A PHYSICALLY SMALL DUAL CIRCULAR MICROSTRIP ANTENNA

James M. DeVries
Pacific Missile Test Center
Point Mugu, California 93042

ABSTRACT

The microstrip antenna has recently gained popularity because it offers the advantage of flush mounting, small size, and low cost when fabricated by etched circuit techniques. In an effort to further reduce the aperture requirements, two circular microstrip antennas were placed one on the other and fed independently. Utilization of the field null at the center of the circular disk antenna allows independent excitation. In this configuration, two different frequencies can be transmitted simultaneously while sharing the same physical aperture. Polarization of the antennas is linear with well behaved radiation patterns exhibiting gains of 6 dBi. Moderate power levels can be accommodated by selection of suitable substrates and control of dielectric thickness.

As a result of the reduced size, the antenna can now be placed in areas otherwise thought impractical. Placement in front of certain antennas or retrodirective reflectors has a very minor effect on their performance.

INTRODUCTION

The placement of antennas on small aircraft target drones is usually a difficult problem due to the limited space available for mounting. At lower microwave frequencies directional antennas become excessively large and highly impractical. When more than one antenna is required, the space for mounting becomes critical and isolation is a problem. Alternative solutions are to make a broadband antenna covering the frequency range of interest or provide independent antennas with a shared aperture.

The dual microstrip antenna solves the problem of providing moderate directivity for two independent antennas sharing the same aperture. Two circular microstrip antennas fed from the back and stacked one above the other provides a relatively small antenna area with gains of 6 dBi. Due to the small size, this combination can now be placed in areas otherwise thought unsuitable for larger antenna mounting.

ANTENNA DESIGN

The dual microstrip antenna was first referred to by Schaubert and Farrar (1) as the piggyback antenna. It consisted of two trapezoidal microstrip patches stacked to share a common aperture with two feed lines providing independent excitation. The circular microstrip antenna can also be utilized as the radiating element and stacked in a similar manner. This shape was chosen because it lends itself easily to placement in aerodynamic shaped radomes. The circular disk element is also a good choice because there exists a field null in the center of the disk such that grounding at the center does not upset the characteristics of the antenna. For this design example, the frequencies of the two antennas were selected to be 2.2 GHz and 8.0 GHz. The frequencies are far enough apart that the disk size for the lower frequency antenna will be large enough to serve as the ground plane for the higher frequency upper antenna. The larger disk is driven by an offset 50-ohm feed in the usual manner, while the smaller disk feed extends through the field null of the larger disk, grounding it at the center and using it as the ground plane for the smaller disk. The presence of the upper element has essentially no effect on the electrical characteristics of the lower element other than to lower its resonant frequency due to the dielectric covering. An illustration of the antenna is shown in figure 1.

The diameter of the circular disk governs the resonant frequency of the microstrip antenna. For the circular disk operating in the dominant TM_{11} mode, the radius is given (2) as a function of frequency, dielectric constant and substrate thickness as:

$$a = \frac{K}{\left[1 + \frac{2h}{\pi \varepsilon_r K}\left\{\ln\left(\frac{\pi K}{2h}\right) + 1.7726\right\}\right]^{\frac{1}{2}}}$$

$$K = \frac{8.794}{f_r\sqrt{\varepsilon_r}}$$

where: a = antenna radius (cm)

f_r = frequency (GHz)

h = substrate thickness (cm)

ϵ_r = dialectic constant of substrate

The driving point impedance of the antenna varies as a function of the radial distance from the center of the disk. The impedance varies from zero at the center to approximately 400 ohms at the disk edge for a dielectric substrate thickness of 0.157 cm (.062 inch). The impedance also decreases with decrease in dielectric substrate thickness. Matching to a 50-ohm connector can be accomplished by selecting the appropriate distance from the disk center (3) and connecting the feed from the back side of the antenna.

