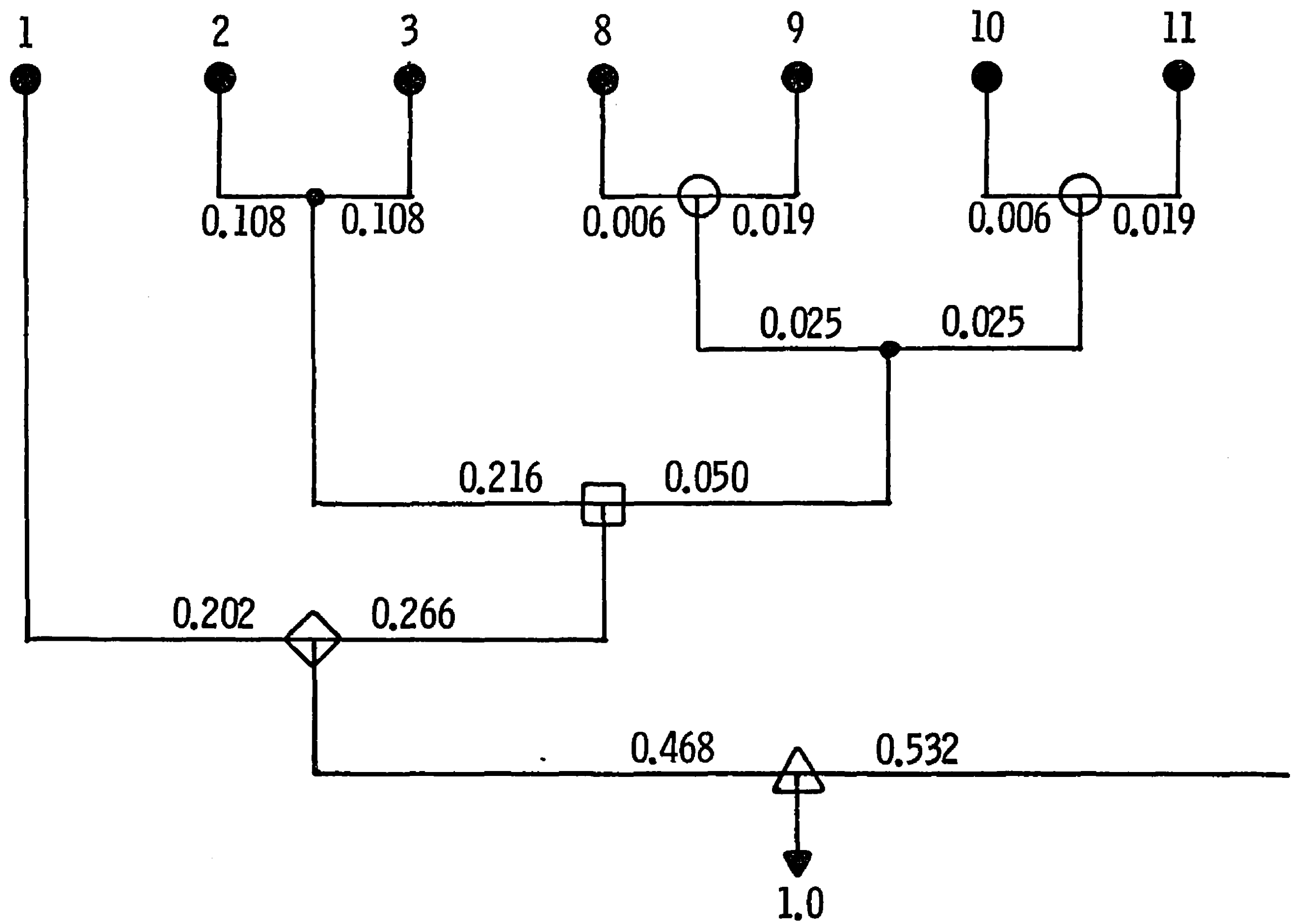

Figure 13. Power divisions required for excitation distribution of figure 2.

