A 95 GHz ARCTIC SURFACE-EFFECT VEHICLE ANTENNA AND RADOME

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I. Introduction

An antenna and a radome have been developed at 95 GHz for use in evaluating certain terrain-avoidance radar techniques that are contemplated for an arctic surface-effect vehicle (SEV) radar. The antenna and radome are both physically and electrically large yet they maintain their performance over a wide range of environmental conditions. The pillbox antenna produces a $0.1^{\circ} \times 1.5^{\circ}$ fan beam with 51 dB of gain. An unusual feature of the antenna is that its beam is focused in the Fresnel zone to improve short-range resolution. The 13.4 foot diameter metal space frame radome introduces less than 1 dB insertion loss and no detectable boresight shift.

II. Antenna Characteristics

The terrain-avoidance techniques planned for the Applied Physics Laboratory 95 GHz SEV radar require a $0.1^{\circ} \times 1.5^{\circ}$ fan beam antenna. This beam can conceptually be produced by a number of simple antenna geometries such as a pillbox, a hog horn feeding a parabolic cylinder, or a dielectric lens corrected horn. Since the antenna will be subjected to vibration and quite probably thermal stress, it is necessary that the structure be stiff in order to maintain the requisite shape and alignment. The pillbox geometry was selected because (1) the reflector shape could be more easily maintained, (2) the primary feed could be aligned easily, and (3) the focal point and reflector shape tend to be self compensating with temperature if the same metal is used throughout the structure.

A conceptual drawing of the pillbox that was fabricated is shown in Figure 1. A primary feed horn having a 0.165 inch H-plane by 0.245 inch E-plane aperture is placed near the focal point of a 35 inch focal length, 100 inch long parabolic reflector. The parallel plates are 1/3-inch thick pure aluminum (Alclad) with the polished surface on the active side. The parallel plates are spaced $2\lambda = 0.250$ inch apart to reduce I^2R loss. No moding problems were encountered with the oversized spacing. The parallel plates were tapered down to 0.050-inch spacing in the cylindrical bend region and then flared to a line-source feed with a 0.280 inch E-plane by 100 inch H-plane aperture. A 0.005-inch thick Mylar radome covers this line source horn. The line source feed illuminates a 5.8 inch high by 100 inch long parabolic cylinder reflector. The primary feed is moved away from the parabolic reflector by approximately 0.030 inch in order to focus the beam at 4400 feet and thus improve short range resolution.

The antenna pattern was measured at 1000 feet, 4400 feet and 2 1/8 miles ($2D^2/\lambda = 2.5$ miles) and over a -20°F to $+80^{\circ}$F temperature range. A tabulation of measured performance is given in Tables I through IV. Calculated I^2R loss in the parallel plates is 0.9 dB. Measured VSWR is less than 1.3:1 over 93.5 to 96.0 GHz. A typical H-plane pattern is shown in Figure 2. Beyond about $\pm 10^{\circ}$ from the main beam the H-plane sidelobes were at least -40 dB.

III. Radome Characteristics

The 95 GHz antenna is protected from the hostile arctic environment by a 13.4 foot diameter radome developed by ESSCO Corp., Concord, Mass. The radome is a metal space frame design, i.e. it consists of webbs of pseudorandomly placed metal members holding triangular shaped dielectric membranes. The membrane material is ESSCOLAM V, a strong dielectric with a dielectric constant of 2.8 and a loss tangent of 0.012 (at 95 GHz). The material thickness is $\lambda/2$ at 95 GHz. The membrane surface is coated with TEDLAR to prevent water adherance. The metal members are rectangular in cross section with dimension 0.35 inches x 1.15 inches with the long dimension toward the antenna. The longest member is 33.6 inches in length. The radome is designed to operate in 150 mph wind and over a temperature range of -65°F to $+140^{\circ}$F. It will withstand an ice and snow load of 75 psf. A blower system prevents the formation of ice on the radome surface by circulating air within the radome surface.