To ensure the dielectric is not stressed to breakdown under peak pulses of up to 500 watts, an analysis of the power handling capabilities was performed. The maximum field developed between the circular disk and the ground plane is calculated as follows:

$$E = \frac{\sqrt{2 P_p Z_0}}{h}$$

where: E = maximum voltage per unit thickness

P_p = peak power

Z_0 = characteristic impedance

h = dielectric thickness

The driving point impedance is a maximum at the edge of the disk, and for the high-frequency element is approximately 400 ohms. For the low-frequency element the impedance is 500 ohms. The electric field can then be calculated given dielectric thickness of 0.318 cm (0.125 inch) for the low-frequency element and 0.157 cm (0.062 inch) for the high-frequency element as:

$$E_\ell = 223 \frac{\text{volts}}{\text{mm}}$$

$$E_h = 402 \frac{\text{volts}}{\text{mm}}$$

The dielectric strength for the type of substrate used, PTFE glass reinforced (RT/Duroid 5870), is 11.8 KV/mm. This dielectric strength is well in excess of the electric fields developed and breakdown should not be a problem. The efficiency for the disk radiator is better than 98 percent at this frequency and average power dissipation is not a problem when the antenna is backed by an aluminum disk.

The antenna was etched from RT/Duroid 5870 type dielectric material and mounted in the tip of an electrically transparent radome, as shown in figure 2. Return loss and isolation measurements were performed to determine the performance of the device over the bandwidth of interest. Figure 3 shows that the return loss of the low-frequency element is greater than 10 dB over a 3.7 percent bandwidth with isolation greater than 40 dB. For the high-frequency element, shown in figure 4, the bandwidth of return loss greater than 10 dB, is 5.7 percent with isolation greater than 18 dB. Antenna field patterns are shown in figures 5 and 6 for the azimuth and elevation planes of the low-frequency antenna. The upper element for high-frequency operation has no apparent effect on the radiation pattern of the lower element. Field patterns are shown for the high-frequency antenna in figures 7 and 8. The field in the H-plane (elevation) is slightly distorted on the left side due to radiation from the feed probe. A thinner dielectric would reduce the effect of radiation from the feed probe. The advantage of combining the two circular apertures can be realized in the mounting of the antenna. As shown in figure 2, the antenna can be mounted at the apex of a small radome with the remainder of the radome used for other devices. To demonstrate the principle, the antenna was mounted in the apex of the radome with a 6-inch Luneberg lens behind it. Figure 9 shows the reflectivity pattern of the reflector with and without the antenna in place. The only effect of the antenna on the reflectivity pattern of the Luneberg lens is a slight disturbance of less than 2 dB for the on-axis aspect.

CONCLUSIONS

The dual circular microstrip antenna has proved to be a very useful design when two antennas at different frequencies are to be placed in a small space. The antennas provide gains of 6 dBi and can radiate moderate levels of power. The low cost of fabrication makes them an attractive alternative for use in expendable applications.

REFERENCES

1. Schaubert, D. H. and F. G. Farrar, “Some Conformal, Printed Circuit Antenna Designs,” Proc. Workshop on Printed Circuit Antennas. Oct. 1979, pp. 5.1-5.21.