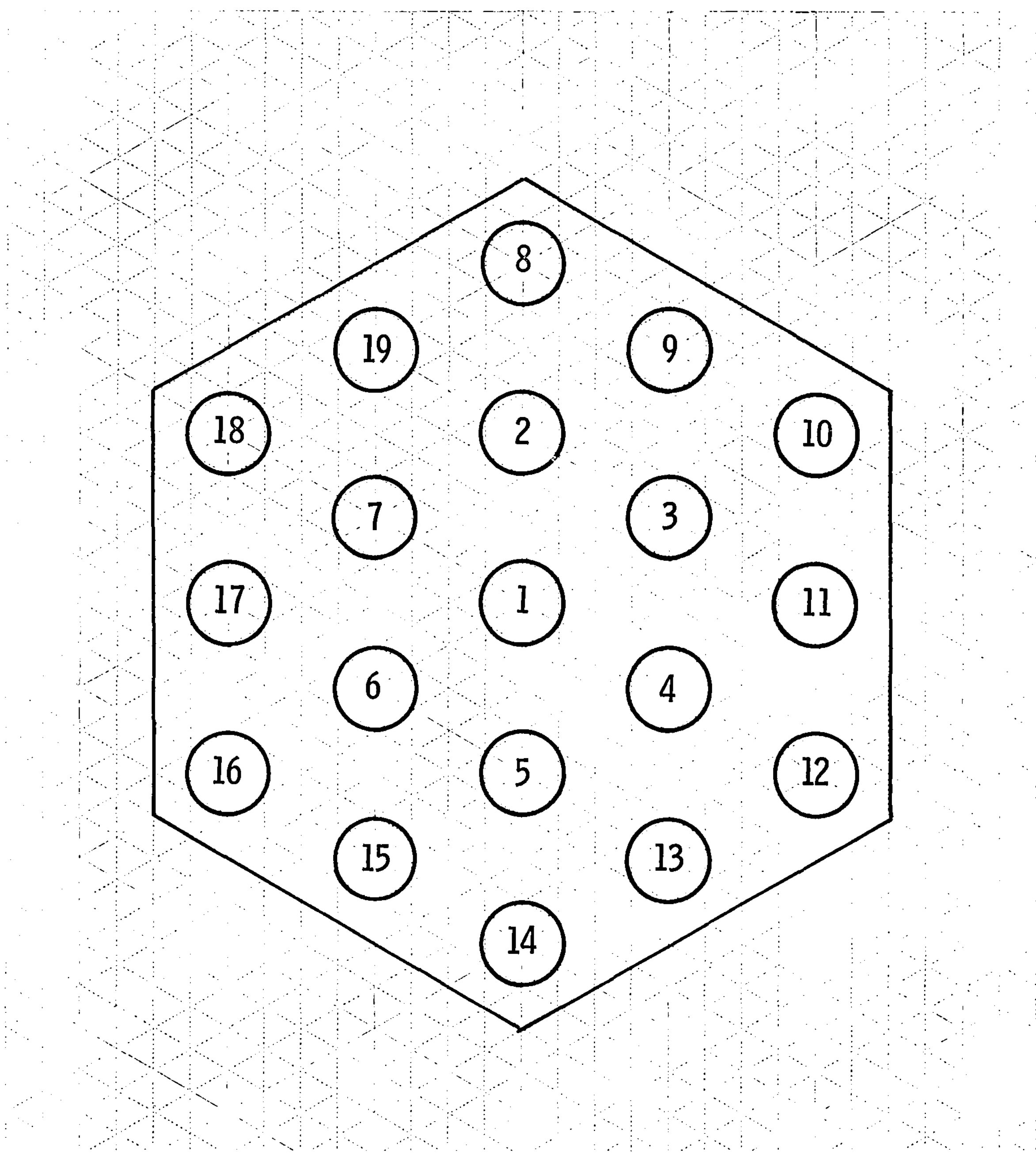

Figure 14. Numbering scheme for 19-element array cluster.

