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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/21273838
Report (National Research Council of Canada. Radio and Electrical Engineering Division : ERB), 1960-06

ERB-551

UNCLASSIFIED

NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

TESTS ON A POLYURETHANE FOAM RADOME OVER A QUADRADAR

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JUNE 1960

ABSTRACT

A polyurethane foam radome was tested electrically for the Royal Canadian Air Force over the Quadradar, an X-band radar set. Transmission loss varied from $1\frac{1}{2}$ to 3 percent as the radome was rotated about the antennas. An increase of 0.7 db was measured on a -24 db side lobe of the azimuth antenna. Increases of 1.5, 0.6, and 0.9 db were measured on -27, -24, and -29 db side lobes of the elevation antenna. Boresight tests on the radome showed a ±0.4 milliradian shift of the beam from the azimuth antenna and a ±0.24 milliradian shift of the beam from the elevation antenna. The radome meets all requirements.

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TESTS ON A POLYURETHANE FOAM RADOME OVER A QUADRADAR

- W. Lavrench -

INTRODUCTION

At the request of the Royal Canadian Air Force, electrical tests were made on a polyurethane foam radome over the antennas of the Quadradar.

The Quadradar operates at X-band frequencies and serves as a height-finder, a search radar, and a precision approach radar. The two antennas, azimuth and elevation, are mounted on a case containing the transmitter and receiver group. This assembly is normally situated alongside the runway or runways that are to be used for precision approach. At many of the Canadian sites such an exposed location of the radar poses servicing problems during the winter. Because of this, the use of a radome over the set is being considered.

Previous X-band tests on stressed skin and foam radomes indicated the superiority of the latter at this frequency. Furthermore, at the time when a radome was first considered for the Quadradar, a polyurethane foam radome of a suitable size (26 foot diameter) was under test at the National Research Council at C-band frequencies. These tests were discontinued temporarily and measurements were made of the effect of this radome over the Quadradar antennas. It was specified by the RCAF that the presence of a radome over the Quadradar should not reduce the radar range by more than 10 percent. It was also required that the maximum allowable shifts in the azimuth and elevation beams were 0.2° and 0.1°, respectively.

THE QUADRADAR

This radar makes use of two separate antennas (see Plate I). The azimuth antenna is a horn-fed reflector three feet high and nine feet wide. It produces a beam with a horizontal width of 0.95° and a vertical width of 3.5° to the half-power points and a cosecant-squared pattern to 30°. This antenna rotates 360° during search use and oscillates in azimuth during precision approach. The elevation antenna is a horn-fed reflector 10 feet high and $2\frac{1}{2}$ feet wide. This antenna produces a beam with a horizontal width of 2.5° and a vertical width of 0.85°. The antenna oscillates in the vertical plane and can be swiveled in azimuth to point in the required direction.

THE POLYURETHANE FOAM RADOME

The radome under which the above antennas were tested is 26 feet in major diameter and is constructed of diamond-shaped panels (see Plate II). The thickness of the panels is $3\frac{1}{2}$ inches. The diagonal dimensions of a typical panel are 56 and 83 inches. During manufacture the edges of the panels were machined to form a cavity between two adjacent panels on assembly. After the radome was completely assembled,foam was introduced into these cavities to bond the panels. The density of the foam used in the joints was the same as that in the panels. This was done to reduce discontinuities in the radome wall and thereby improve its performance. Each ring of the radome is formed of 12 panels. Thus there is a 30-degree repetition in the geometry of the radome.

RADOME TESTS

During the tests only the two antennas and their mounts were used. The antennas were mounted on a steel tower in the radome to occupy the same position that they would have in actual practice. The tests performed included measurement of transmission loss, antenna pattern deterioration, andbeam shift produced by placing the radome over the antennas.

i) Transmission Loss

The loss in transmission produced by the radome was checked by comparing the amount of signal received from a distant transmitter with, and without the radome over the antenna. The radome was also rotated about the antenna to check the variation in transmission for different radome-antenna orientations. Both of the Quadradar antennas were tested in this fashion. The reduction in field strength was found to vary from $1\frac{1}{2}$ to 3 percent. There is an uncertainty of about 1 percent due to line voltage fluctuations caused by the turntable drive motors. Nevertheless, it can be stated that the loss is very close to 2 percent. This was established in the following pattern tests during which the motors were not used.

ii) Antenna Radiation Patterns

Antenna patterns were taken by swinging the antenna in question and plotting the variation of the received signal with, and without the radome over the antenna. This test was performed on both the azimuth and the elevation antennas.