2. Bahl, I. J. and P. Bhartia, Microstrip Antennas, Artech House 1980, pp. 119.

3. Ibid pp. 95.

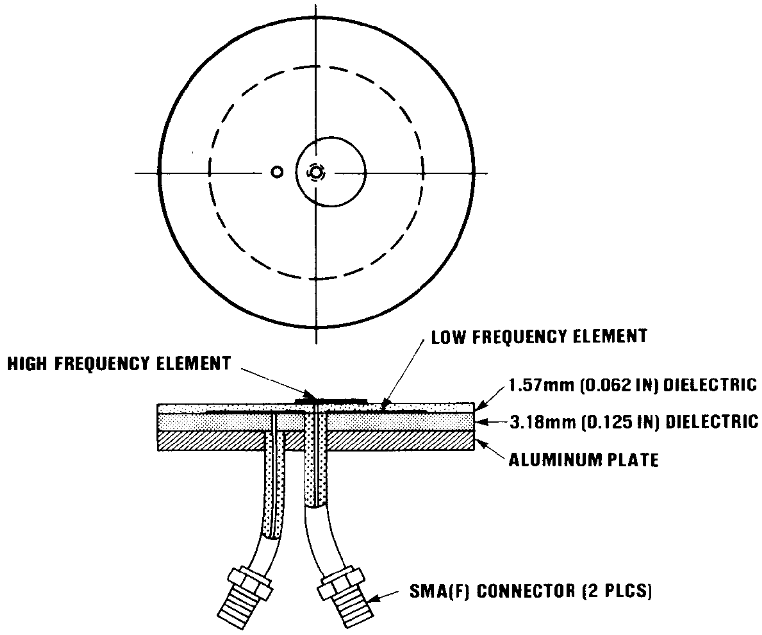

FIGURE 1. DUAL CIRCULAR MICROSTRIP ANTENNA CROSS SECTION

