AD-A285 673

[illegible]

A VHF/UHF ANTENNA FOR THE PRECISION ANTENNA MEASUREMENT SYSTEM (PAMS)

Daniel E. Warren

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

Rome Laboratory
Air Force Materiel Command
Griffiss Air Force Base, New York

RL-TR-94-85 has been reviewed and is approved for publication.

APPROVED:

CARMEN J. LUVERA, Chief
Electromagnetic Systems Division
Electromagnetics & Reliability Directorate

FOR THE COMMANDER:

JOHN J. BART
Chief Scientist
Electromagnetics & Reliability Directorate

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1994	In-House

4. TITLE AND SUBTITLE
A VHF/UHF ANTENNA FOR THE PRECISION ANTENNA MEASUREMENT SYSTEM (PAMS)

5. FUNDING NUMBERS
PE - 64256F
PR - 3321
TA - PR
WU - OJ

6. AUTHOR(S)
Daniel E. Warren

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Rome Laboratory (ERSE)
525 Brooks Road
Griffiss AFB NY 13441-4505

8. PERFORMING ORGANIZATION REPORT NUMBER
RL-TR-94-85

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Rome Laboratory (ERSE)
525 Brooks Road
Griffiss AFB NY 13441-4505

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Rome Laboratory Project Engineer: Daniel E. Warren/ERSE (315) 330-4471

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This report describes the development of an antenna concept that is to be used to extend the lower frequency limit of the Precision Antenna Measurement System (PAMS) down to 30 MHz. It includes a discussion of the concepts of reflection ranges, log periodic antennas, half space antennas, nonsteerable antennas, and numerical definition of antenna patterns in two dimensions. PAMS is located at the Verona Research Facility, and is a system for measuring the radiation patterns of antennas on aircraft while they are in flight.

14. SUBJECT TERMS
Aircraft Antennas, VHF, UHF, Airborne Antenna Measurements

15. NUMBER OF PAGES
36

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	U/L

I. INTRODUCTION

The Precision Antenna Measurement System (PAMS), located at the Rome Laboratory (RL) Verona Research Facility, is a system that measures aircraft antenna patterns while the aircraft is in flight. It consists of a FPS-16 tracking radar (Figure 1), a receive antenna platform (Figure 2) synchronized to the tracking radar antenna and a receiving system. In principle, the radar tracks the test aircraft while simultaneously aiming the receive antenna at the aircraft so that the received signal is independent of the receive antenna pattern. The received signal level is recorded along with aircraft position and time. The data is corrected for distance and parallax and the radiation pattern of the aircraft antenna is determined. A limitation exists when making measurements at elevation angles close to the horizon due to multipath reflections from the ground. This unwanted multipath causes perturbations in the receiver antenna patterns, particularly for antennas with a wide beamwidth. The narrower the receive antenna beamwidth, the closer to the horizon one can operate, resulting in more volume that the airplane can fly in. At microwave frequencies, it is feasible to use a high gain receive antenna in order to achieve a narrow beamwidth, but at frequencies below 400 MHz, high gain narrow beam antennas become physically too large to place on the positioner; hence, only limited measurements using PAMS have been made at these lower frequencies.

II. REQUIREMENT

Since a high gain narrow beam steerable antenna would be very cumbersome at these lower frequencies, an effort was initiated to develop a fixed antenna with a wide enough azimuth beamwidth and a low enough elevation coverage to cover the volume in which the airplane was required to fly. The aircraft will fly through the antenna pattern rather than have the antenna track the aircraft. In order to use a fixed antenna for such airborne measurements, the design goals for this

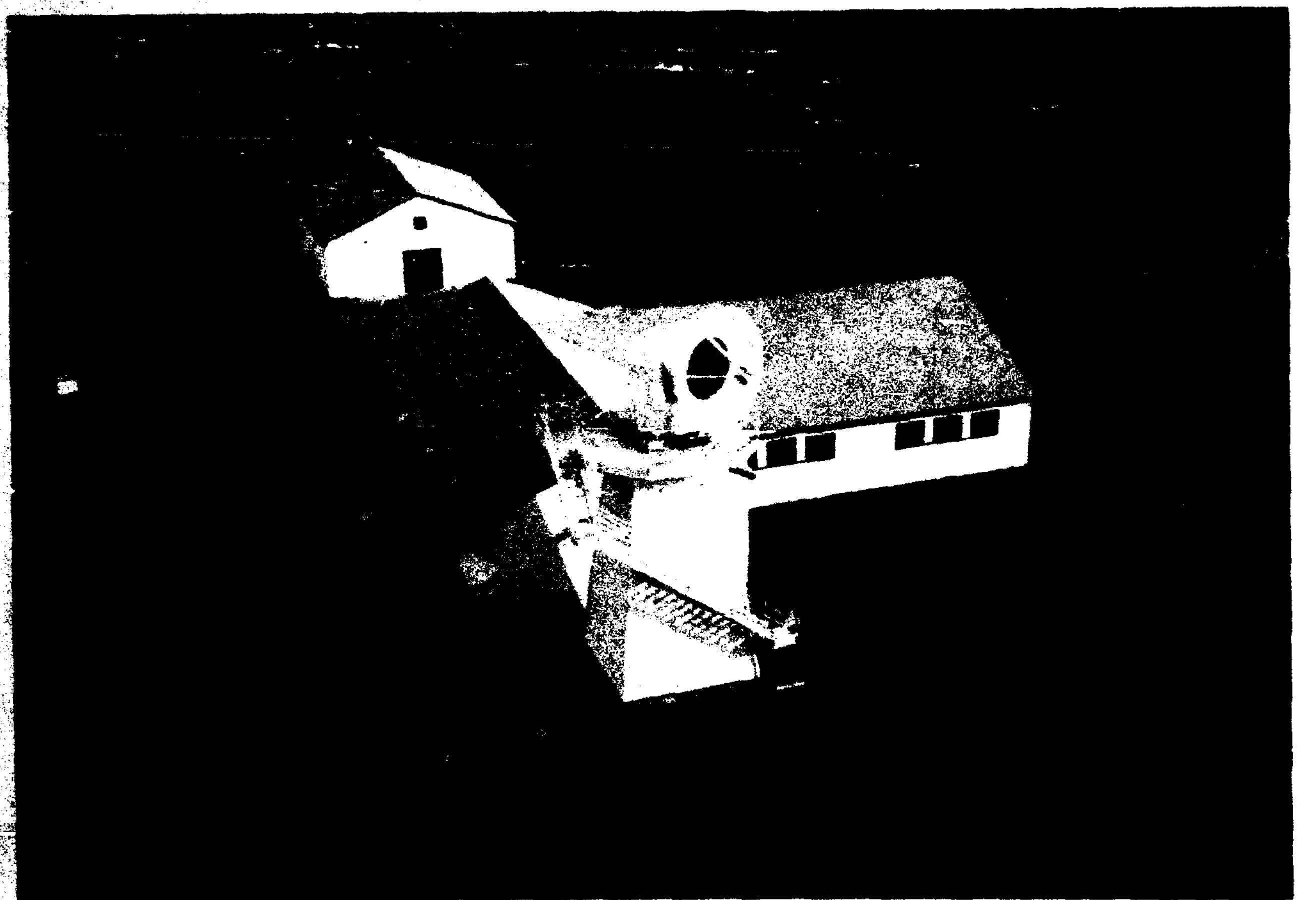


Figure 1. FPS-16 Tracking Radar

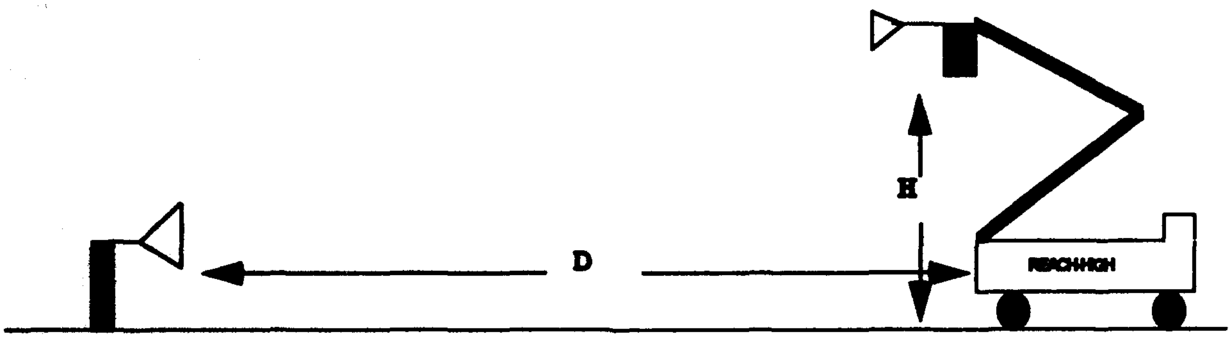
Figure 2. PAMS Positioner

application were 120 degrees of horizontal beamwidth, 30 degrees of vertical beamwidth and a repeatable gain down to 3 degrees above the horizon. A front to back ratio of at least 10 dB was required to reduce the multipath due to buildings located to the rear. In order to evaluate airborne antennas in both the VHF and UHF spectrum, the antenna must cover the frequency range of 30 to 400 MHz. The coverage at lower elevation angles can only be accomplished by controlling the ground reflections. Conventional means of controlling these reflections are by the use of reflection fences which reflect the ground reflections off in a direction that will cause no problems, scatter fences which scatter the ground reflection in all directions, thereby reducing its amplitude to the measurement noise level, and by building a ground reflection range so that the ground reflections behave in a controlled manner such that a plane wave can be established in the direction of the antenna under test. The reflection fence was discounted because its dimensions would be on the order of several wavelengths, which would be very large at 30 MHz. Scattering fences would not be much better because a large number of fences would be needed and each would be very long in order to cover a wide field of view as the aircraft flies past the facility. The reflection range concept appeared to have the most potential for success, thus an experimental range was set up to evaluate its limits.