Fig. 1 is a reproduction of the pattern obtained with, and without the radome over the azimuth antenna. Very little change in the pattern, other than a 2 percent drop in received signal, is evident. Fig. 2 is a repetition of Fig. 1; however, in this case the transmitted signal strength was increased by 20 db in order to study the side lobes. The main beam extends beyond the top of the chart by a factor of ten, but this is of no concern. It will be noted that of the two largest side lobes, the height of the 9.5 percent (-20.5 db) side lobe has been slightly reduced and the height of the 6.6 percent (-23.6 db) side lobe has been increased by the radome. The increase in this case is 0.7 db.

Results of similar tests on the elevation antenna are shown in Figs. 3 and 4. Fig. 3 shows a regular set of patterns with, and without the radome. Again a loss of 2 percent is evident on the peak of the main beam.

The transmitted signal was increased 20 db to obtain the patterns of Fig. 4. In this instance, the left end of the pattern was obtained when the elevation antenna pointed down towards the ground. Consequently this portion of the pattern is not very reliable. On the other side of the main beam, it will be noted that the amplitude of the first and third side lobes has been reduced and that of the second, fourth, and fifth side lobes has been increased. The increases amount to 1.5, 0.6, and 0.9 db at the -27, -24, and -29 db levels, respectively.

iii) <u>Beamshift</u>

Tests were carried out to check the beam shift produced by the radome. For these tests the feeds in the antennas were modified to produce twin beams in the vertical plane from the elevation antenna, and twin beams in the horizontal plane from the azimuth antenna. This was done by placing two closely spaced horns at the focus of the reflectors. Signals picked up by the two horns were detected and then compared in a difference circuit. In this manner a sharp null in the difference signal occurs when the antenna is positioned in such a manner as to give equal signals in the two horns. A subsequent shift of the beam (by the radome, for example) will increase the output of one horn and decrease that of the other, thereby producing an error signal proportional to beam shift. This error signal is plotted by a recorder.

When the beam is shifted in the opposite direction, the signal is decreased in the first horn and increased in the second. This results in an error signal of opposite polarity which drives the pen in the other direction. In this way left-right shifts of the azimuth beam and up-down shifts of the elevation beam are resolved. The entire system is calibrated by moving the distant transmitter antenna by known amounts and noting the pen deflection on the recorder.

Fig. 5 is a plot of the horizontal boresight shift obtained as the radome is rotated about the azimuth antenna. The maximum beam swing is ±0.4 milliradians (± 0.023°). A 30-degree period can be seen in the plot indicating that the panel joints are the chief cause of the beam shift.

Fig. 6 is a plot of the vertical boresight shift as the radome rotates about the elevation antenna. Again a 30-degree period is evident. In this case the beam shift is ± 0.24 milliradians (± 0.014°).

CONCLUSIONS

The estimated requirements to be met by a radome over a Quadradar and the measured values are listed in the following table.

TABLE I

COMPARISON OF MINIMUM RADOME REQUIREMENTS AND MEASURED PERFORMANCE

Item	Required Performance	Measured Performance
Transmission Loss (Radar range reduction)	Not more than 10%	2%
Beam Shift:		
Azimuth	± 0.2°	± 0.4 mils (± 0.023°)
Elevation	± 0.1°	± 0.24 mils (± 0.014°)
Side Lobe Increase	Not specified	Azimuth antenna: -24 db side lobe up, 0.7 db Elevation antenna: -27, -24, and -29 db side lobes up 1.5, 0.6, and 0.9 db, respectively

It is apparent that the polyurethane foam radome meets the requirements and can be recommended for this application.

