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A PARABOLIC CYLINDER REFLECTOR SYSTEM WITH LOW SIDELOBES - EXPERIMENTAL RESULTS

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Contents

1. INTRODUCTION	5
2. GENERAL CONSIDERATION	6
3. PRIMARY FEED ANTENNA	7
4. FAR FIELD PATTERN	13
5. CONCLUSION	19

Illustrations

1. Parabolic Cylinder	6
2. Pillbox Antenna	7
3. Feed Network	7
4. Multimode Horn Impedences	8
5. Primary Horn Pattern 9.3 GHz	9
6. Primary Horn Pattern 9.5 GHz	9
7. Primary Horn Pattern 9.7 GHz	10
8. Primary Horn Pattern 9.9 GHz	10
9. Primary Horn Pattern 10.1 GHz	11
10. Primary Horn Pattern 10.3 GHz	11
11. Primary Horn Pattern 10.5 GHz	12

Illustrations

12. Primary Horn Pattern 10.7 GHz	12
13. Theoretical Horn Pattern	13
14. Pillbox Antenna on the Mount	14
15. Antenna Pattern With Wide Angle Sidelobe at 10.1 GHz	15
16. Antenna Far Field Patterns 9.3 GHz	16
17. Antenna Far Field Patterns 9.5 GHz	16
18. Antenna Far Field Patterns 9.7 GHz	17
19. Antenna Far Field Patterns 9.9 GHz	17
20. Antenna Far Field Patterns 10.3 GHz	18
21. Antenna Far Field Patterns 10.5 GHz	18
22. Antenna Far Field Patterns 10.7 GHz	19

A Parabolic Cylinder Reflector System With Low Sidelobes-Experimental Results

1. INTRODUCTION

In the past, radar antenna design has been guided by the premise that maximum aperture efficiency was the ultimate goal to be achieved, and that sidelobe levels just low enough to minimize false returns of passive targets were completely acceptable. Present and future electronic countermeasures (ECM) techniques present serious problems for these types of radar. Basic changes in radar design are needed in the next generation radars to decrease substantially their vulnerability to the sophisticated ECM techniques that they are required to face in an increasingly hostile tactical environment. The requirement of reliable radar operation in a hostile environment imposes the following characteristics on the antenna system: greatly suppressed transmit and receive sidelobes, wide instantaneous bandwidth, high angular resolution and polarization diversity.

At the present time several large antenna configurations ($>50\lambda$) are under investigation for possible use in high resolution and extremely low sidelobe radar systems. A good candidate, which is both economical and relatively easy to fabricate, is the off-set parabolic cylinder, Figure 1. Based on the need for a low sidelobe antenna and the simplicity of the parabolic cylinder, a study for an offset feed was initiated¹ to determine an optimum illumination to give the desired radiation pattern.

(Received for publication 20 November 1979)

1. Fante, Ronald L. (1977) Design of Parabolic Cylinder Reflector Systems with Low Sidelobes, RADC-TR-77-204.

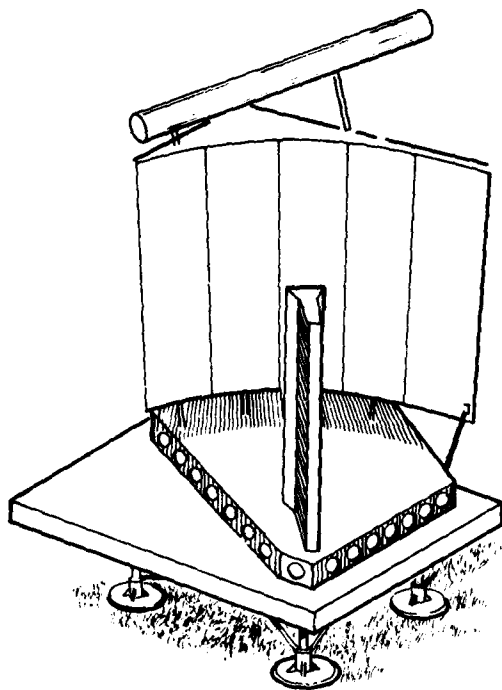


Figure 1. Parabolic Cylinder

2. GENERAL CONSIDERATION

The objectives of the work reported here are to verify experimentally the theoretical results obtained by Fante¹ for reflective parabolic cylinder antenna systems with low sidelobes and to optimize the primary feed system to obtain the desired secondary radiation pattern of the antenna. In order to demonstrate the validity of the theoretical results, it was decided that a relatively large aperture antenna ($>50\lambda$) was required. However, an aperture of this size in two dimensions would be cumbersome, heavy, and unduly complex. Since very low sidelobes are usually required in only one plane (the azimuthal plane), it was decided to use a pillbox type antenna (Figure 2). The antenna is essentially a parallel plate pillbox to insure a true TEM mode of propagation while operating at a center frequency of 10.05 GHz. Details of design, dimensions, feed location, and theory of operation are described by Fante¹. Since primary horn excitation is critical to the goal of achieving wide bandwidth and low sidelobes, correct excitation in the feed horn was developed first, then the combined horn reflector measurements were made.