III. REFLECTION RANGE EVALUATION

To explore the suitability of using a ground reflection range, an AEL APN-107C log periodic antenna with a frequency range of .05 GHz-1.1 GHz was mounted 10 feet above the ground and vertically polarized (as are most VHF and UHF aircraft communication antennas) with the broad H plane pattern in the horizontal plane. The longest element was about 10 feet long, therefore, its phase center should not be placed any closer than 10 feet to the ground. A closer spacing will perturb the current distribution on the array causing additional perturbations to the pattern beyond those caused by the ground reflection. A higher spacing from the ground will cause additional nulls to appear in the pattern, some of which will be close to the horizon. Measurements of the vertical pattern were made on boresight to evaluate the perturbations caused by the presence of the ground.

Elevation cuts were initially made at a distance of 200 feet from the antenna using an identical log periodic antenna as a probe. To make measurements up to 15 degrees in elevation at the 200 foot range, it was necessary to elevate the probe to 75 feet. To accomplish this, the probe was mounted on a cantilever attached to a "cherry picker" which could be raised in a near vertical line (Figure 3). The elevation angle, referenced to the receive antenna, was determined by using a transit. The receive antenna was connected to a HP-8569 spectrum analyzer and the received signal strength was recorded manually as the "cherry picker" was raised and tracked with the transit and the vertical radiation patterns of the antenna under test were derived and are shown in Figures 4-10. These patterns appeared to be better behaved than expected near the horizon which can be explained as follows. Since the antenna under test was ten feet above the ground, parallax due to the finite range of the far field measurements, had to be considered, which is best illustrated in Figure 11. At an elevation angle of 0 degrees, the probe antenna is also ten feet above the ground (hence, the negative elevation angles in the data) with the reflection point in the middle. The multipath angle is about 6 degrees, just where the reflection coefficient of a vertically polarized wave, for typical earth, is undergoing a drastic phase change as shown in Figure 12. This phase change in the reflected wave will cause the resultant pattern to have a null at the horizon, as the reflected wave subtracts from the direct wave, rather than a peak which would occur if the ground were a perfect conductor. To verify this, the probe was then moved out to 600 feet from the antenna in order to decrease this parallax. Now the parallax



D = 200 ft & 600 ft
H = 0 - 75 FT

Figure 3 Probing Test Antenna With A Cherry Picker

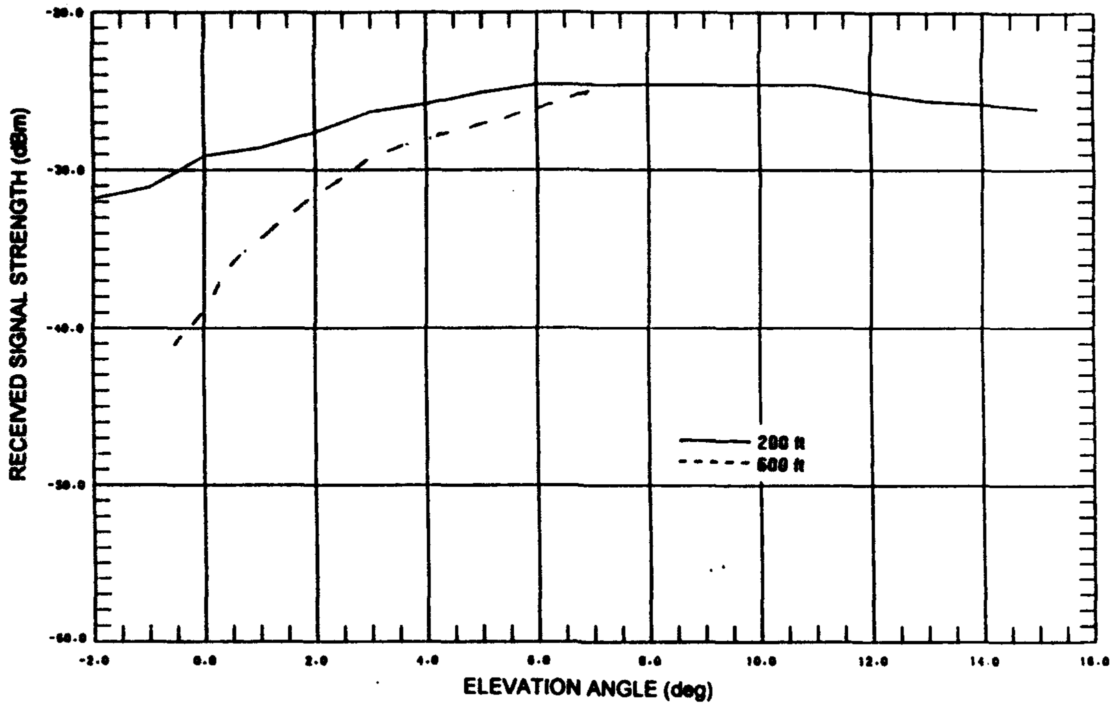


Figure 4 Elevation pattern of a log periodic antenna 10 feet above real ground at 50 MHz.

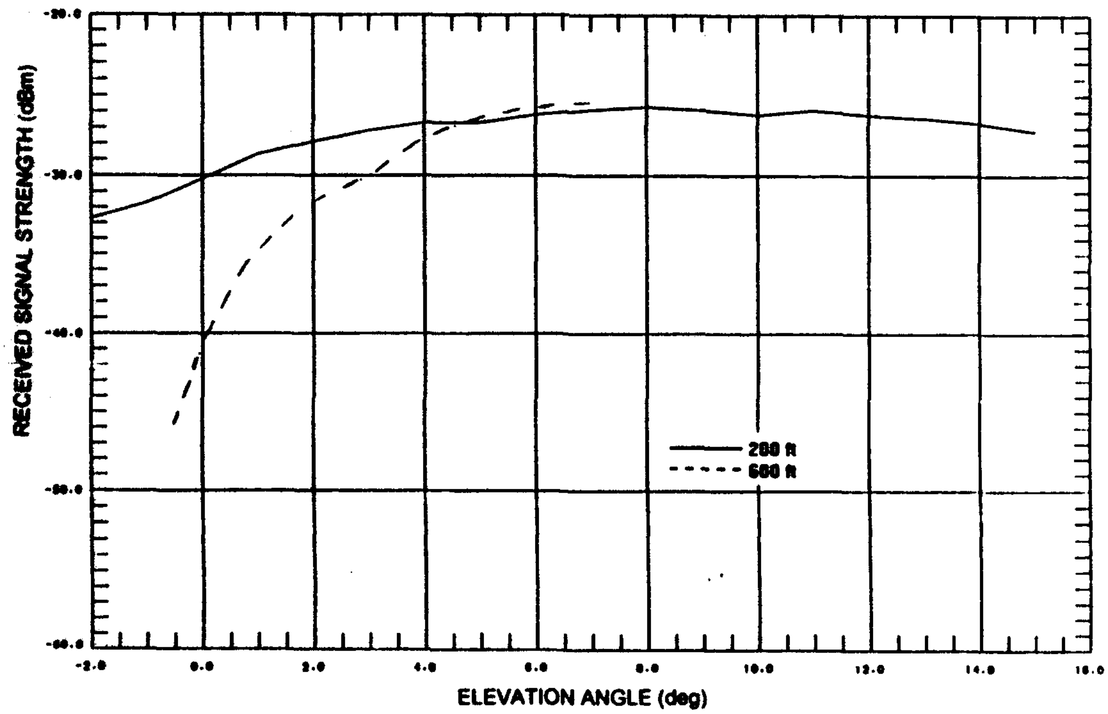


Figure 5 Elevation pattern of a log periodic antenna 10 feet above real ground at 80 MHz.

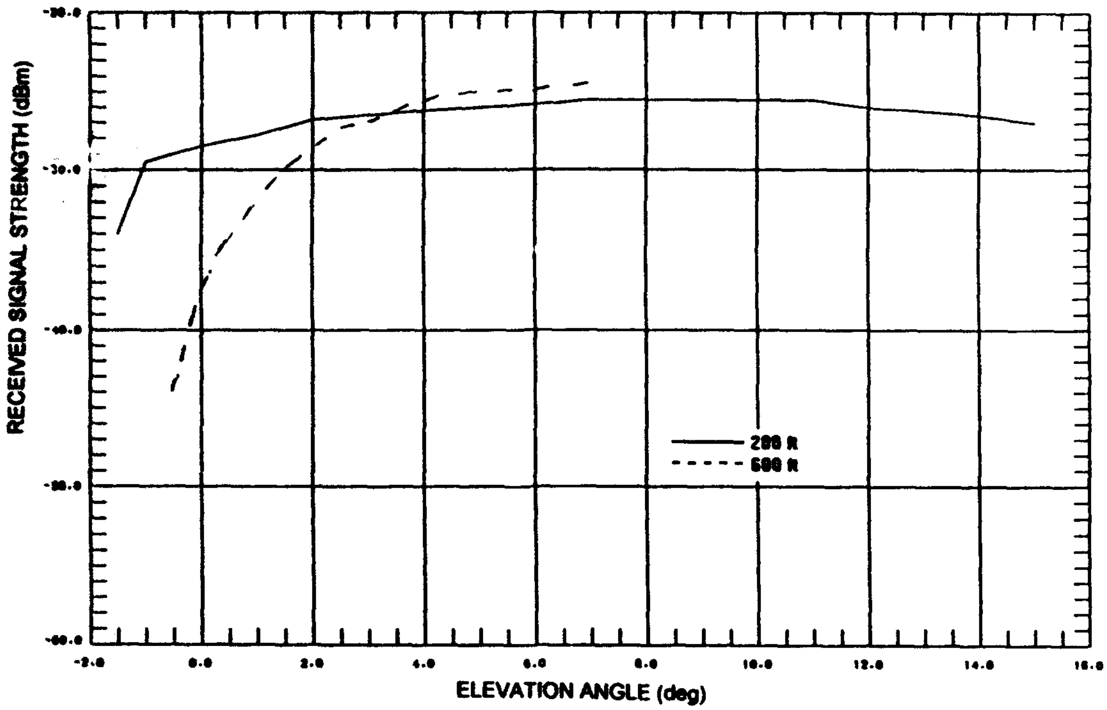


Figure 6 Elevation pattern of a log periodic antenna 10 feet above real ground at 100 MHz.