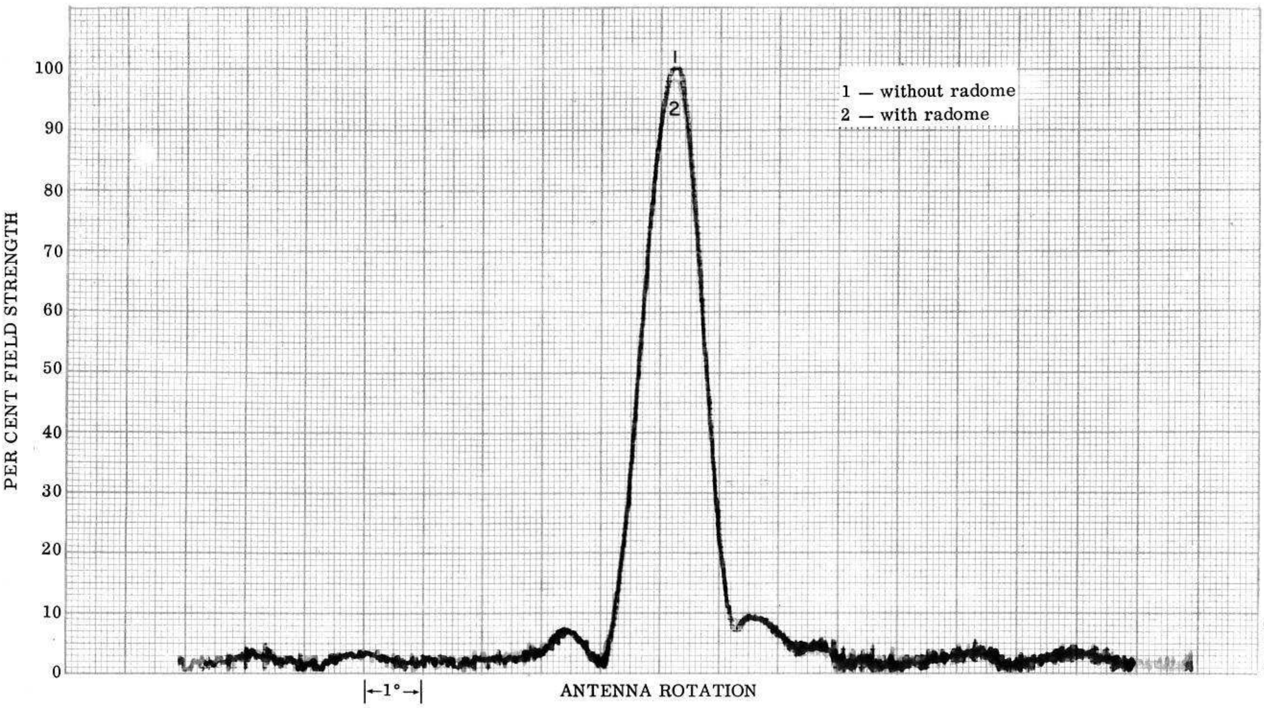

FIG. 1 HORIZONTAL RADIATION PATTERN OF AZIMUTH ANTENNA