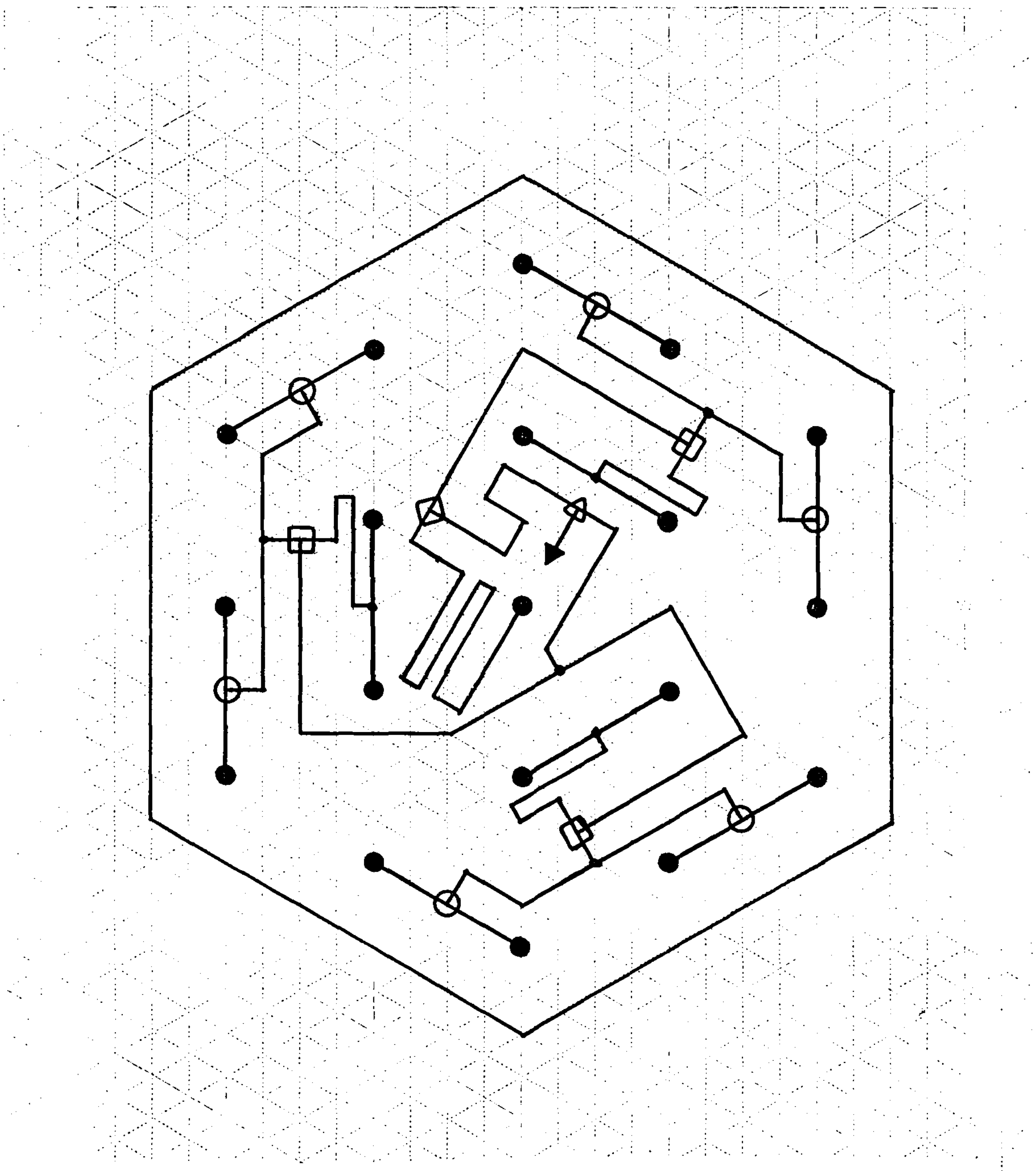

Figure 15. Layout of feed network for 19-element array cluster.