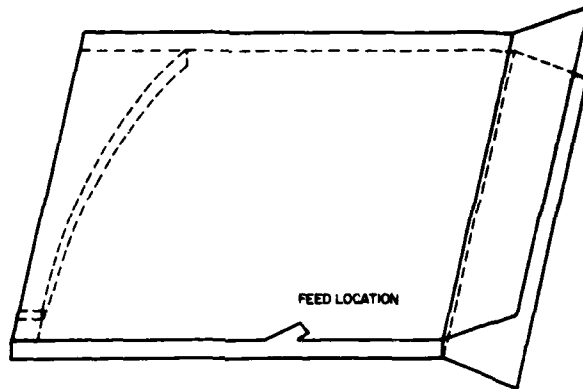


Figure 2. Pillbox Antenna

3. PRIMARY FEED ANTENNA

The primary feed antenna was constructed in two stages: first the horn waveguide was fabricated, then the feed network. The network required assembling components with a high degree of precision, because of the requirements on the primary horn pattern. The feed network used a hybrid, two-way power divider and a cable length (for differential phase shift) for the fixed value power divider. The design required that one port be 4.6 dB below the other. Two ports were then fed through two unequal-length, rigid-coaxial cables into two matched two-way power dividers. The two higher power ports feed the two inner probes of the waveguide feed. The outer probes are fed from the upper power divider. The feed network is shown schematically in Figure 3.

The phase and amplitude response of several power dividers and hybrids was measured very carefully, and the best components were selected. Cable lengths were also carefully cut and measured to give the correct path lengths.

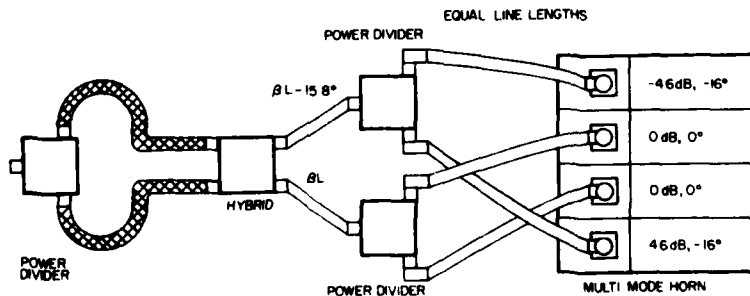


Figure 3. Feed Network

As a result of careful fabrication and measurements, the resulting phase and amplitude values (of the network) were within 1.5° and 0.2 dB, respectively, of the design value. The design tolerance were calculated as 2.5° and 0.3 dB.

Since the geometry about each probe is not identical, the actual currents on each of the four probes can be expected to be slightly different from the design or isolated measured values. Measurements of the impedance of each probe were made over the frequency range with the other three ports terminated.

The probes were trimmed equally to reduce the overall VSWR over the frequency band of 9.3 to 10.6 GHz. The resulting input impedances are shown in Figures 4a and b. Mutual impedances were measured for the mid-band frequency.

An indication of how much distortion was introduced by the horn geometry and by mutual impedance effects is shown by the horn radiation patterns in Figures 5 to 12. Figure 13 gives a comparison of the calculated horn pattern and the measured pattern at the mid-band frequency. As can be seen from the figures, agreement between measured and calculated values over the band is quite good. For a reflector with 14 dB gain, the sidelobes of the horn pattern must be below 36 dB to give the desired 50 dB sidelobes for the reflector-horn combination.

It is clear from the set of horn patterns that only at one frequency, 10.60 GHz, is the 36 dB criterion for the primary horn pattern met. Some of these sidelobes are likely to be caused by scattering from various parts of the measuring range. Only at the lower frequencies below 9.7 GHz is the pattern wider than required. The effect is larger than expected from frequency change alone, and results from the merging of the close-in sidelobes into the main beam. The primary horn pattern came quite close to matching the calculated values required for 50 dB sidelobe levels.