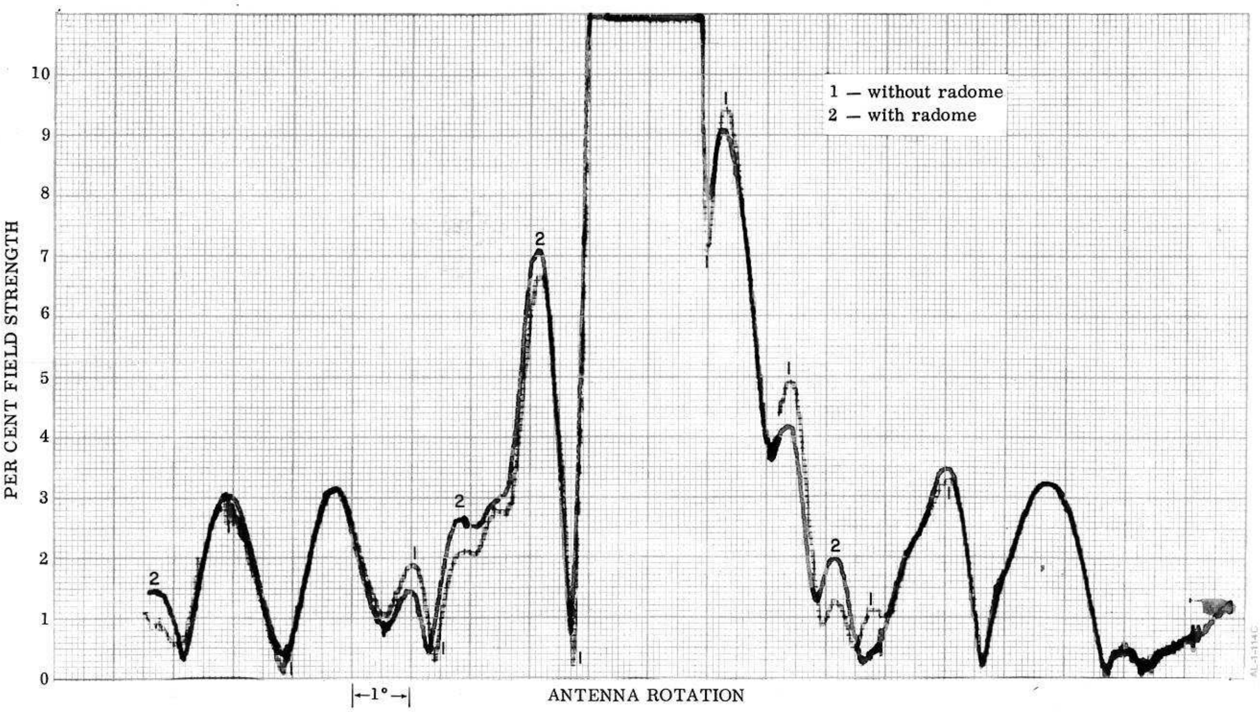

FIG. 2 HORIZONTAL RADIATION PATTERN OF AZIMUTH ANTENNA
(expanded 20 db)