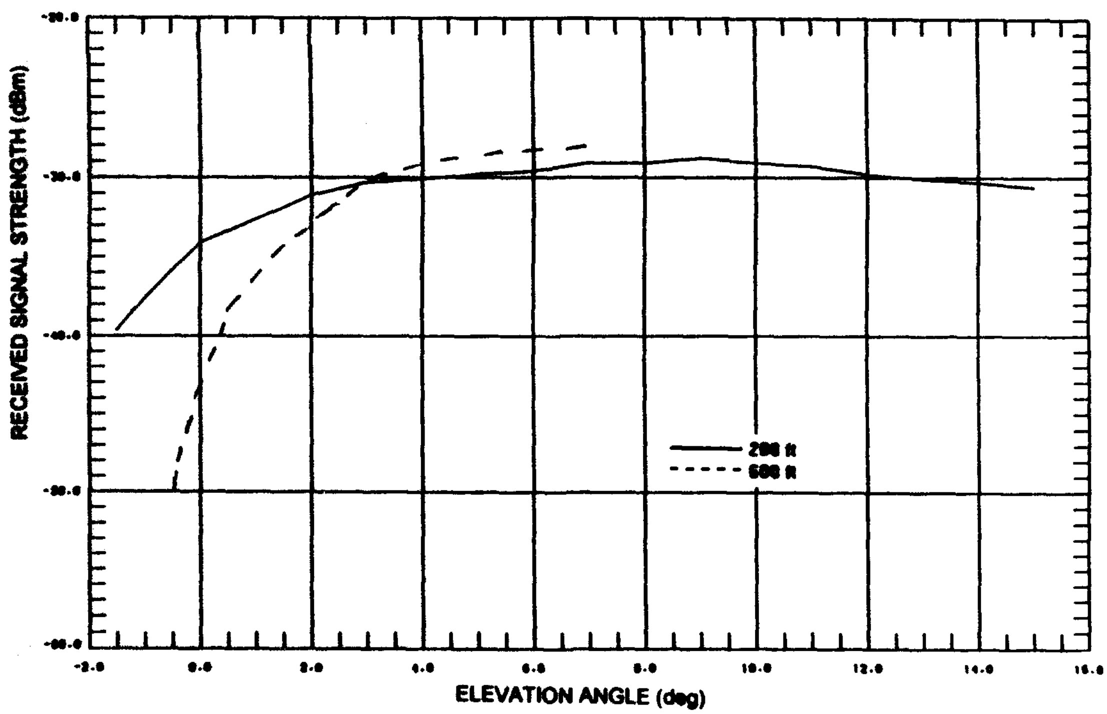


Figure 7 Elevation pattern of a log periodic antenna 10 feet above real ground at 150 MHz.

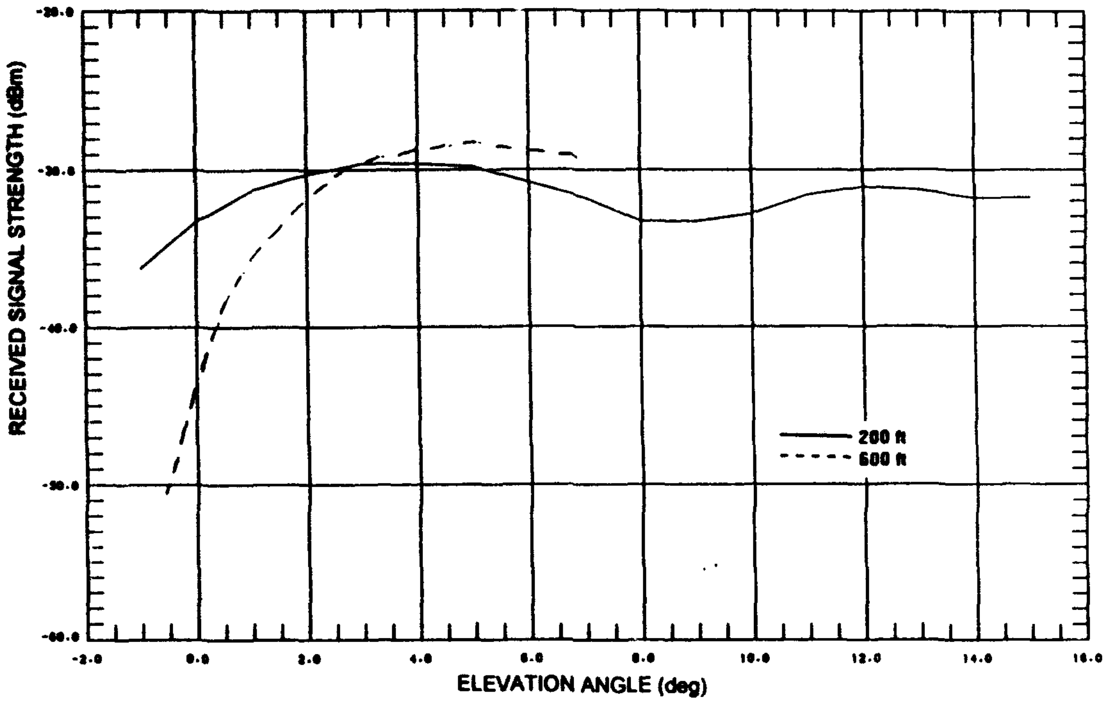


Figure 8 Elevation pattern of a log periodic antenna 10 feet above real ground at 225 MHz.

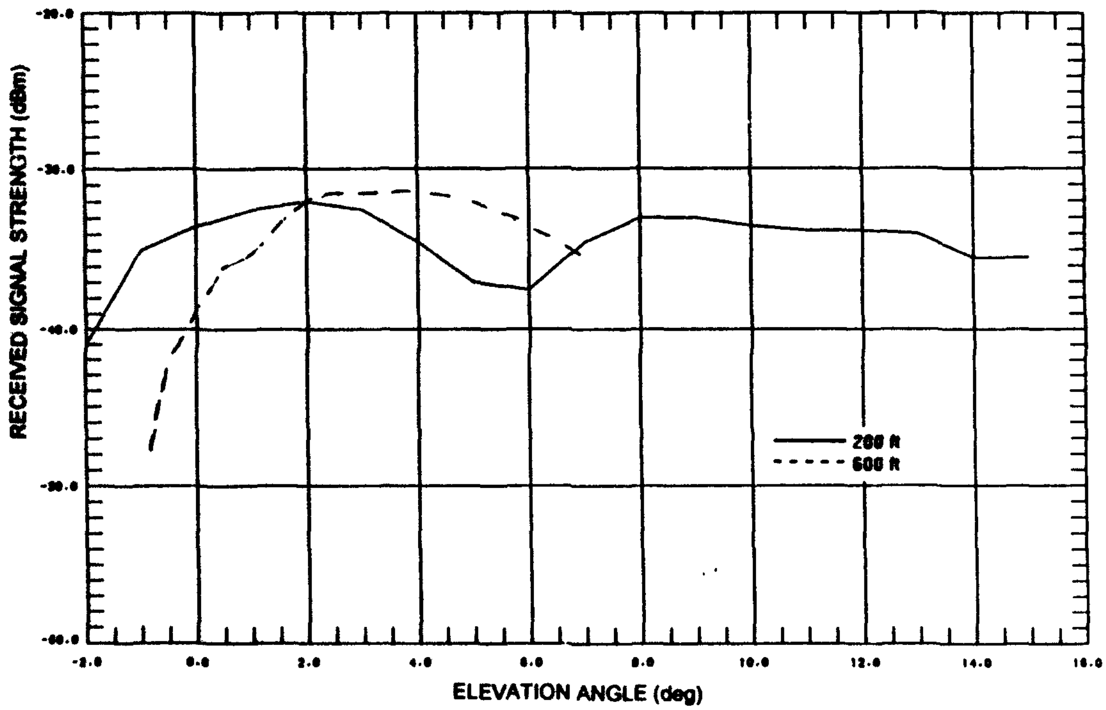


Figure 9 Elevation pattern of a log periodic antenna 10 feet above real ground at 300 MHz.