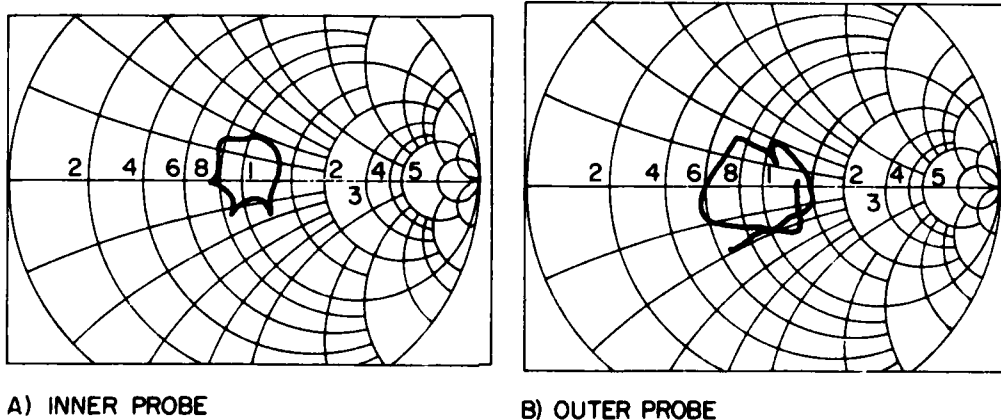


Figure 4. Multimode Horn Impedances

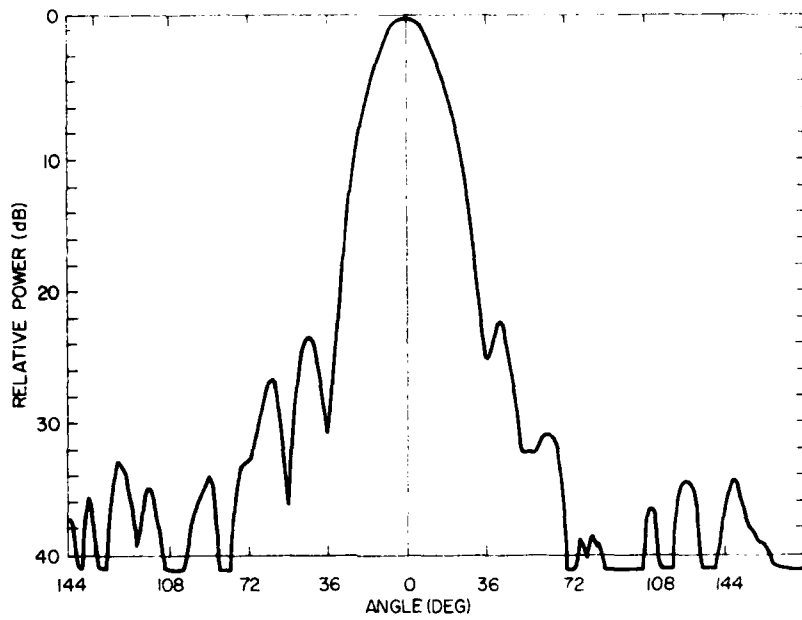


Figure 5. Primary Horn Pattern 9.3 GHz

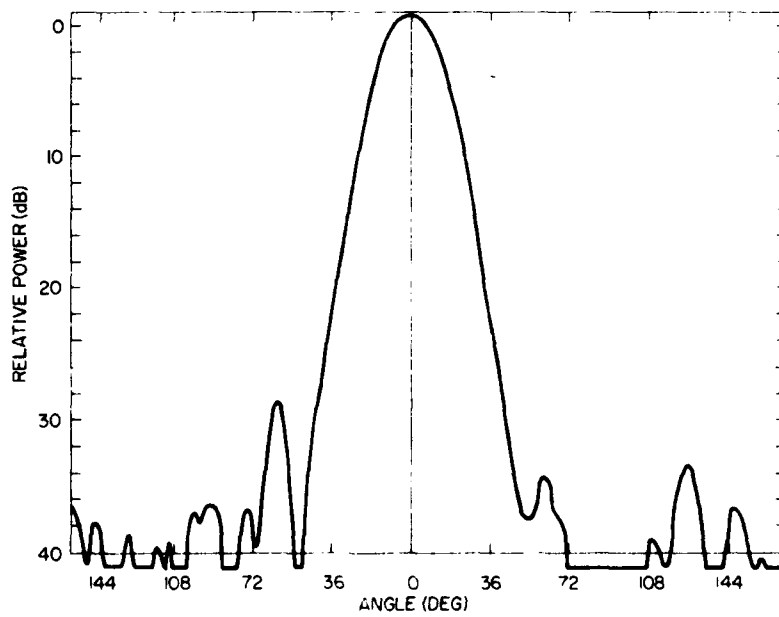


Figure 6. Primary Horn Pattern 9.5 GHz

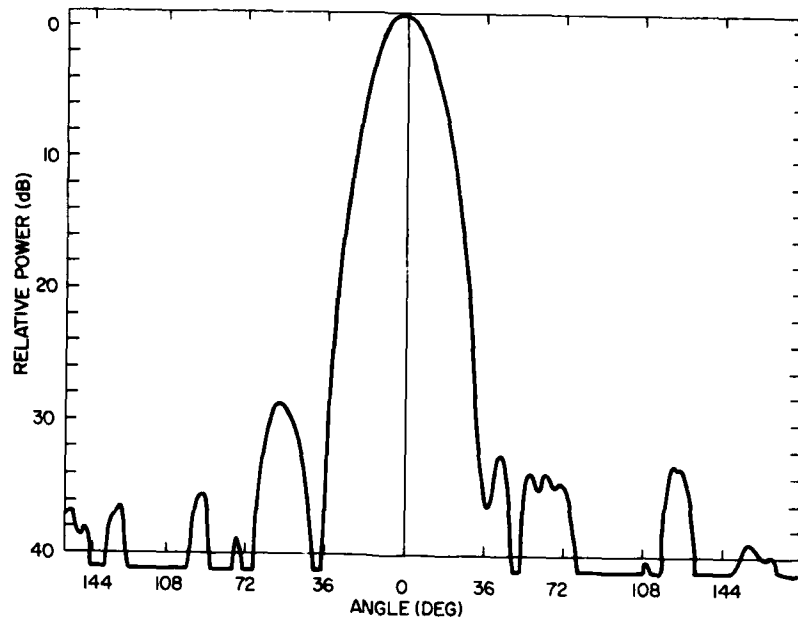


Figure 7. Primary Horn Pattern 9.7 GHz

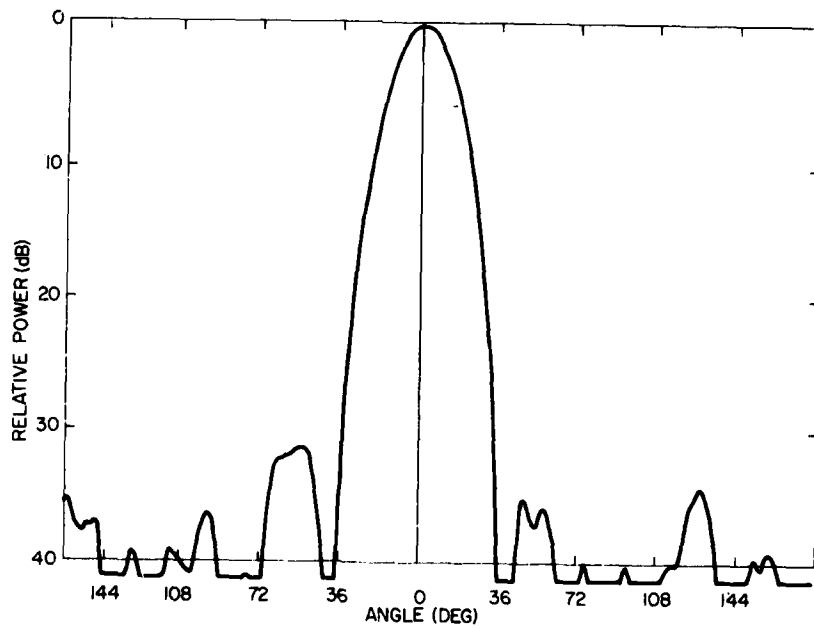


Figure 8. Primary Horn Pattern 9.9 GHz

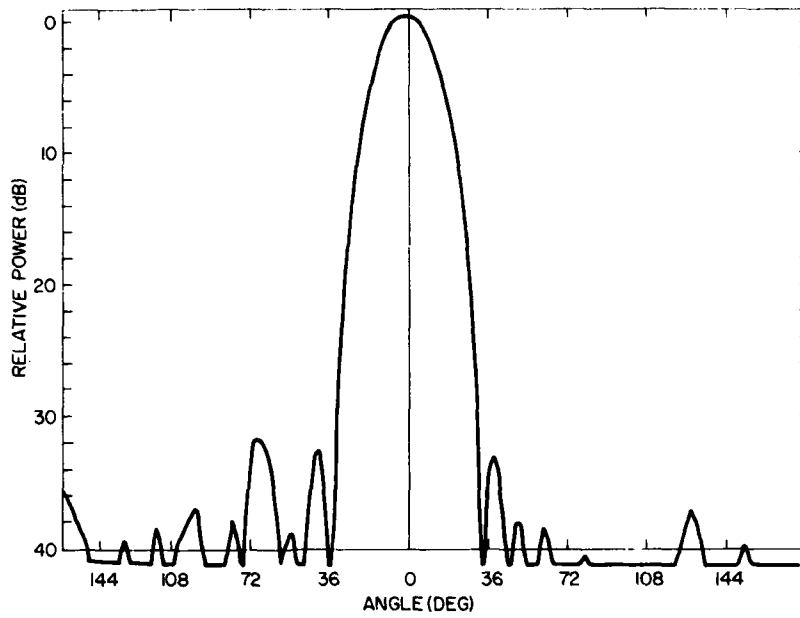


Figure 9. Primary Horn Pattern 10.1 GHz

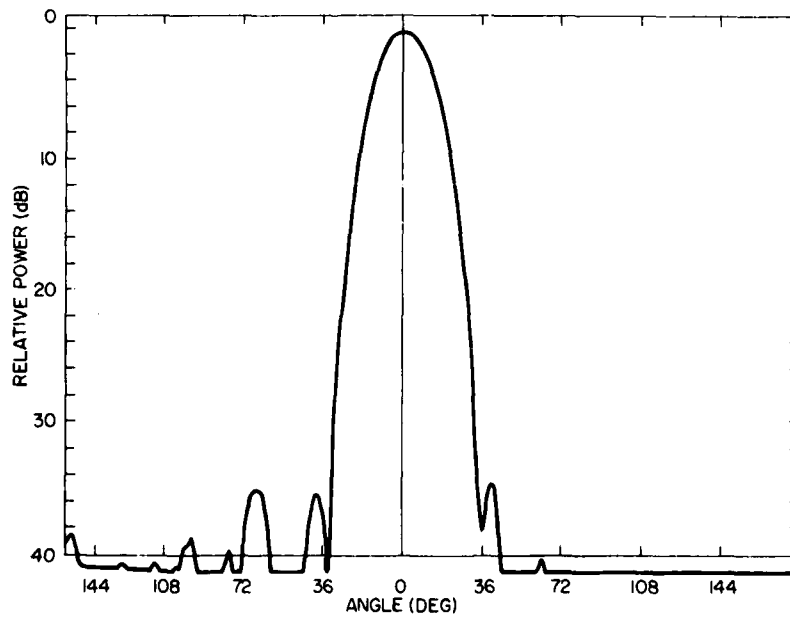