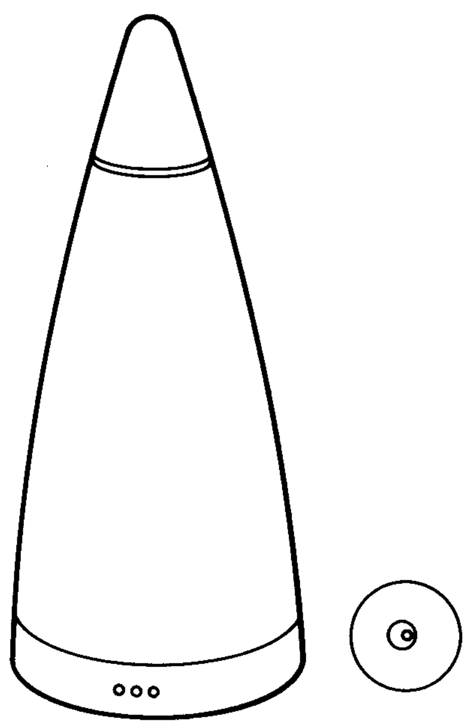

FIGURE 2. DUAL CIRCULAR MICROSTRIP ANTENNA AND RADOME

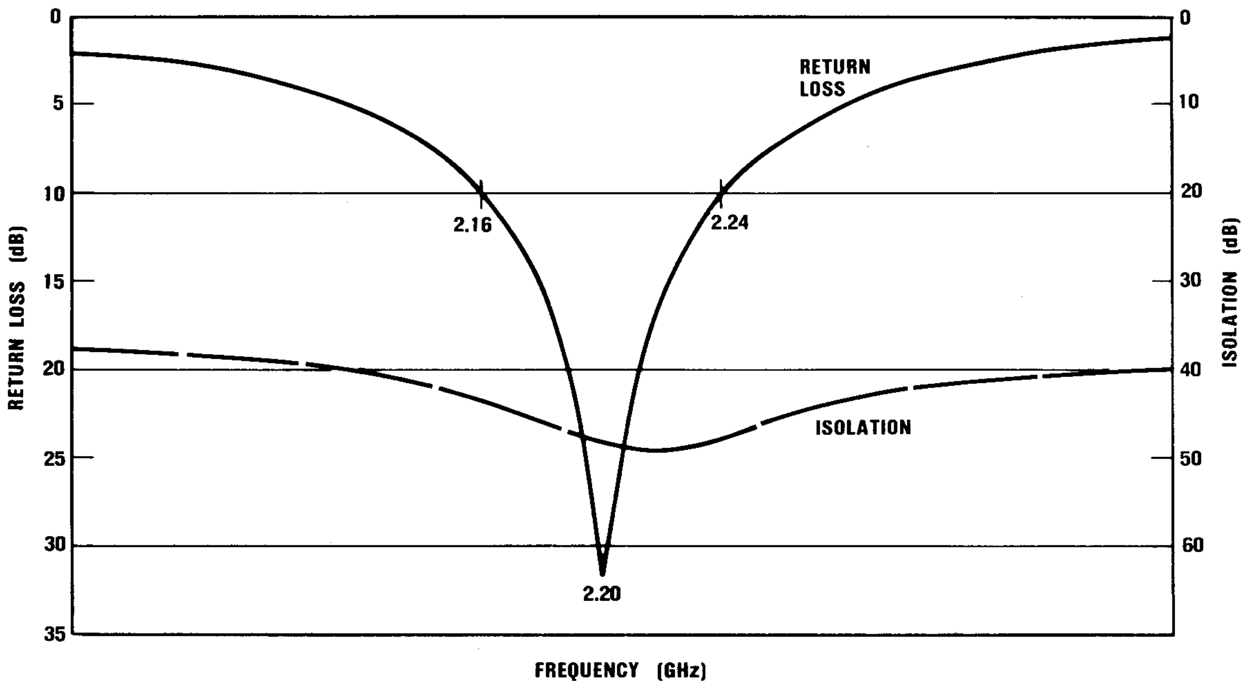

FIGURE 3. RETURN LOSS AND ISOLATION LOW FREQUENCY ANTENNA