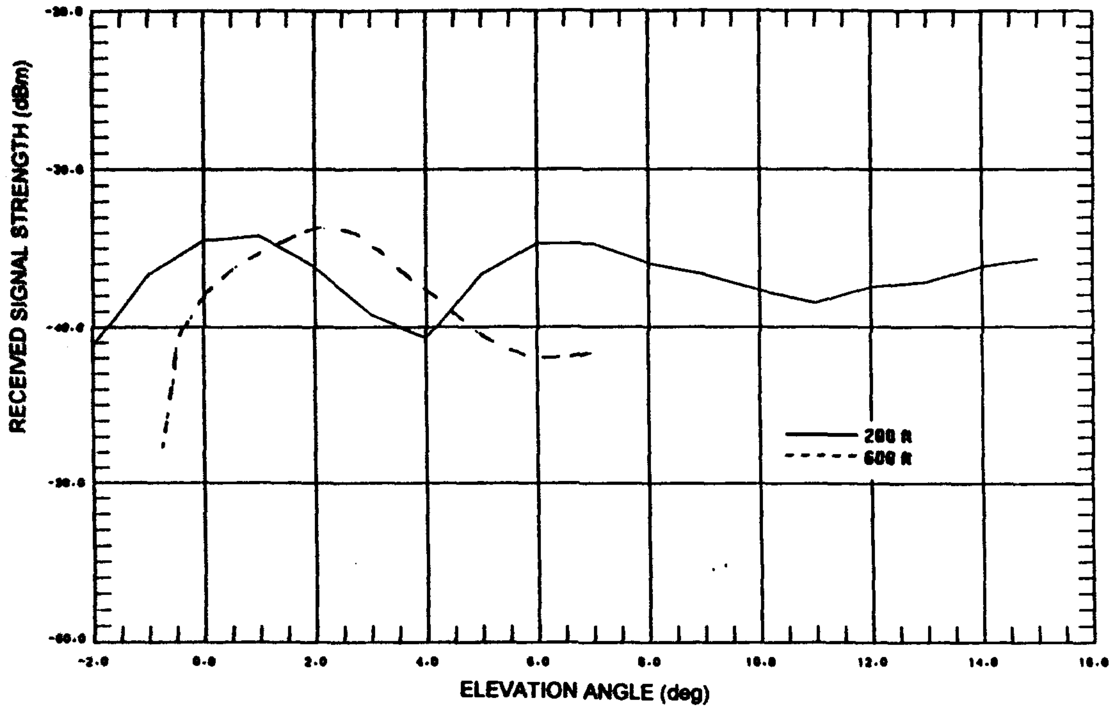
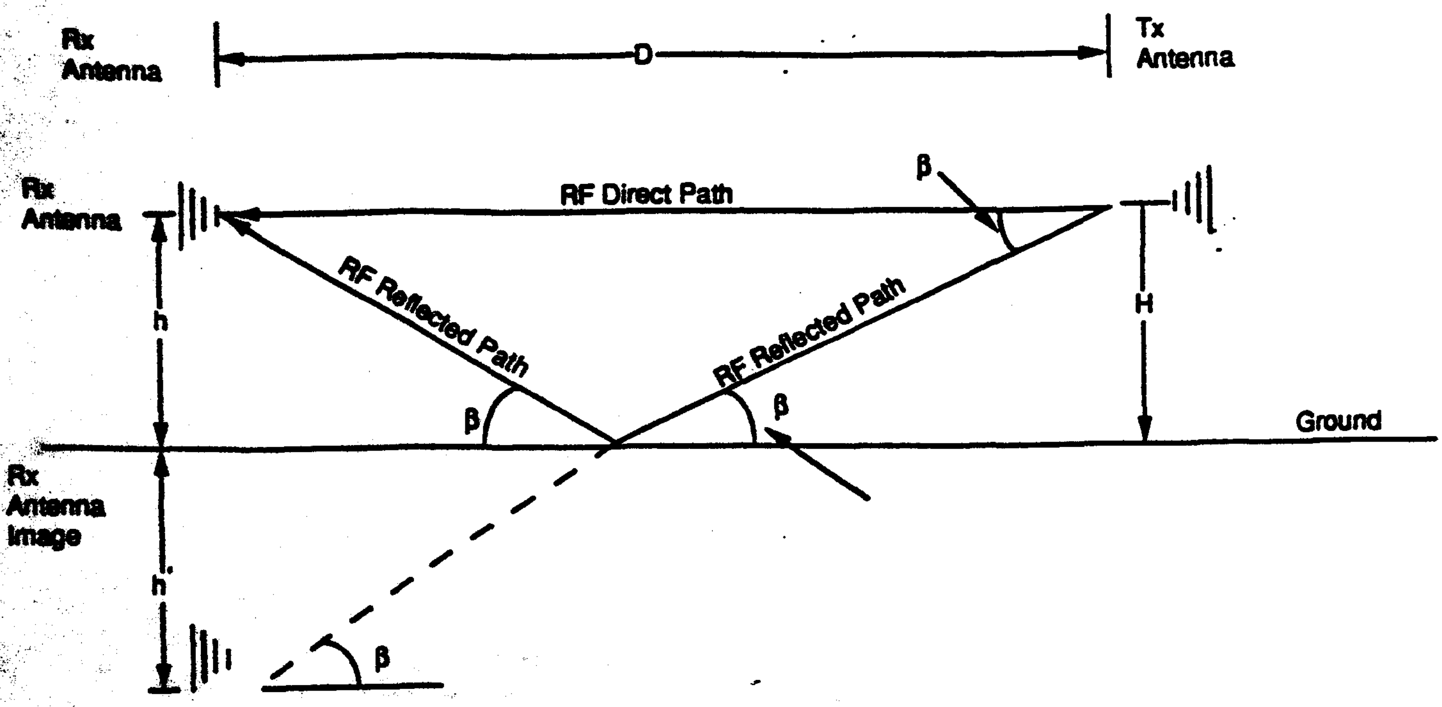


Figure 10 **Elevation pattern of a log periodic antenna 10 feet above real ground at 400 MHz.**



If:
h = h'
H = h

Then:
The elevation angle between the TX and Rx antenna is 0°

When D = 200 ft.
β = 6°

When D = 600 ft.
β = 2°

Figure 11. Parallax of Multipath When Measuring Patterns at a Finite Distance

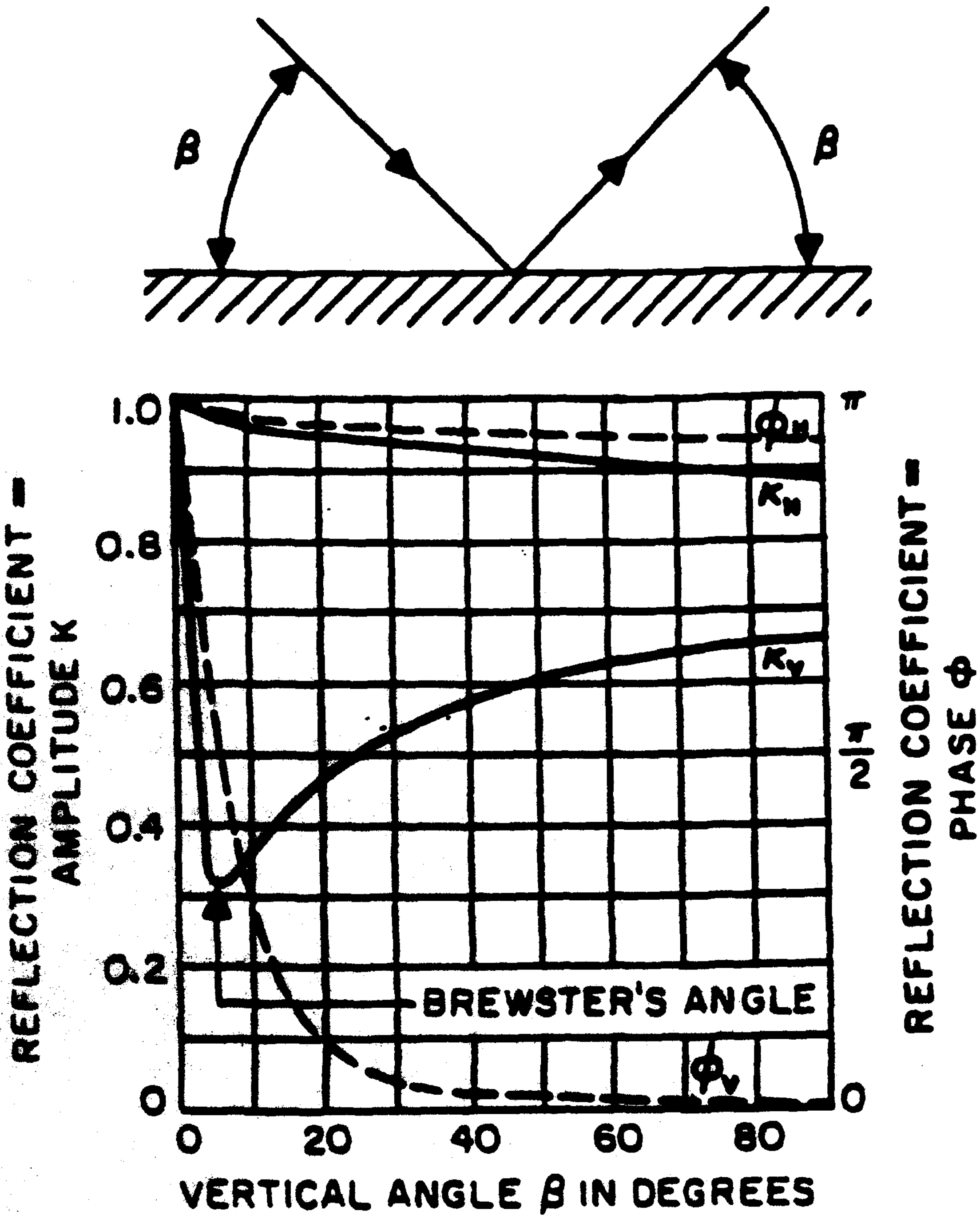


Figure 12. Reflection Coefficient of Typical Earth

between the elevation angle and multipath angle is only 2 degrees, and as hypothesized, the measured data shows the pattern tucks in more severely near the horizon (due to the limited reach of the "cherry picker", the maximum elevation angle was limited to 7 degrees for these measurements)

A log periodic antenna mounted above real ground is not a satisfactory choice for a reflection range especially when measurements are needed near the horizon. The reflection coefficient is too dynamic and too dependent upon the water content of the soil to produce a repeatable pattern. Another disadvantage to this configuration was that at the UHF frequencies, there was severe lobing in the pattern because the antenna was electrically a number of wavelengths above the ground which aggravates the problem discussed above.

IV. CUSTOMIZED APPROACH

The problems encountered with the reflection range approach are related to the fact that the phase center of the antenna is located a finite distance above a ground of finite and variable conductivity. If the phase center of the antenna were to be on a perfectly conducting ground, of infinite extent, there would be no nulls due to ground multipath or any tuck in of the pattern at the horizon due to the phase change of the reflection co-efficient. In order to place the phase center of the antenna on the ground, elements must be used which are designed to be fed against the ground such as monopoles rather than dipoles. While a perfect conductor of infinite extent is not physically realizable, a metallic surface which is electrically large will suffice, but there will still be at least a 6 dB tuck in the pattern approaching the horizon as the contribution of the image vanishes and due to diffraction off of the edge of the ground plane. The closer to the horizon one wishes to receive, the larger the ground plane must be (about 200 feet for a usable pattern at 3 degrees elevation at 30 MHz).

While this 6 dB variation in the pattern is not ideal, it will be demonstrated that it can be made workable.

Since the pattern of a log periodic antenna in free space is about the optimum for the measurement of the airborne patterns using this technique, it was decided to build one using monopoles on a ground plane. Using the relationships in Jasik (1), an antenna was designed with an H plane beamwidth of 120 degrees. It had a geometrical progression of .7 and a taper of 30 degrees (60 degrees for a conventional log periodic antenna made with dipoles). A conventional log periodic antenna usually has two feed rails making up a balanced transmission line in order to feed the alternate elements 180 degrees out of phase, but it was necessary to modify the feed in order to use only one-half of the array (the other half being an image). The original concept was to feed every other element from a single rail and ground those in between, allowing them to be parasitically fed 180 degrees out of phase with the driven elements. That technique did not give a satisfactory front to back ratio because the phase shift due to the parasitic feed was not precise enough to provide good cancellation to the backside of the pattern. Another technique that was more successful was to use a 0-180 degree power divider to feed two micro strip rails 180 degrees out of phase and then connect alternate elements to opposite rails. The height of the rails was adjustable so that their impedance could be adjusted to obtain a match with the power divider and the elements.