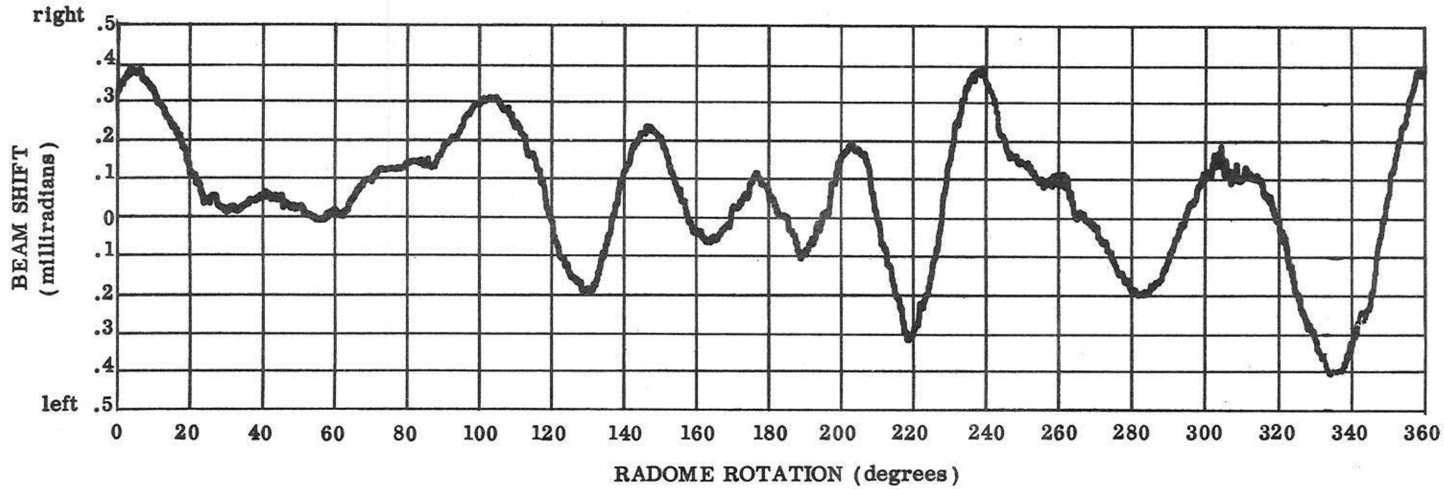

FIG. 5 HORIZONTAL SHIFT OF AZIMUTH BEAM

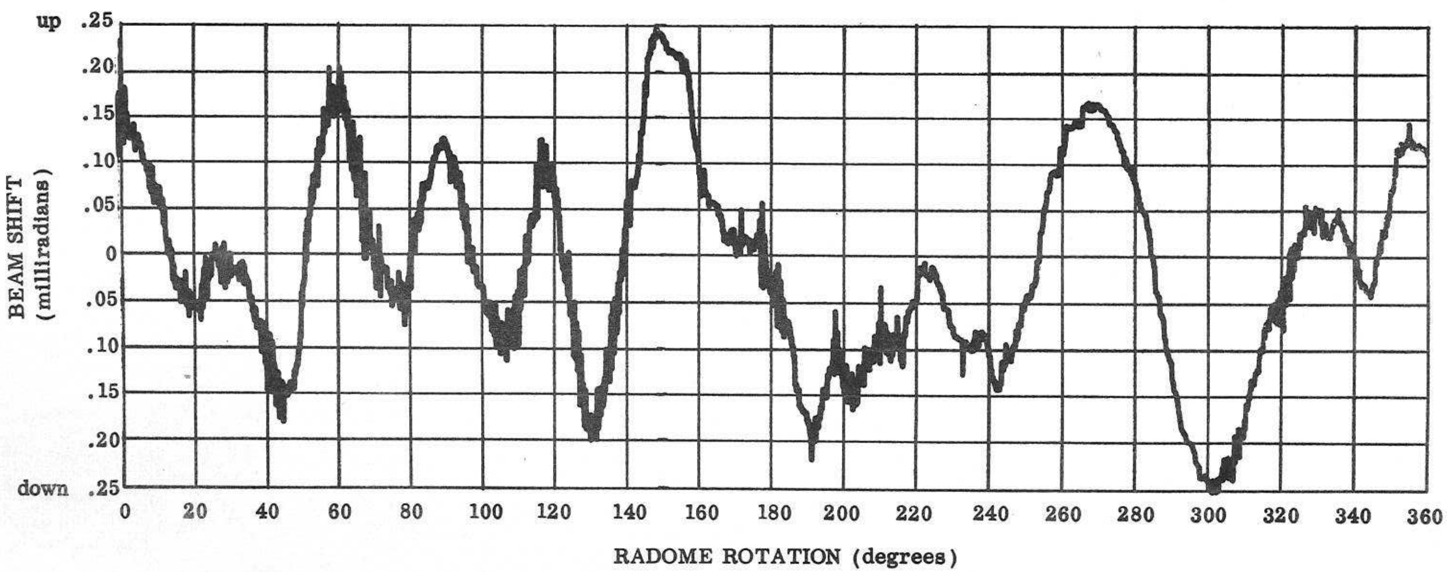

FIG. 6 VERTICAL SHIFT OF ELEVATION BEAM