Figure 10. Primary Horn Pattern 10.3 GHz

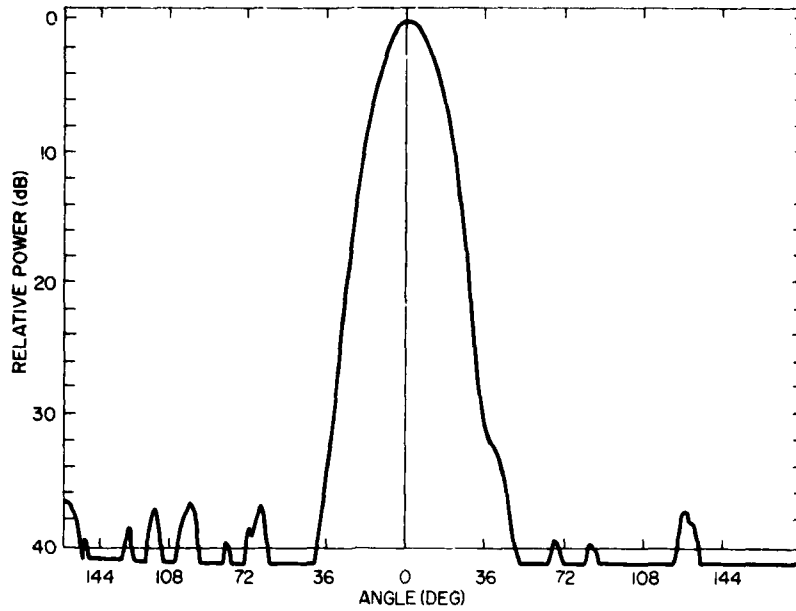


Figure 11. Primary Horn Pattern 10.5 GHz

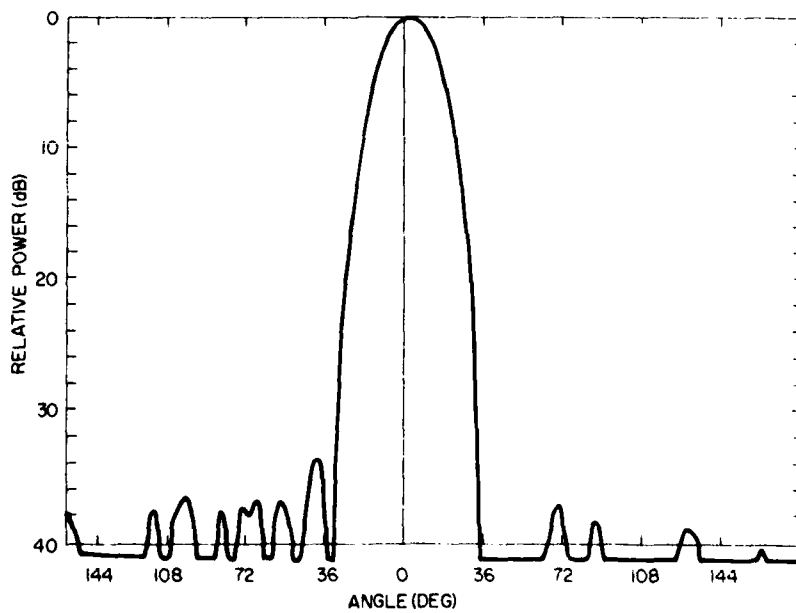


Figure 12. Primary Horn Pattern 10.7 GHz

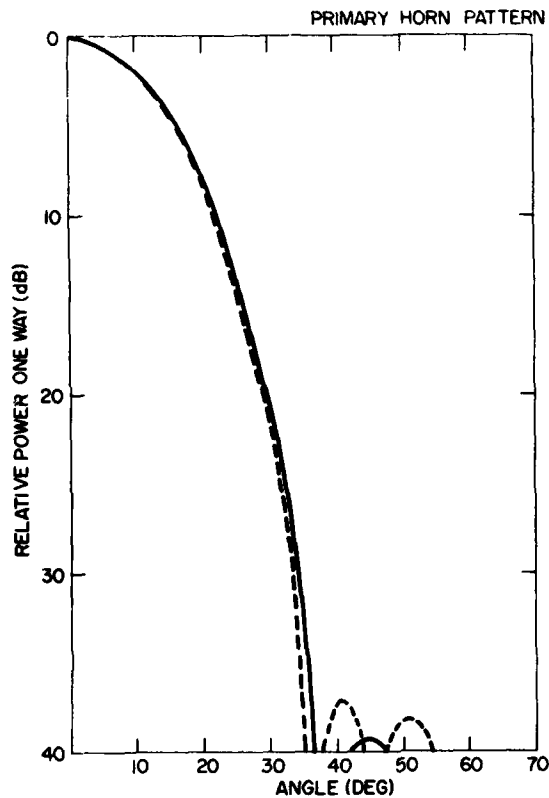


Figure 13. Theoretical Horn Pattern

4. FAR FIELD PATTERN

Figure 14 shows the antenna mounted on the Ipswich "round house" antenna positioner. This is an excellent location for an antenna positioner, since it is large and elevated enough to position the antenna in nearly any position required and there are no nearby sources of reflections at a comparable height. Both of these characteristics are required because the need to maintain a high-tolerance antenna led to a rather bulky structure. The size and weight of such a large antenna would make the taking of antenna patterns over 180° on a smaller antenna positioner very difficult. Also, since very small nearby reflectors can seriously affect the pattern sidelobes at the 50 dB level, the absence of nearby sources of reflection for this positioner was of great importance.