A one-tenth scale model was built with a designed lower cutoff frequency of 250 MHz as shown in Figure 13. The scaled array was then mounted on a circular ground plane 14 feet in diameter and evaluated at a 700 foot outdoor antenna range at the Rome Laboratory's Newport Research Facility. The radiation patterns were then measured in azimuth at elevation angles of 0, 3, 5, 7, 15, 20 and 30 degrees, and elevation patterns were measured at azimuth angles of 0, 45, 90 and 180

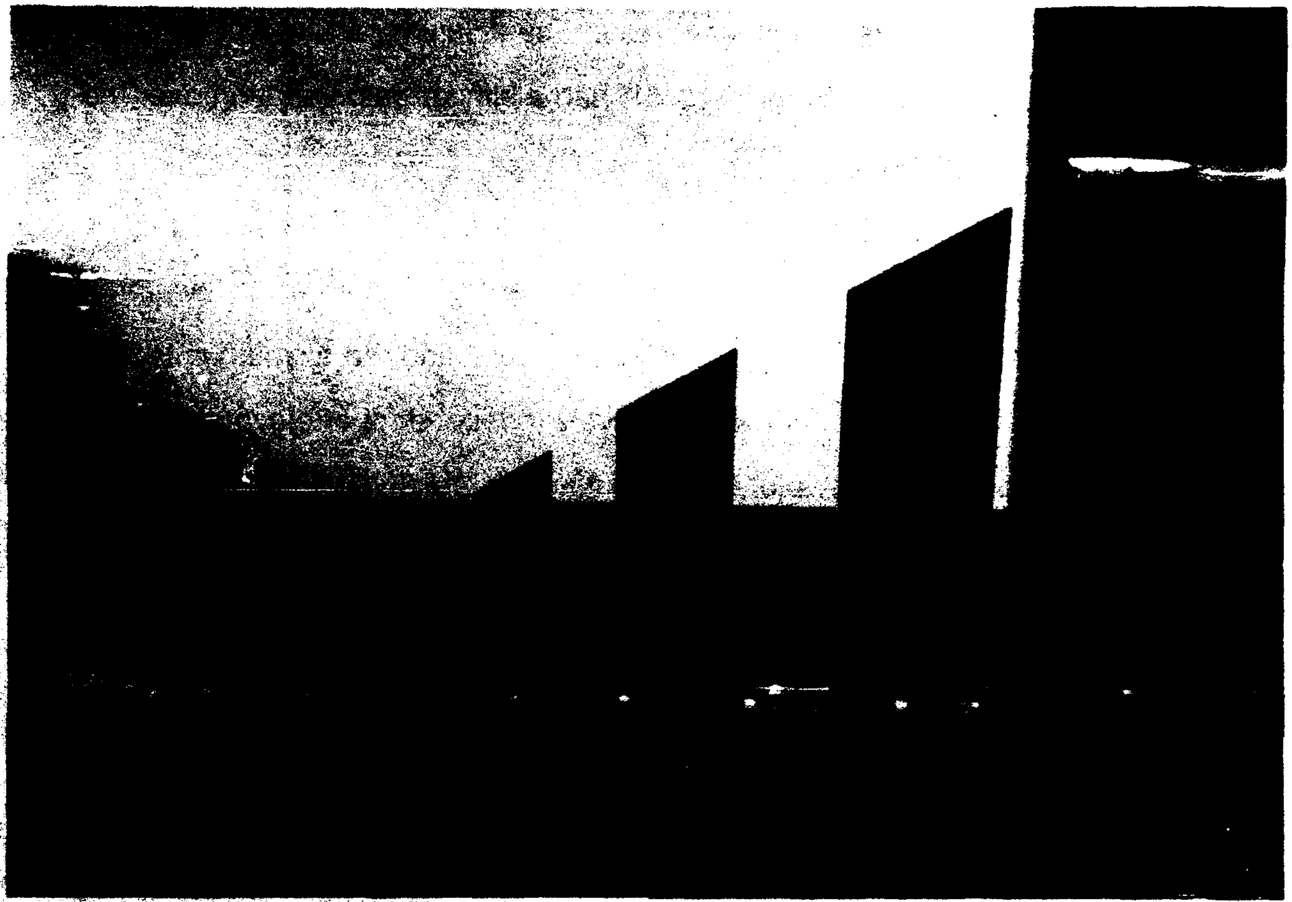


Figure 13. Scale Model of the Half Space Log Periodic Antenna

degrees. This was done at frequencies of 250, 500, 1000 and 1250 MHz[2]. The elevation cuts at 0 degrees azimuth, shown in Figures 14-17, have a variation of about 6 dB from the peak value to the horizon. The azimuth patterns, at an elevation angle of 0 degrees, shown in Figures 18-21, had a similar gain variation over the 120 degree azimuth domain.

V. ANALYTICAL DEFINITION

Although the gain was not uniform over the entire azimuth and elevation domain, the deviation from a uniform gain was graceful and the azimuth cuts, at any given frequency, had a shape that was relatively independent of elevation angle. Similarly, the shape of the elevation patterns was also relatively independent of azimuth. This being the case, it was decided to fit the horizontal cuts at 0 degrees elevation and the vertical cuts at 0 degrees azimuth, independently, to polynomial expressions using the method of least squares with typically a dozen co-efficients to define the pattern for each frequency. This results in a simple numerical expression for the antenna radiation patterns. This is useful for the measurement system since this ground antenna is fixed and does not track the aircraft over its flight path. For elevation angles up to 20 degrees and azimuth angles to about 60 degrees either side of boresite the average error was generally less than .5 dB. An example of this technique is illustrated in Figure 22 where it was applied at a frequency of 1250 MHz which was where the pattern was the most complicated. Using this technique, it is possible to factor out the receive antenna patterns when the flight test data is reduced which is a much more efficient technique than using a look up table.

VI. SUMMARY

This report describes three efforts that were important in the development of a VHF/UHF antenna that was used to extend the lower frequency limit of the PAMS down to 30 MHz. First, the concept of a reflection range was studied but rejected because of the severe tuck-in of the pattern near the horizon and the nulls at the higher elevation angles; both effects will vary with the water content of the soil. A log periodic antenna made of monopole elements which had its phase center on the ground was studied and found to eliminate the above concerns. A numerical technique was then used to define the gain of the antenna over its usable azimuth and elevation coverage.

VII. RECOMMENDATION

Based upon the success of the experiments with the scale model antenna, it was recommended that a full scale antenna be fabricated for the PAMS facility. This antenna was installed at the Verona Research Facility and successfully used to evaluate the communication antennas on an operational aircraft.