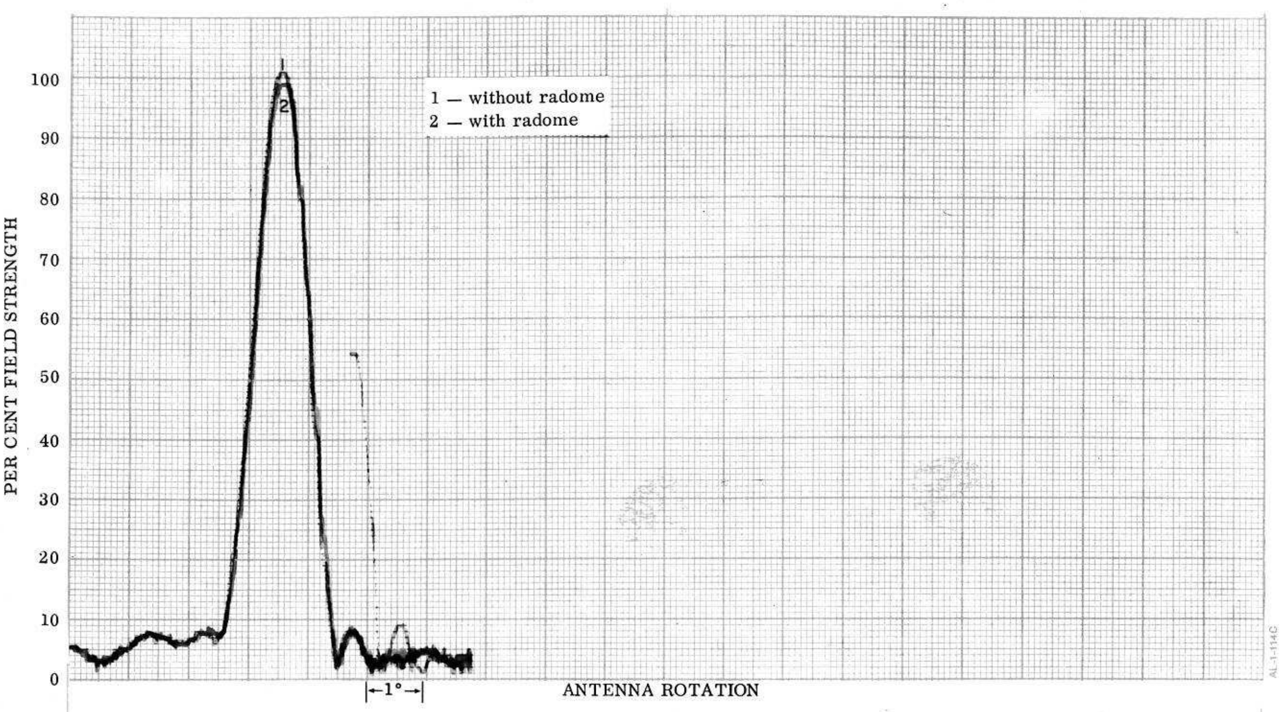

FIG. 3 VERTICAL RADIATION PATTERN OF ELEVATION ANTENNA

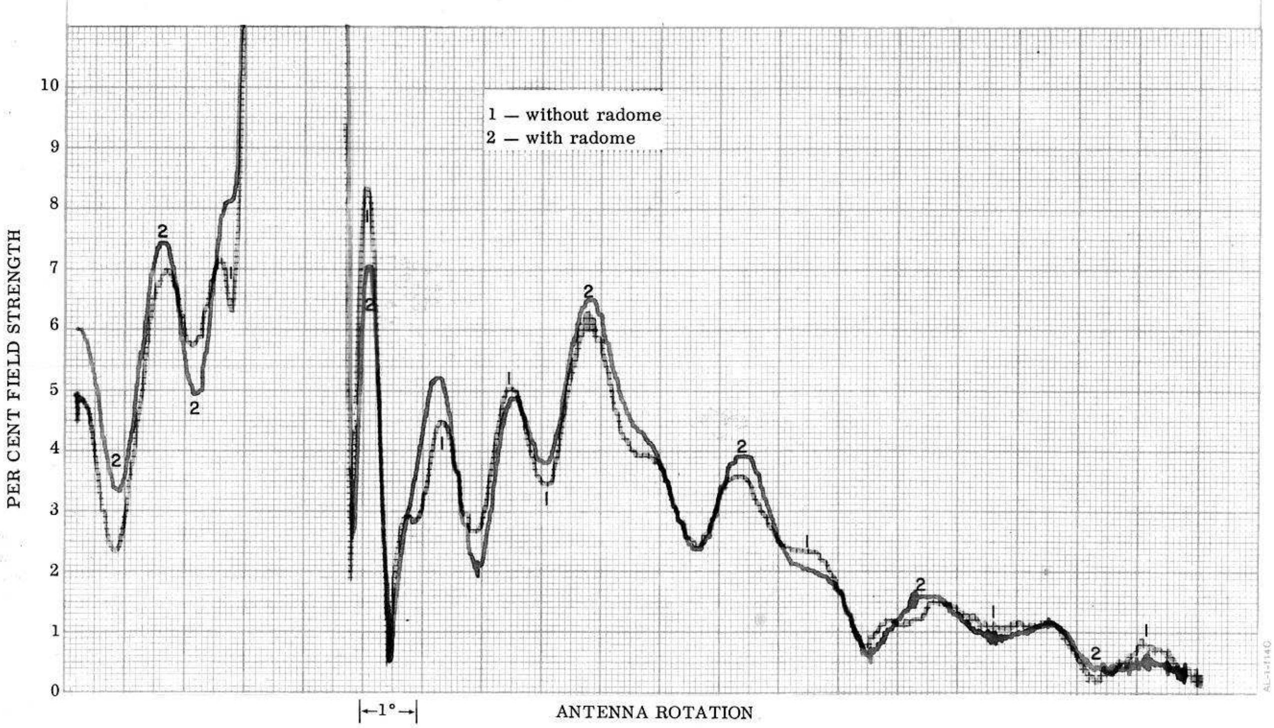

FIG. 4 VERTICAL RADIATION