Again, because very little energy is needed to distort sidelobes at the 50 dB level, several additional techniques were employed to reduce possible sources of

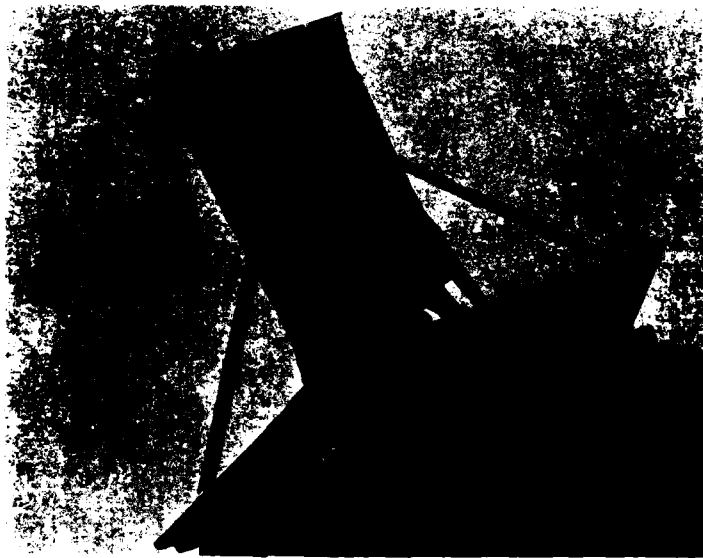


Figure 14. Pillbox Antenna on the Mount

error. First, the patterns were taken with an elevation scan only; that is, the main beam was pointed skyward and rotated 90° down towards the horizon and the transmitter. The antenna was then rotated over an azimuthal axis through 180° with the main beam still on the transmitter, and then the beam was scanned back up to zenith. By this measurement technique the main beam should receive ground scatter only when it is pointed at the transmitter. In other words, the sidelobes should have no main beam ground scattering in them. In addition, several other methods were used to reduce spurious scattering. These included the use of an absorber to reduce the amplitude of a feed horn sidelobe reflecting off the close-in sidewall. This effect produces a wide region of sidelobes near broadside.

In a similar fashion, the feed horn sidelobe on the other side radiates directly out the pillbox aperture, giving a broad single lobe at about 75° from the main beam, Figure 15. A piece of absorber placed between the horn aperture and the opposite edge of the pillbox aperture greatly reduced this lobe. There is, however, little room for this absorber, since placing it too close to the horn can affect the primary horn pattern, hence the illumination on the parabolic reflector and ultimately the low sidelobe pattern is degraded. On the other hand, a location too far from the horn will block the edge of the reflector, changing the illumination and thus the far-field pattern. The large piece of absorber required, however, raised the in-close sidelobes a significant amount. A small reduction in the

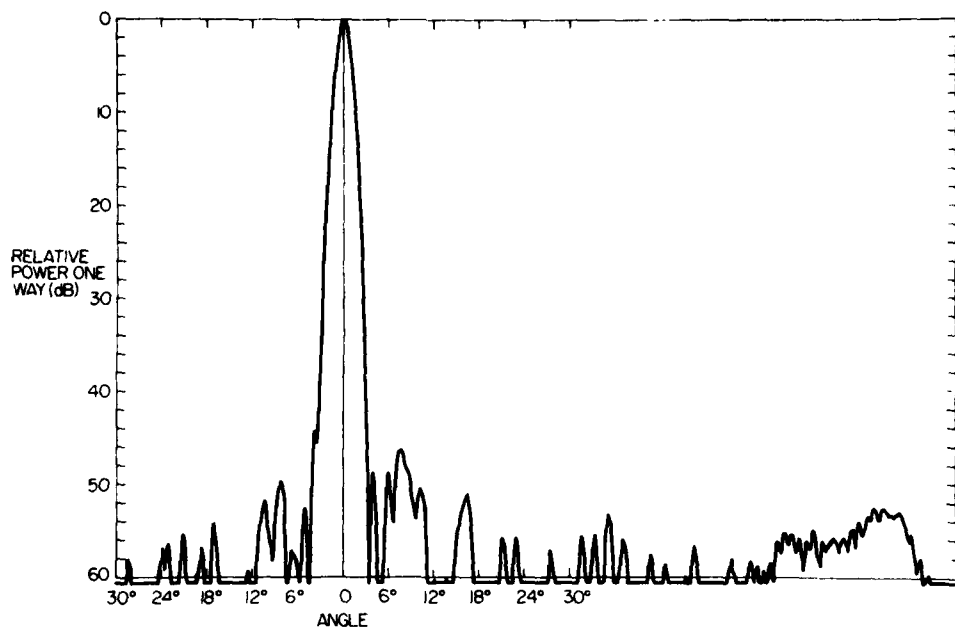


Figure 15. Antenna Pattern With Wide Angle Sidelobe at 10.1 GHz

average sidelobe level occurred with the use of chokes along the flared edges of the pillbox aperture. The chokes reduced the backscatter from the mount and supporting structure. Finally, the feed network that had all of its connecting junctions covered with metallic tape was also covered with absorber. This also reduced the sidelobe levels somewhat.