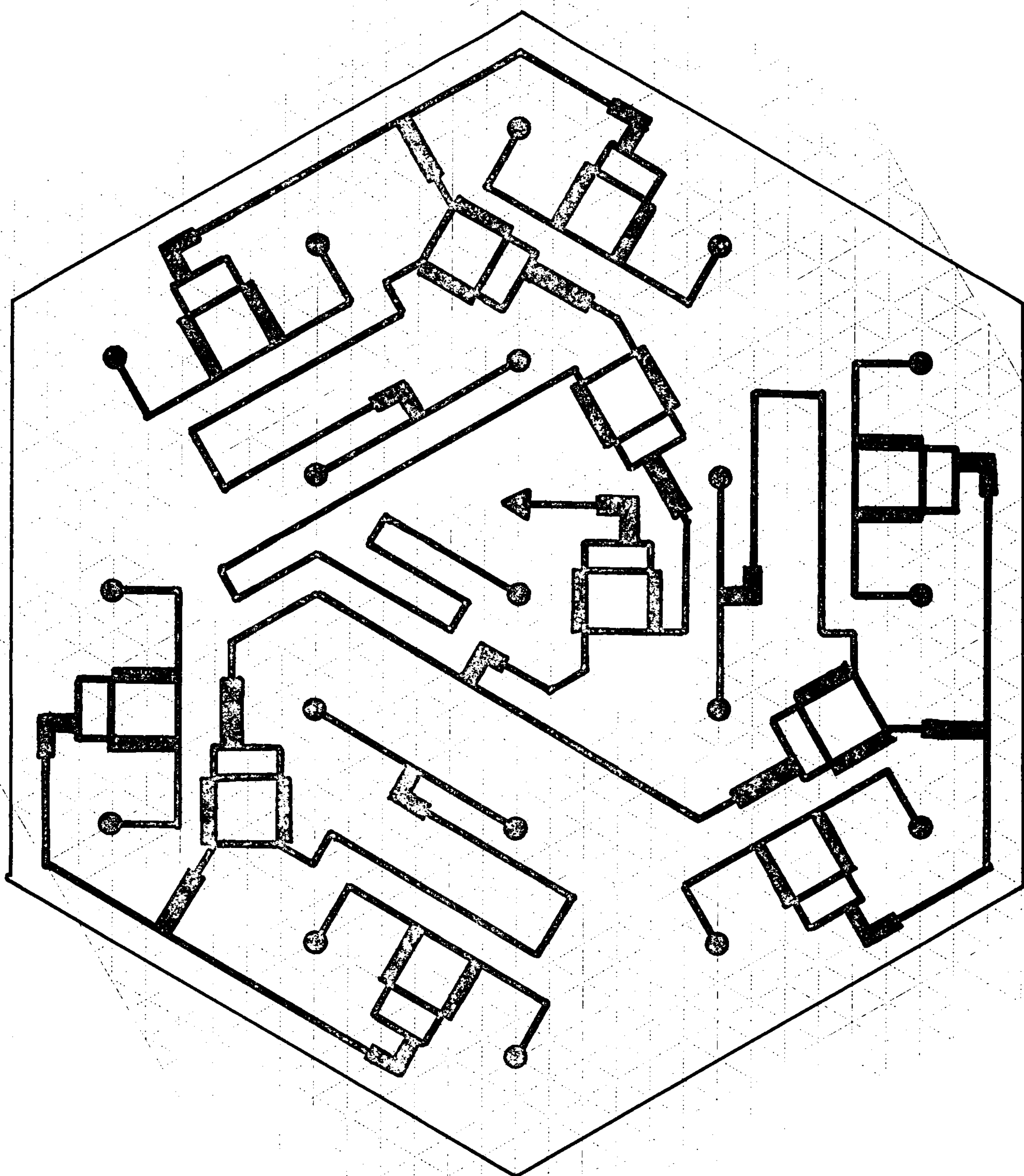

Figure 16. Stripline distribution network using unequal power dividers.