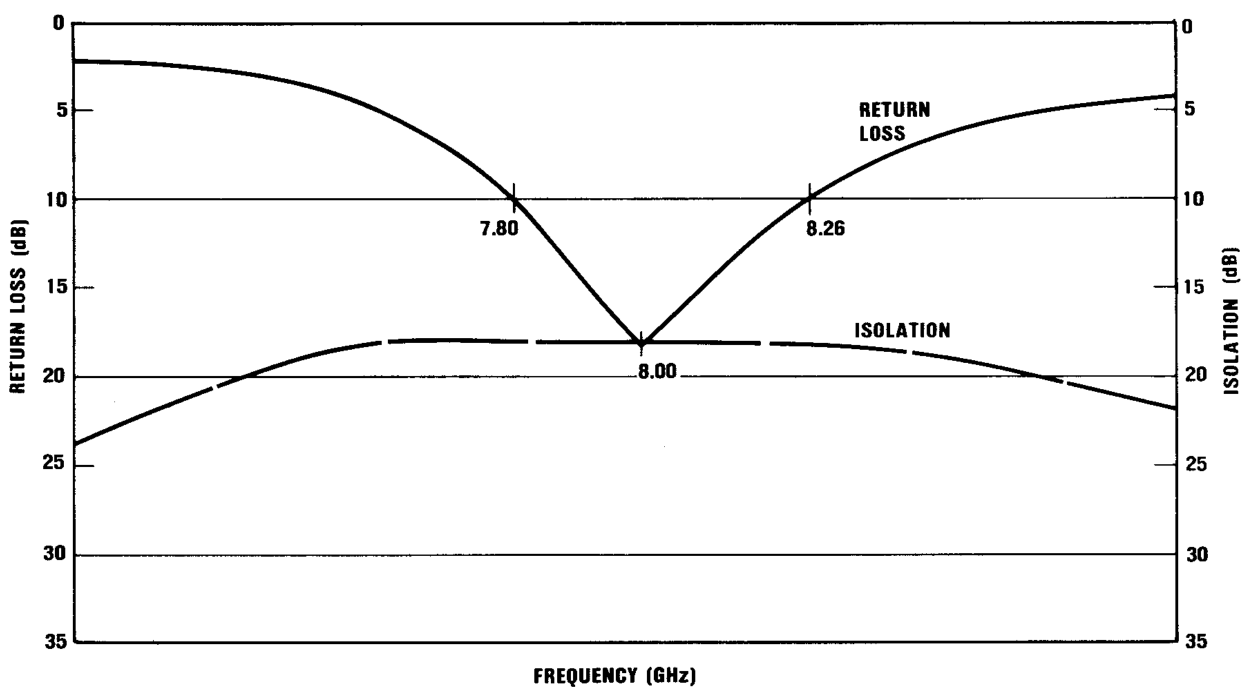

FIGURE 4. RETURN LOSS AND ISOLATION HIGH FREQUENCY ANTENNA

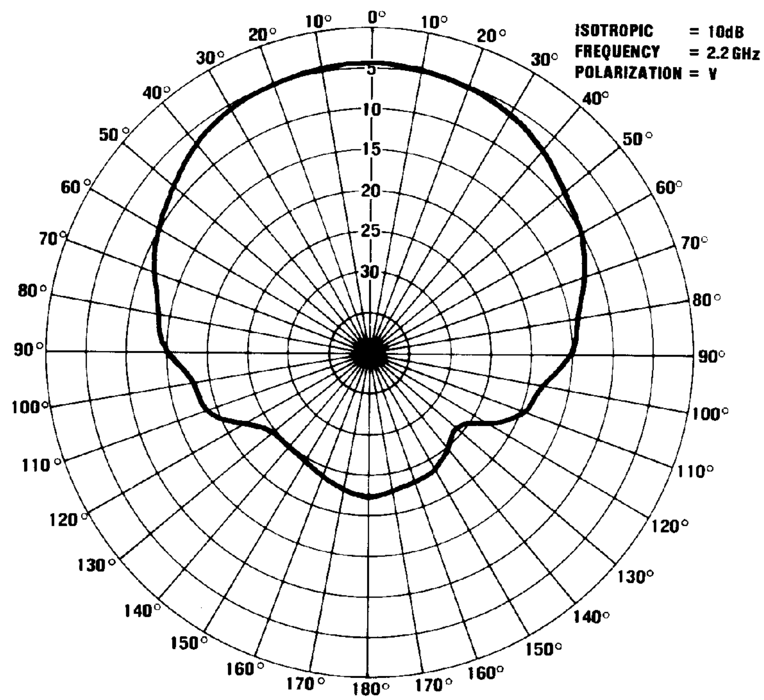

FIGURE 5. ANTENNA PATTERN LOW FREQUENCY AZIMUTH