An examination of the primary horn pattern beamwidth at the 20 dB level at several frequencies indicates that this beamwidth varies more rapidly than the theoretical beamwidth. Comparing the in-close sidelobes behavior with frequency indicates that the variation in the beamwidth is the largest source of error remaining. Improvement might be possible by reducing the VSWR of the outer probes of the primary feed system.

Beyond these changes, another source of error is likely to be the absorber close to the feed horn rescattering energy. The final far-field patterns are shown in Figures 16 to 22. Again, a comparison with the theoretical pattern over the band indicates sidelobe levels are about 4 to 6 dB higher than the error-free theoretical sources. At frequencies of 9.3, 9.7, 10.1, and 10.7 GHz the deviation is less, and these are the frequencies of minimum primary horn pattern (20 dB beamwidths) discussed above. In general these patterns are quite close to the expected pattern, indicating very small residual errors remain.

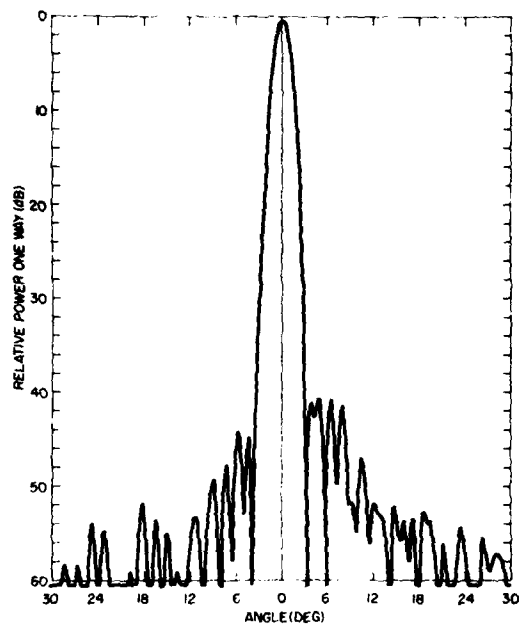