PATTERN OF ELEVATION ANTENNA
(expanded 20 db)

PLATE I THE QUADRADAR
Gilfillan Bros. Photo

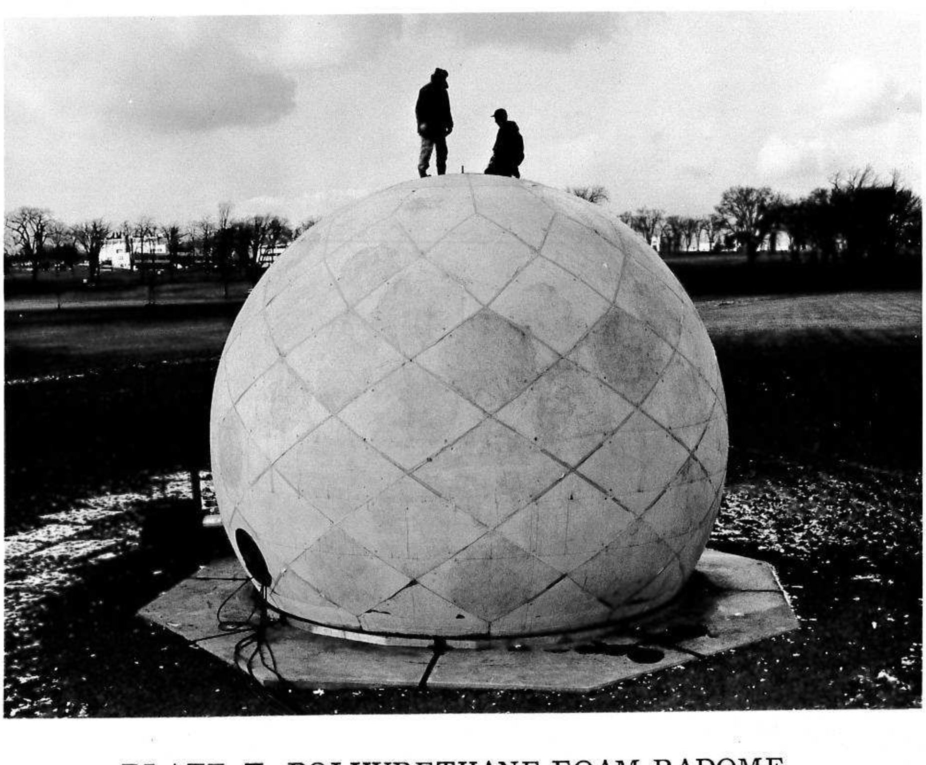

PLATE II POLYURETHANE FOAM RADOME