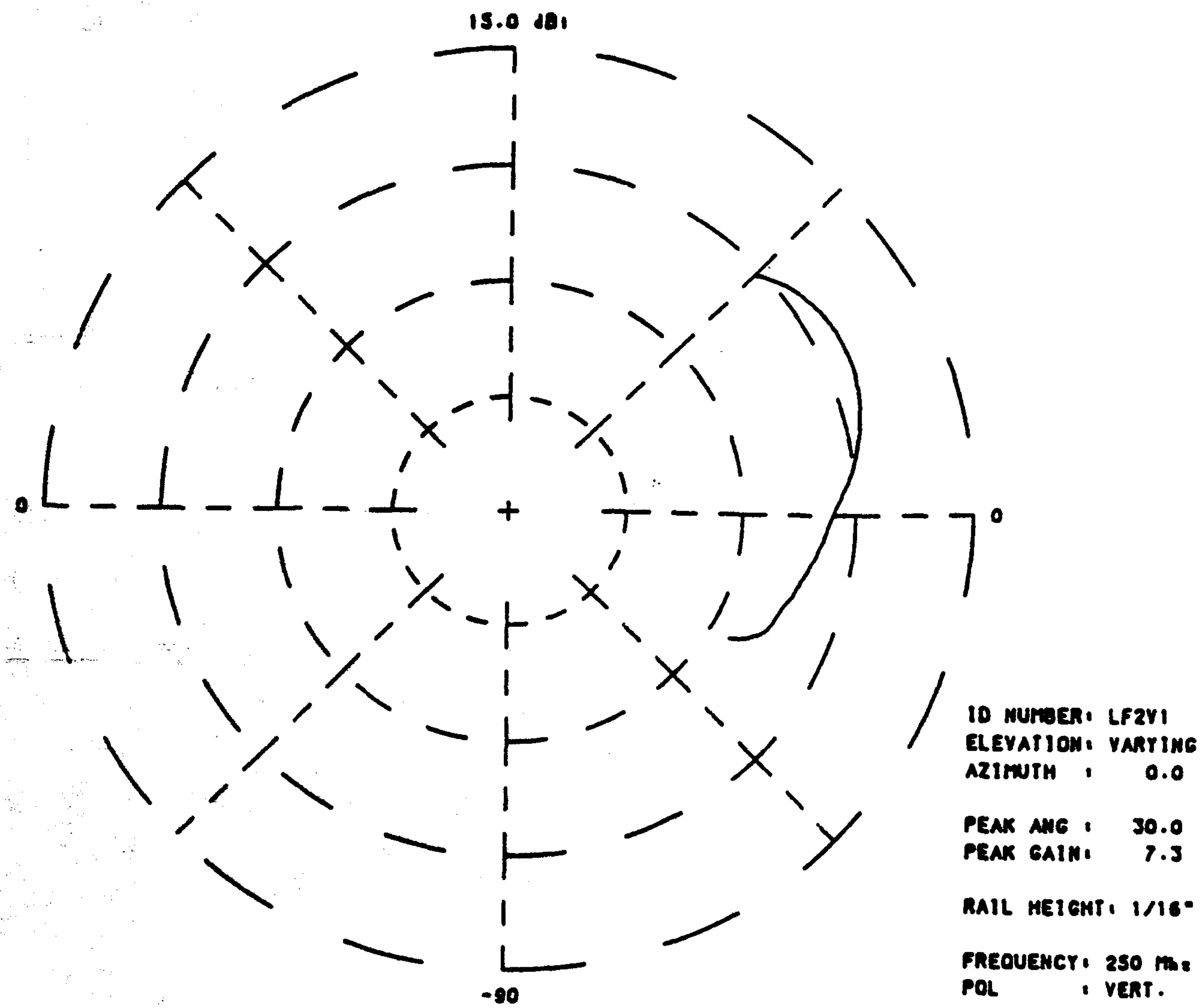


Figure 14. Elevation Pattern of Scale Model Antenna at 250 Mhz

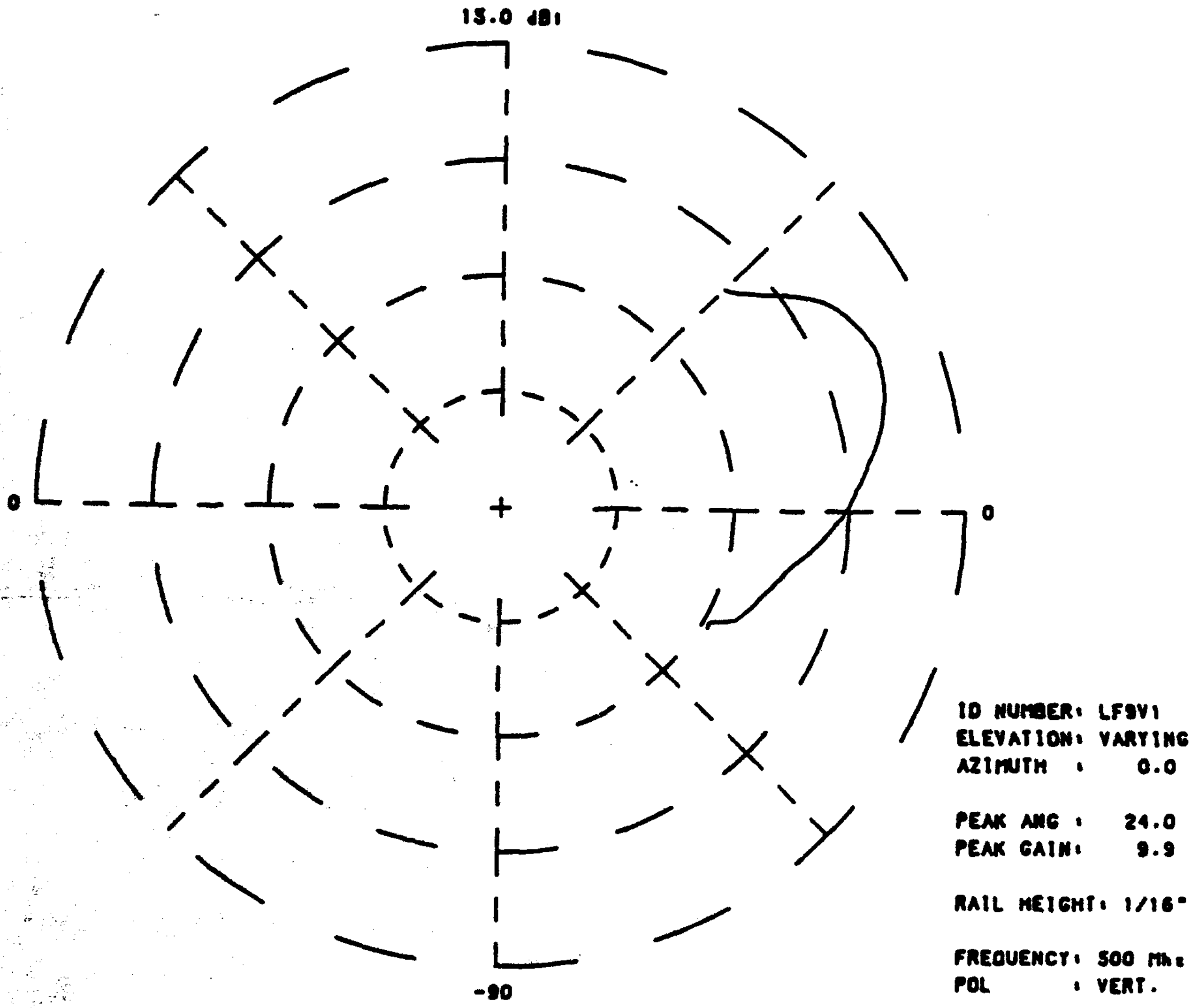


Figure 15. **Elevation Pattern of Scale Model Antenna at 500 Mhz**

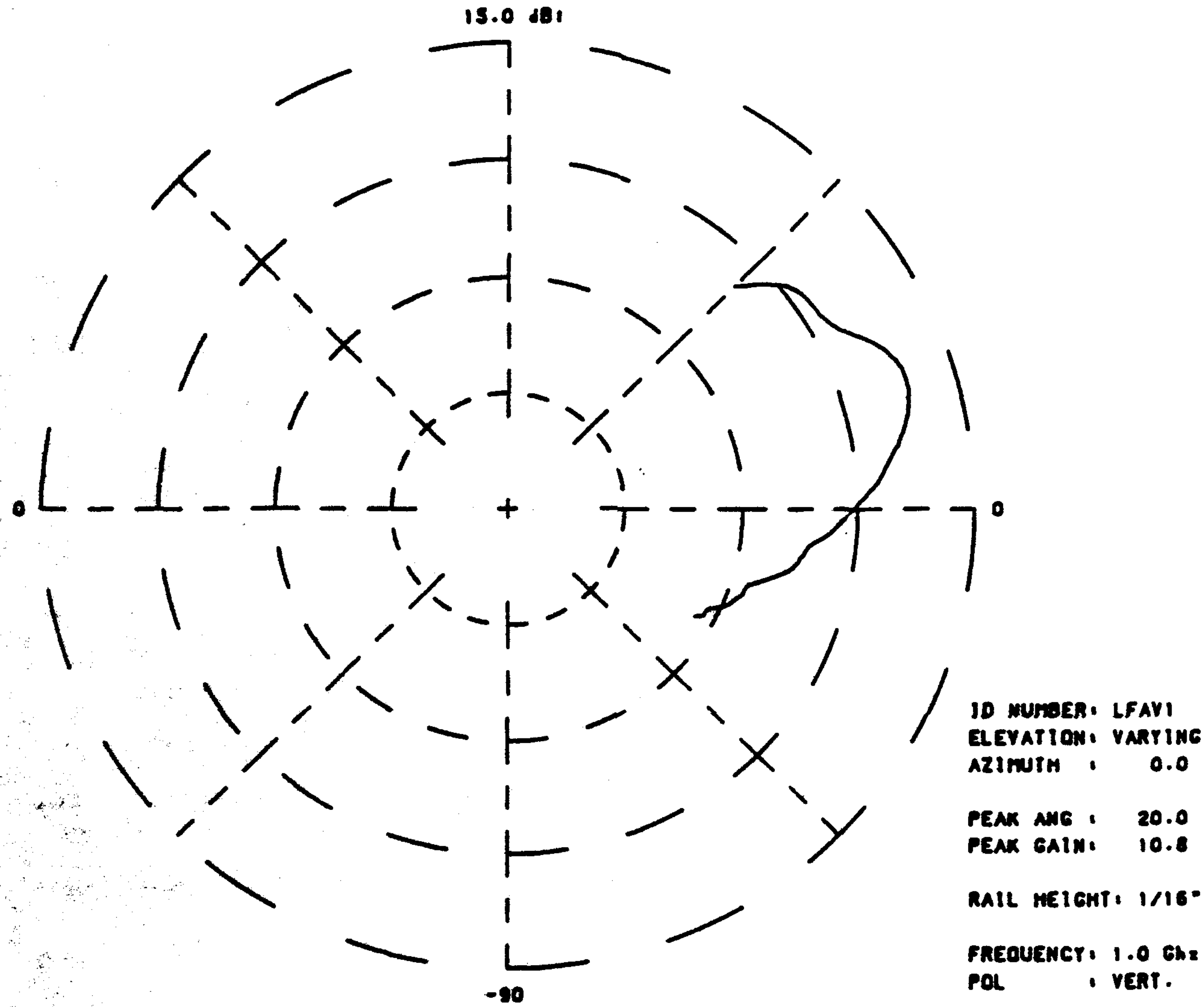


Figure 16. Elevation Pattern of Scale Model Antenna at 1.0 Ghz