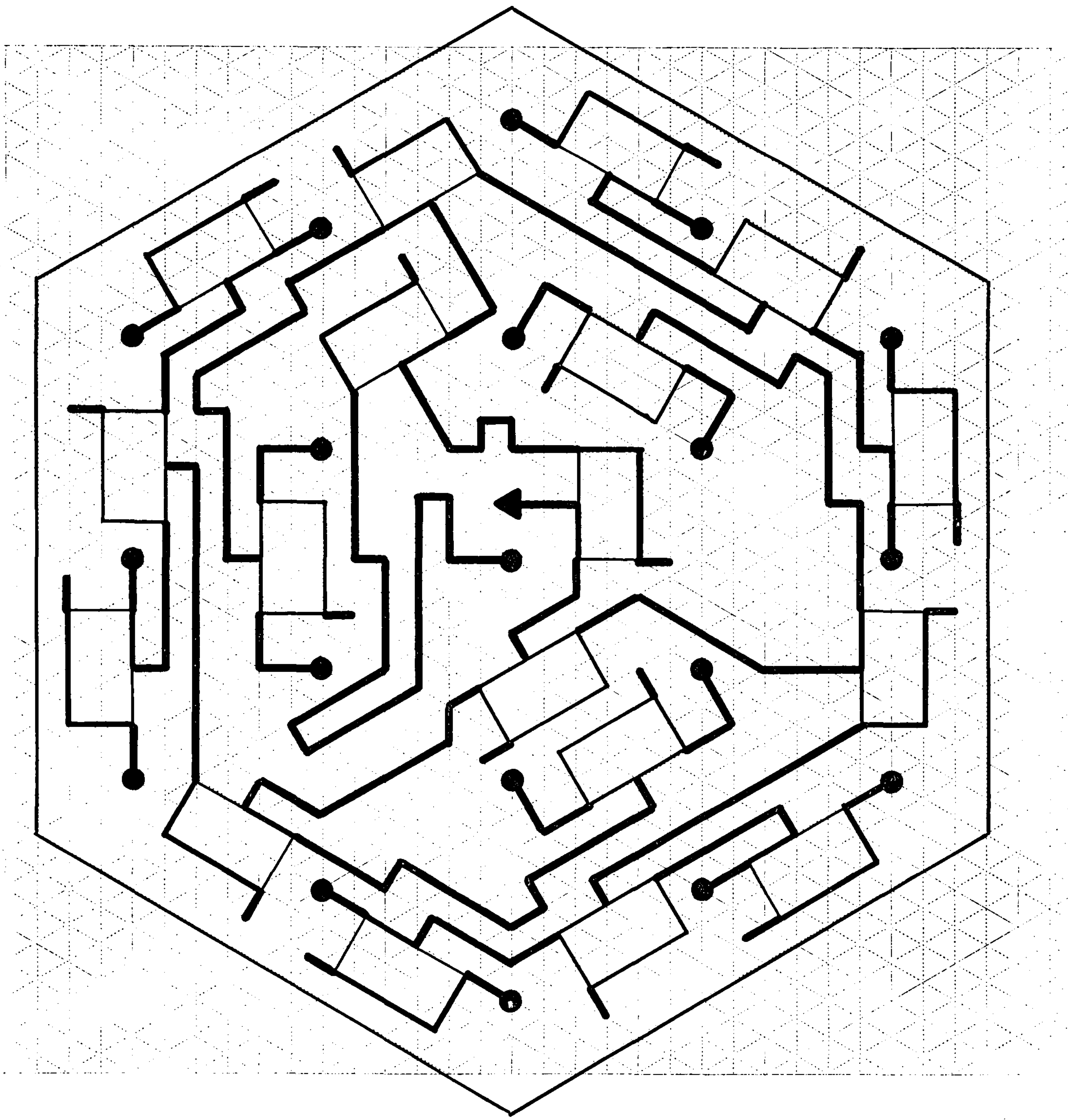

Figure 17. Stripline distribution network using 1.5 wavelength hybrids.

1. Report No. NASA TM-85666	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PRELIMINARY DESIGN OF 19-ELEMENT FEED CLUSTER FOR A LARGE F/D REFLECTOR ANTENNA		5. Report Date August 1983
		6. Performing Organization Code 506-58-23-01
7. Author(s) M. C. Bailey		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The design of a low sidelobe 19-element microstrip cluster and its distribution network is described. The problem of spillover illumination of an adjacent reflector in a multiple aperture reflector system is addressed. A practical implementation of the array is presented which requires only one printed circuit board for the distribution network with the potential for being easily tailored to a wide range of excitation distributions.

17. Key Words (Suggested by Author(s)) Antennas, Arrays, Antenna design, Microstrip, Stripline	18. Distribution Statement Unclassified - Unlimited; Subject Category 32

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	23	A02

N-305