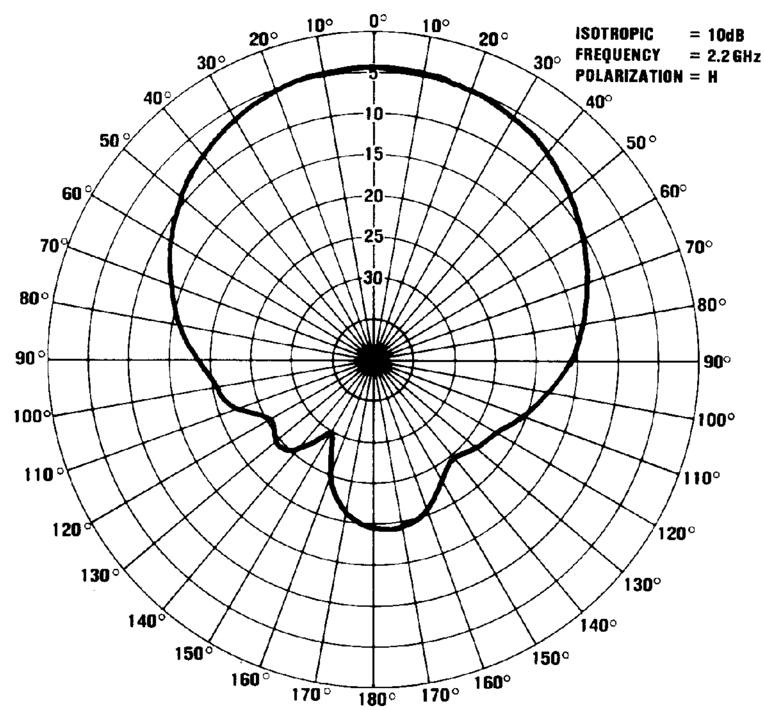

FIGURE 6. ANTENNA PATTERN LOW FREQUENCY ELEVATION

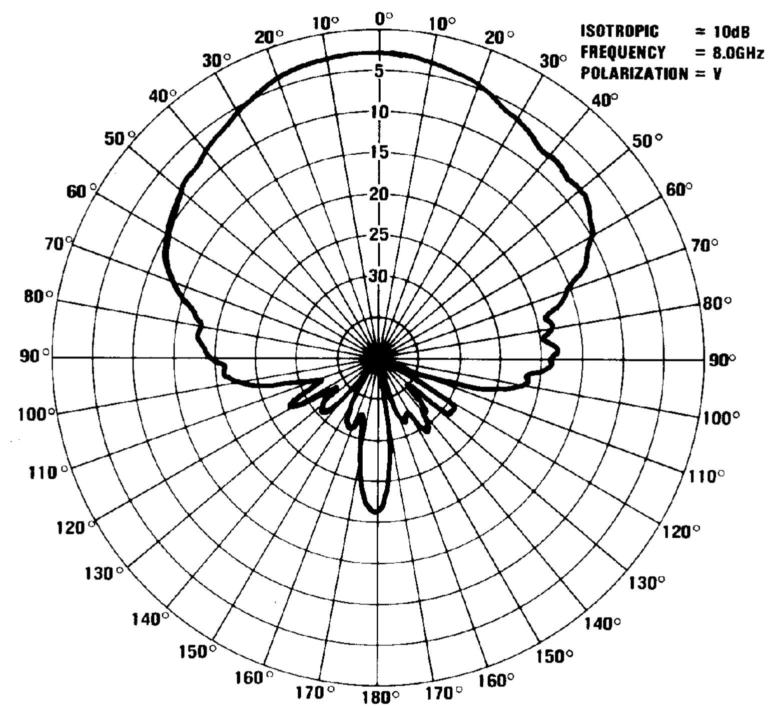

FIGURE 7. ANTENNA PATTERN HIGH FREQUENCY AZIMUTH