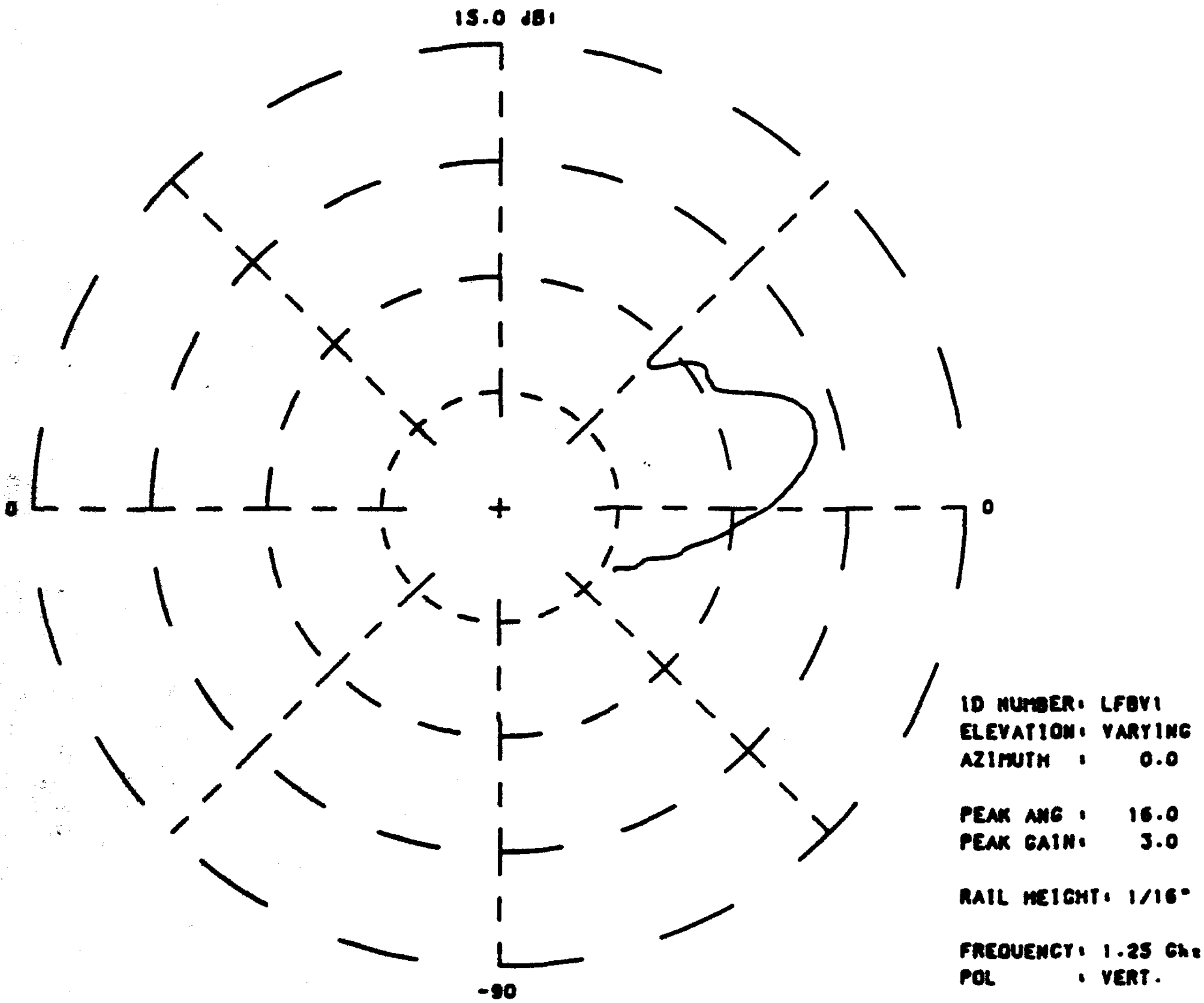


Figure 17. Elevation Pattern of Scale Model Antenna at 1.25 Ghz

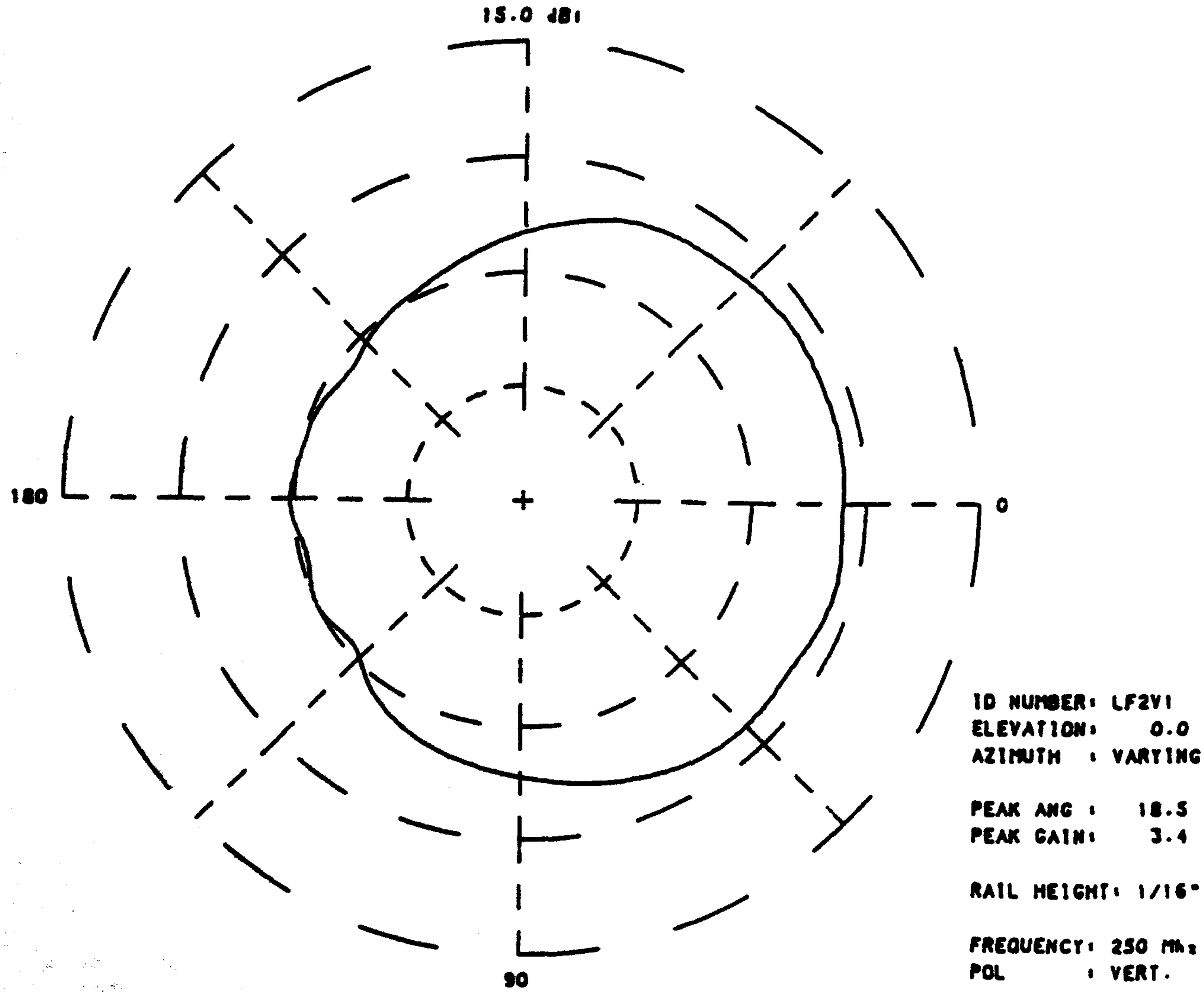


Figure 18. Azimuth Pattern of Scale Model Antenna at 250 Mhz

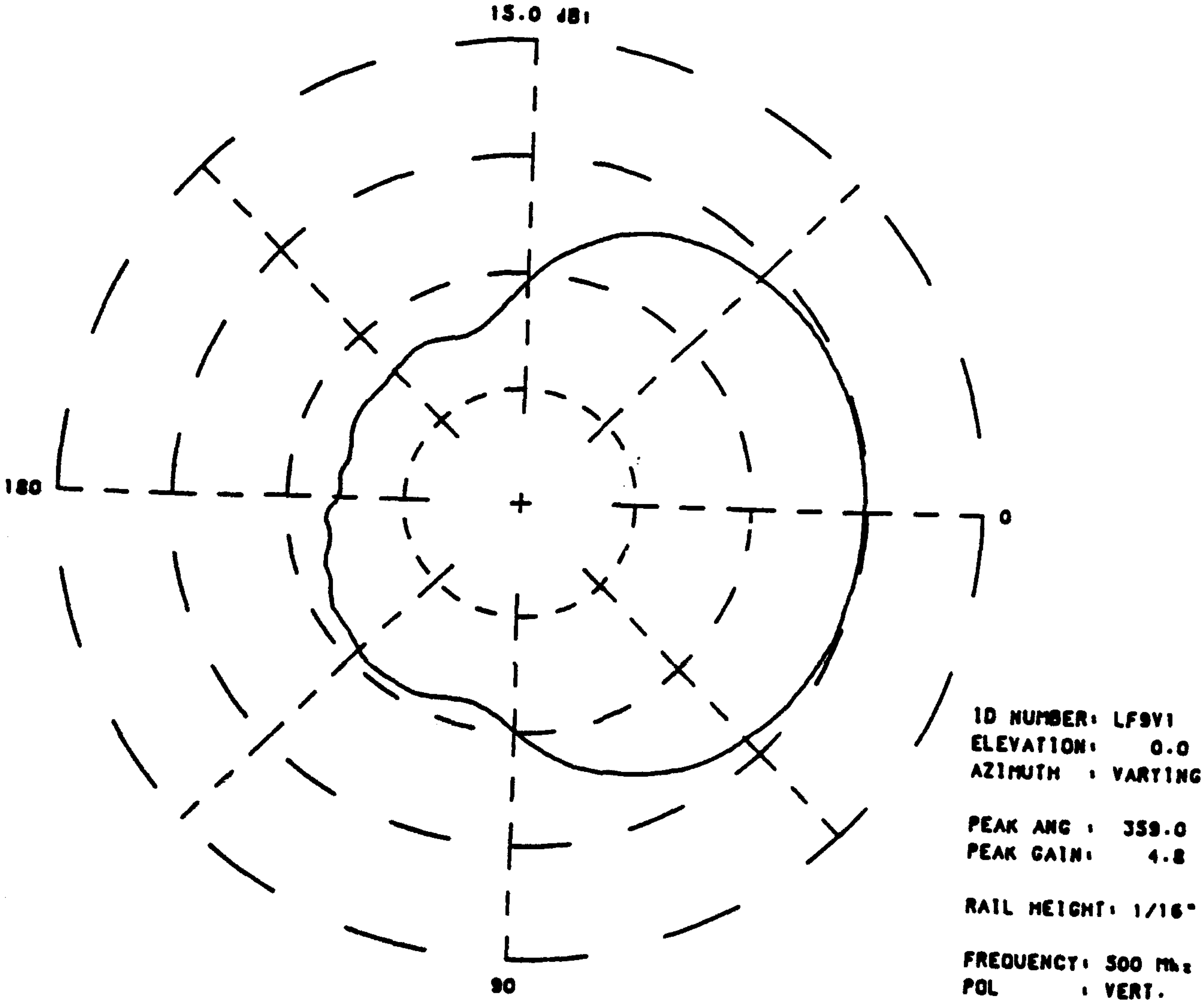