An extensive series of tests were conducted on the antenna/radome combination. It was determined that the radome insertion loss was less than 1 dB as had been theoretically predicted. No boresight shift was detected indicating it was certainly less than 0.1 beamwidths, i.e. $<0.01^{\circ}$. Changes in levels of 20 dB sidelobes were less than 1 dB, 25 dB sidelobes were changed less than 2 dB, and 30 dB sidelobes were changed 5 dB. An extensive stress analysis and thermal analysis was conducted and indicated a conservative mechanical design.

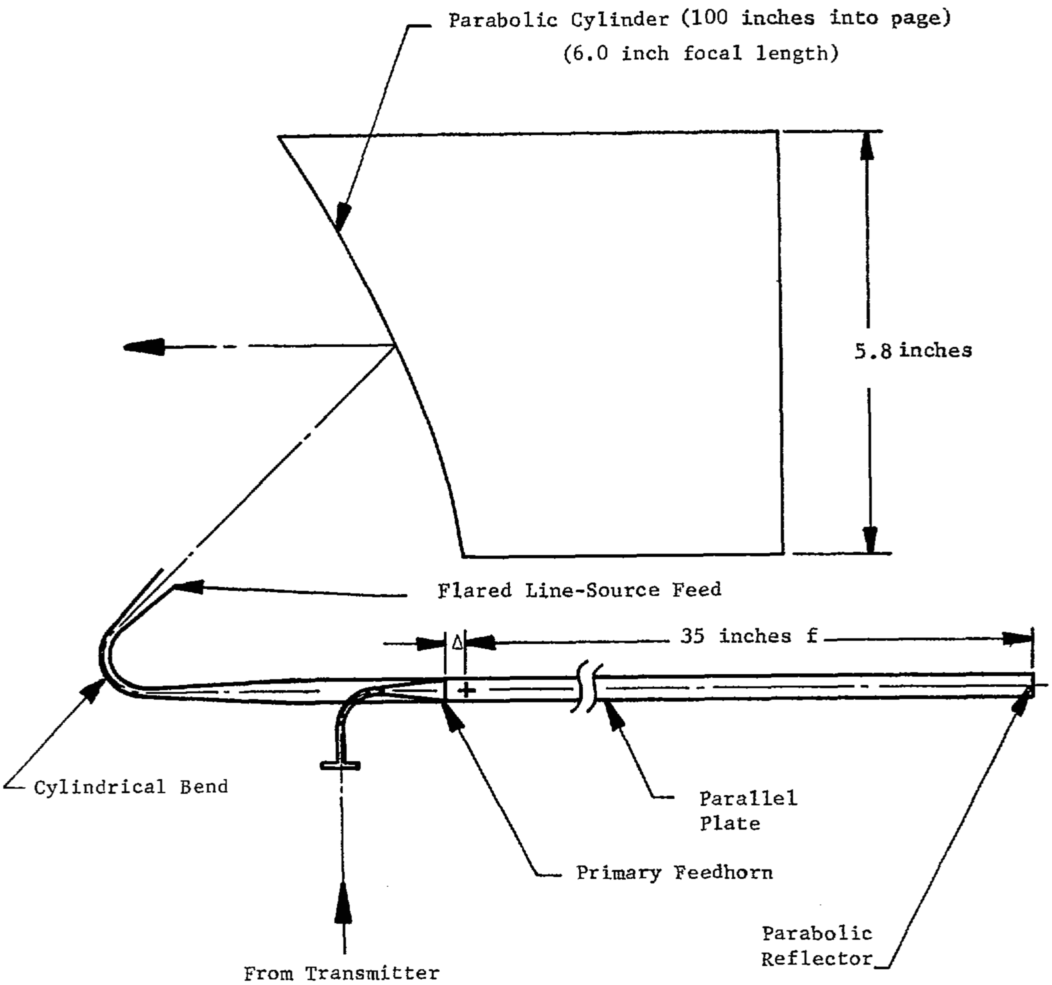

Figure 1. Antenna configuration consisting of primary feed, pillbox, line-source feed, and parabolic cylinder.

TABLE I

Gain, beamwidth, and sidelobes at
$50^{o}F$ and at a range of 2-1/8 miles.