Figure 16. Antenna Far Field Patterns 9.3 GHz

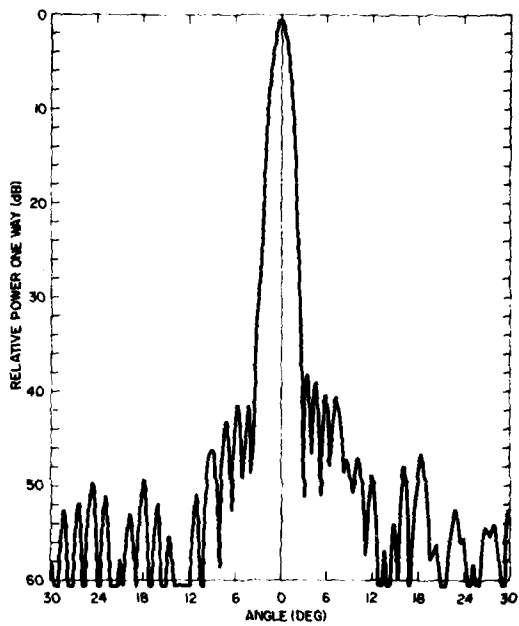


Figure 17. Antenna Far Field Patterns 9.5 GHz

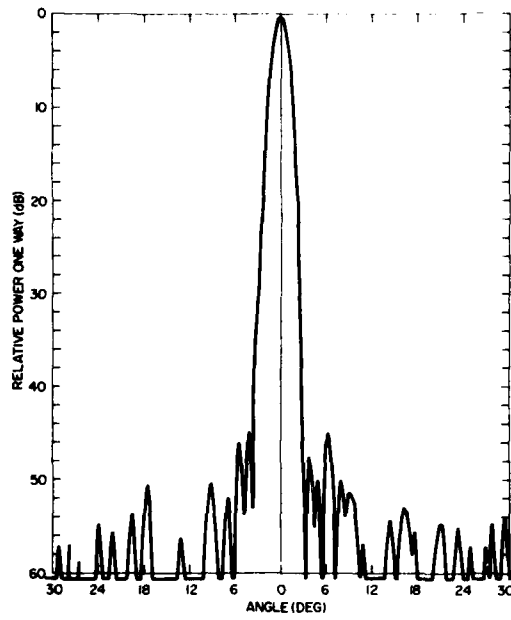


Figure 18. Antenna Far Field Patterns 9.7 GHz

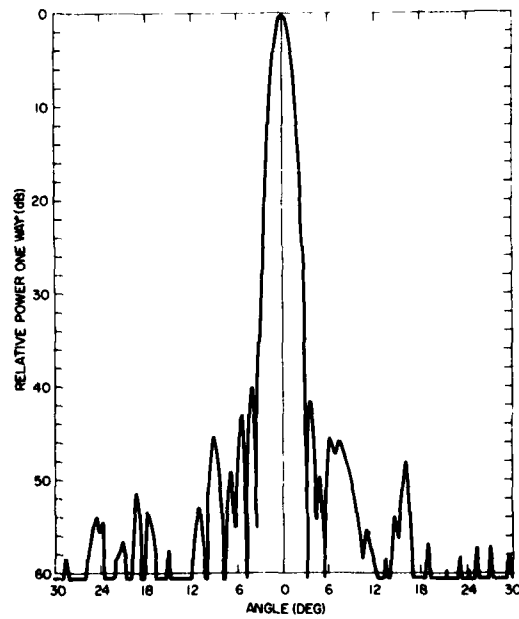


Figure 19. Antenna Far Field Patterns 9.9 GHz

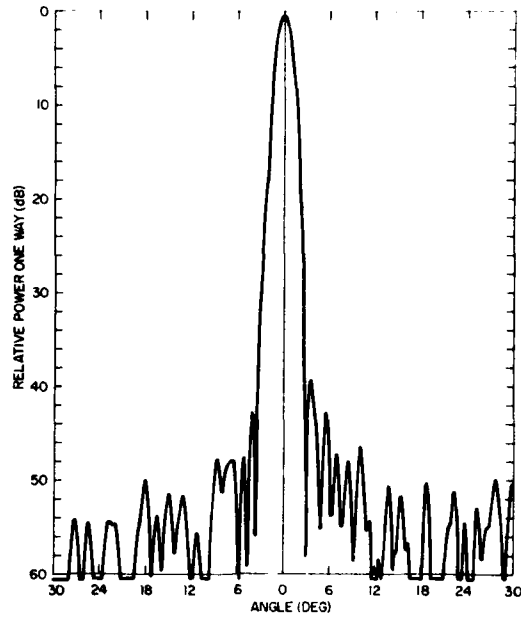


Figure 20. Antenna Far Field Patterns 10.3 GHz

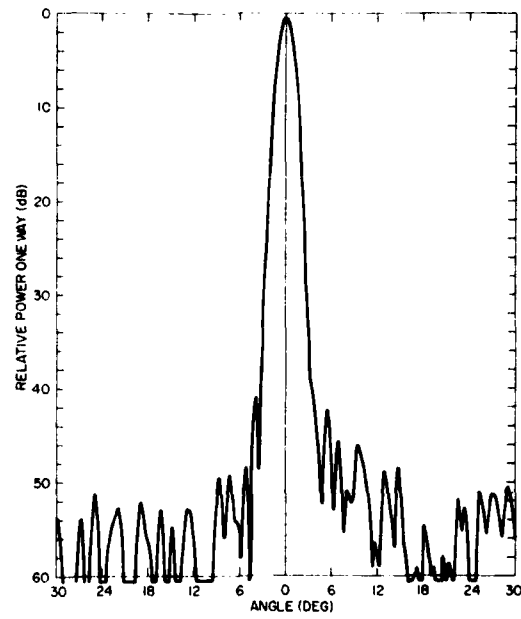


Figure 21. Antenna Far Field Patterns 10.5 GHz

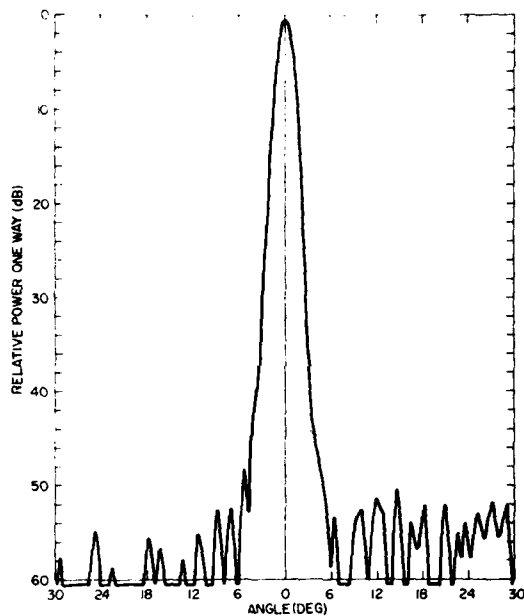


Figure 22. Antenna Far Field Patterns 10.7 GHz

5. CONCLUSION

The measurement program described here has demonstrated that an *offset* parabolic cylinder can yield 50 dB sidelobe patterns. Although wideband width was not a primary goal, good pattern performance over a wide band has resulted. Improved bandwidth is possible when greater emphasis is on the feed network, particularly at low frequencies.

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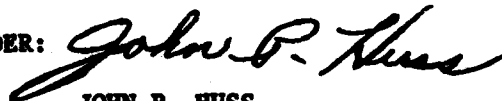
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