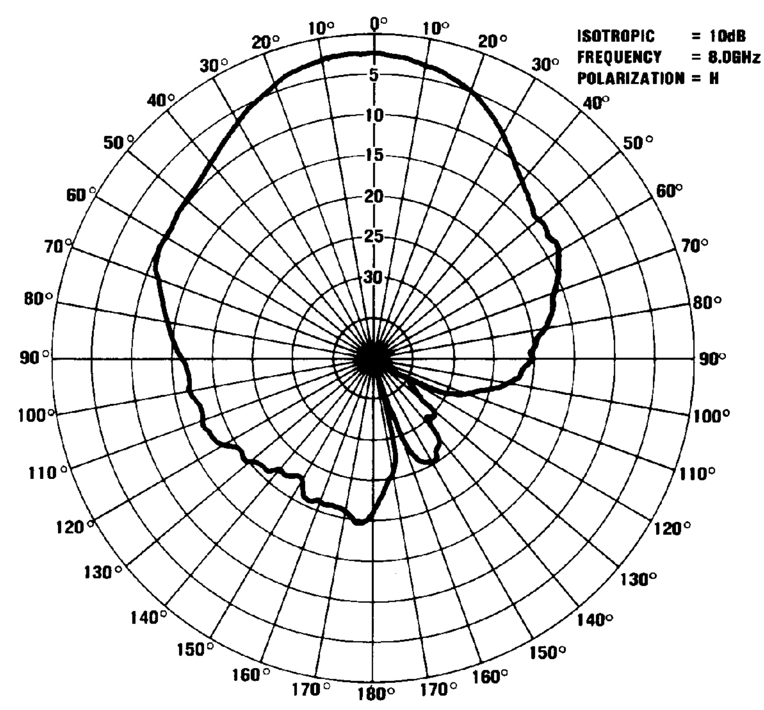

FIGURE 8. ANTENNA PATTERN HIGH FREQUENCY ELEVATION

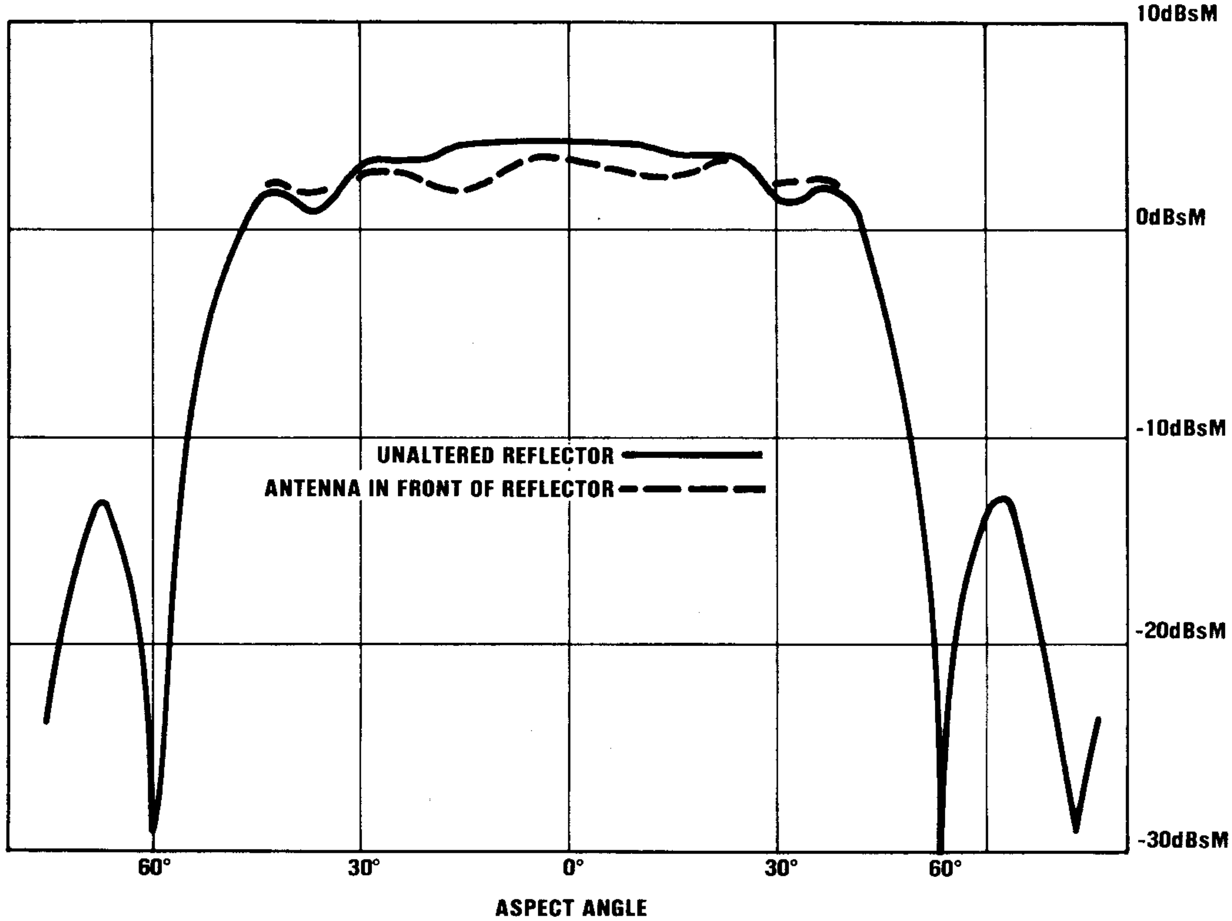

FIGURE 9. RADAR CROSS SECTION REFLECTOR