Freq. (GHz)	Gain (dB)	Beamwidth		Sidelobe Level (dB)	
		H-Plane	E-Plane	H-Plane	E-Plane
95.0	48.9	0.11^{o}	1.49^{o}	-28.2	-22.0

TABLE II

Gain, beamwidth, and sidelobes at
$55^{o}F$ and at a range of 1000 feet.

Freq. (GHz)	Gain (dB)	Beamwidth		Sidelobe Level (dB)	
		H-Plane	E-Plane	H-Plane	E-Plane
95.0	47.6	0.15^{o}	1.45^{o}	-27.0	-21.0

TABLE III

Gain, beamwidth, and sidelobes averaged
over 93.5 to 96.0 GHz at a range of 4400 feet.

Temp. (^{o}F)	Measured Gain (dB)	Corrected Gain* (dB)	Beamwidth		Sidelobe Level (dB)	
			H-Plane	E-Plane	H-Plane	E-Plane
-20	49.8	51.8	0.11^{o}	1.47^{o}	-26.2	-20.3
0	50.4	51.6	0.11^{o}	1.47^{o}	-26.1	-20.7
+70	51.3	51.3	0.11^{o}	1.47	-27.0	-20.7

TABLE IV

Gain, beamwidth, and sidelobes averaged
over temperature and frequency at a range
of 4400 feet.

Measured Gain (dB)	Corrected Gain (dB)	Beamwidth		Sidelobe Level (dB)	
		H-Plane	E-Plane	H-Plane	E-Plane
50.5	51.6	0.11^{o}	1.47^{o}	-26.4	-20.5

*Gains measured with heavy frost on both the line-source radome and on the parabolic-cylinder reflector have had 2dB added to them.

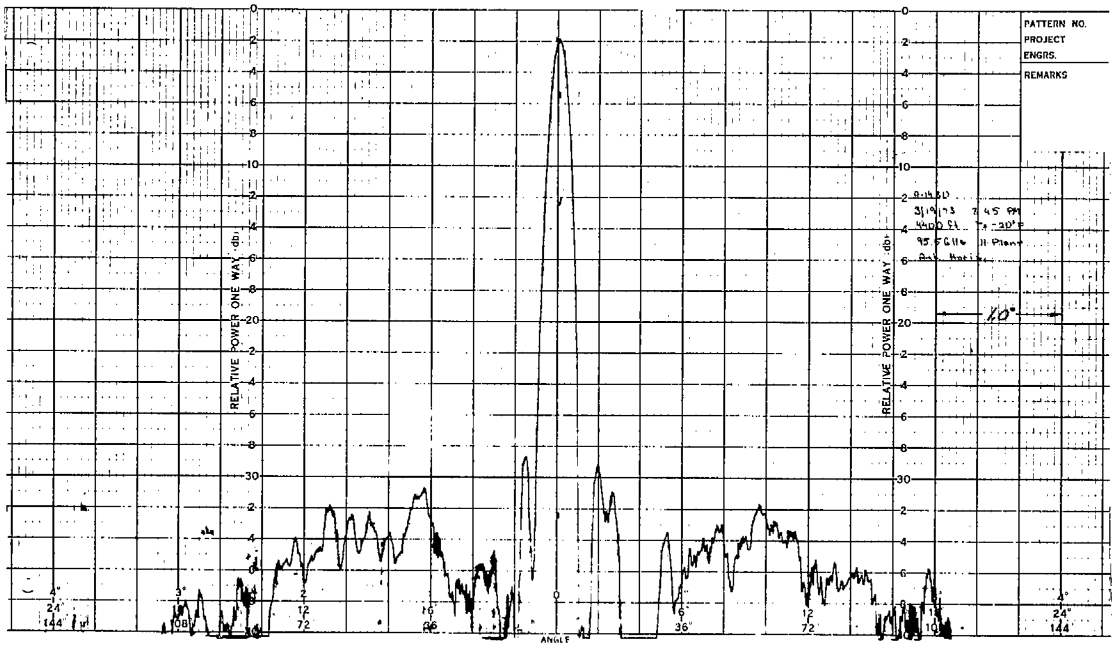

Figure 2. Expanded H-plane antenna pattern at 95.5 GHz on 4400 foot range with temperature at -20° F.