Figure 19. Azimuth Pattern of Scale Model Antenna at 500 Mhz

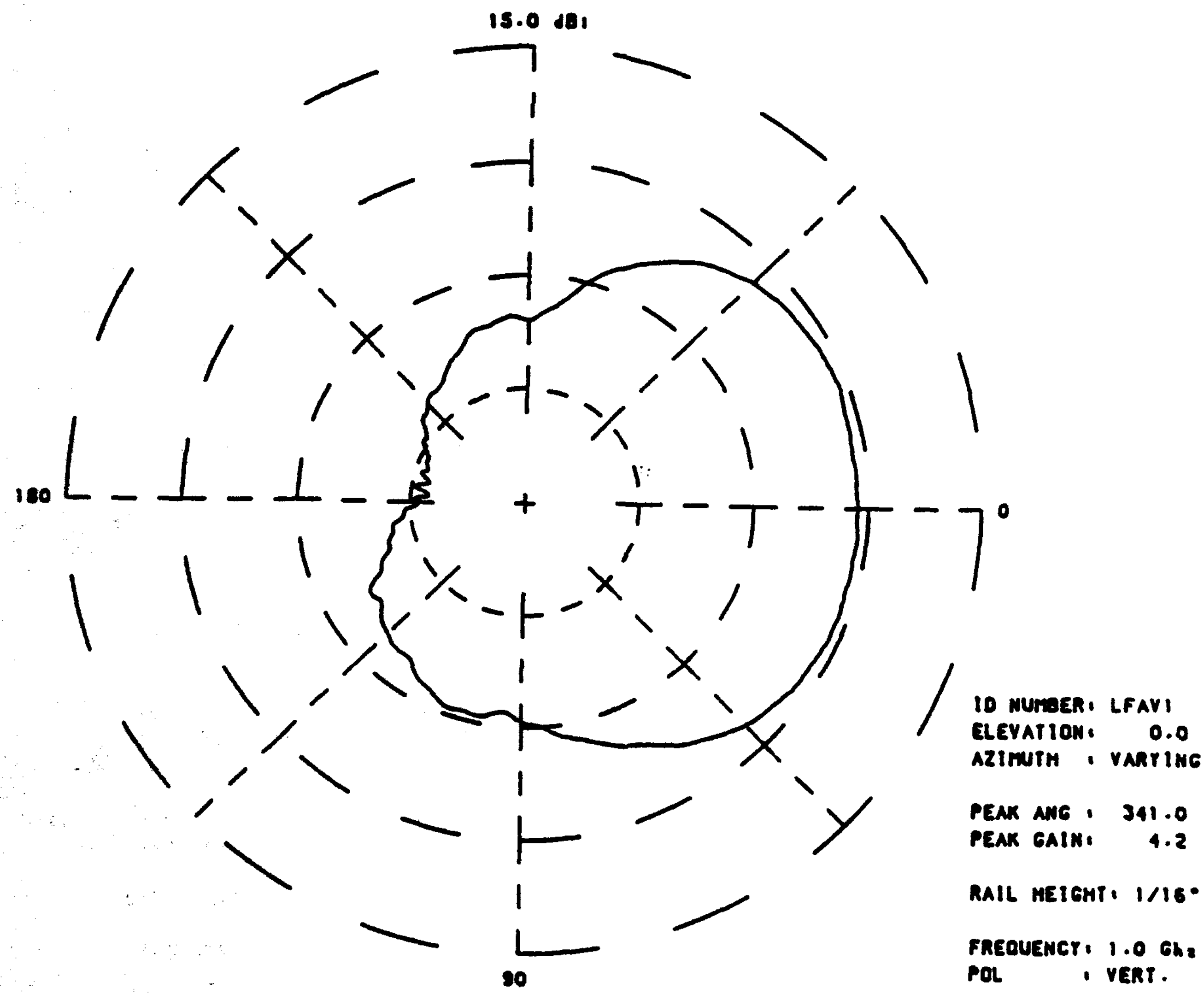


Figure 20. Azimuth Pattern of Scale Model Antenna at 1.0 Ghz

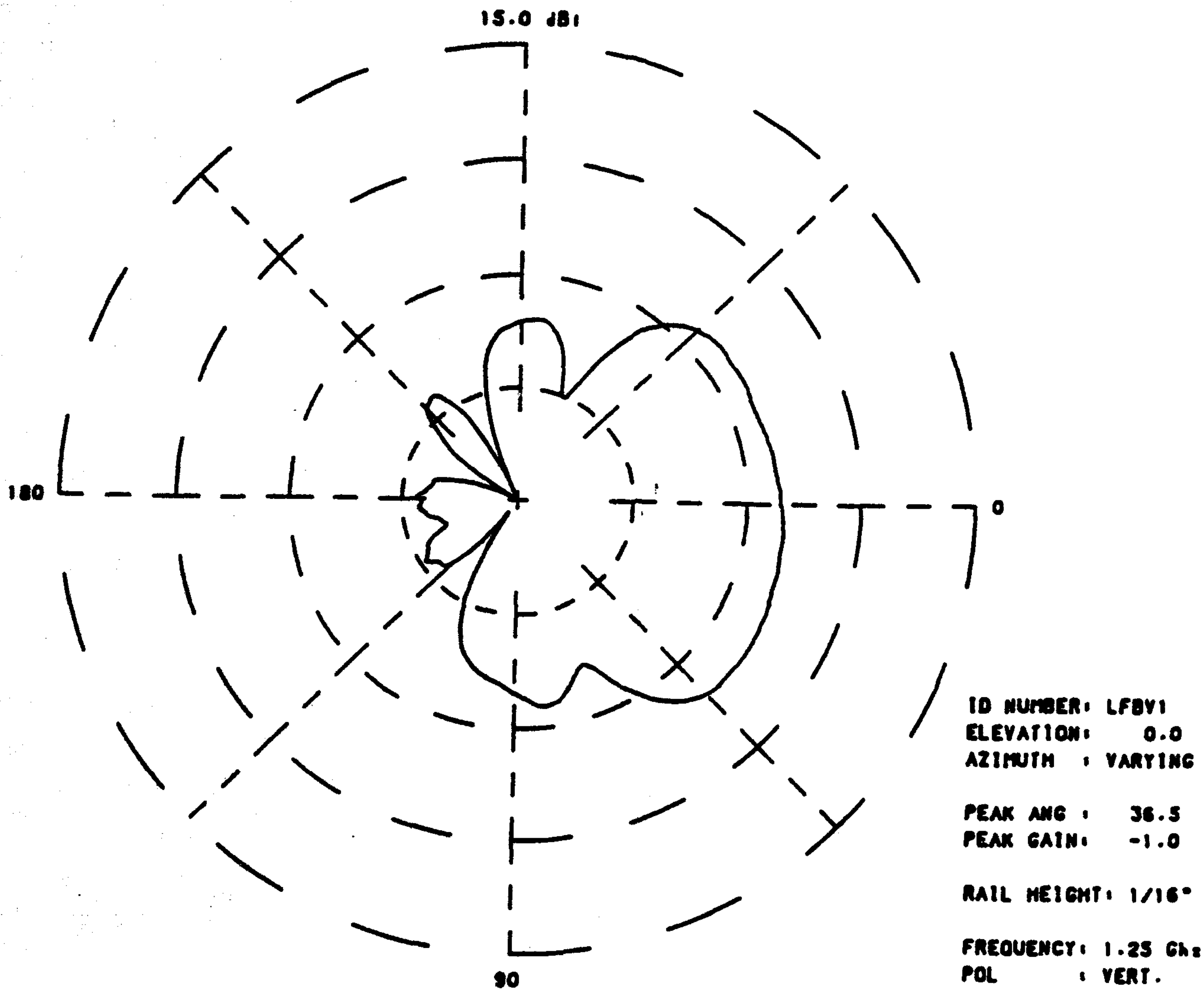
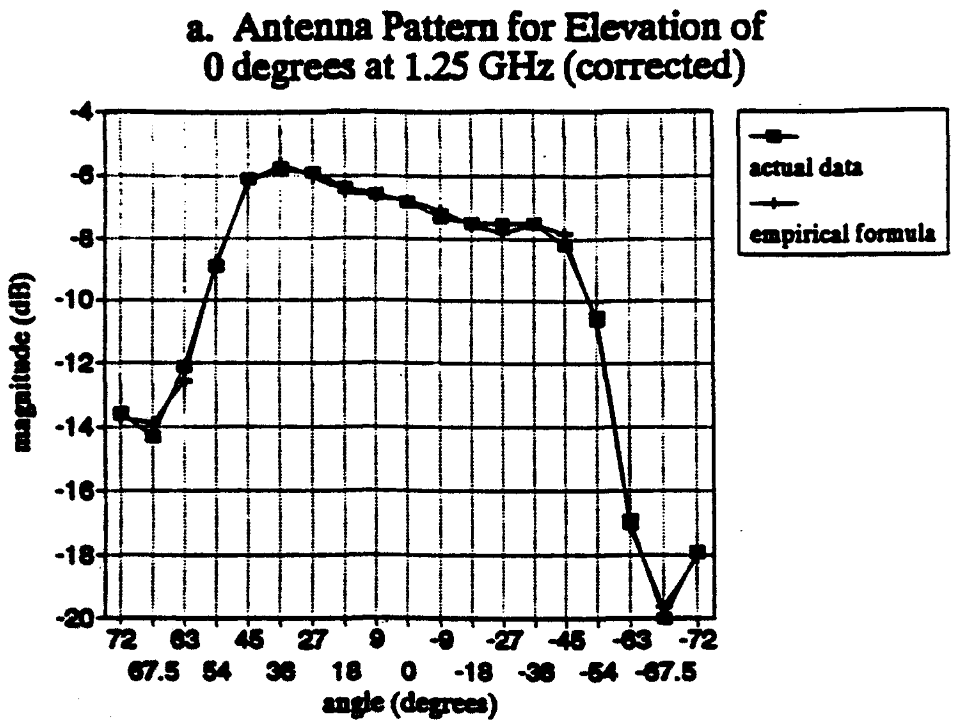


Figure 21. Azimuth Pattern of Scale Model Antenna at 1.25 Ghz



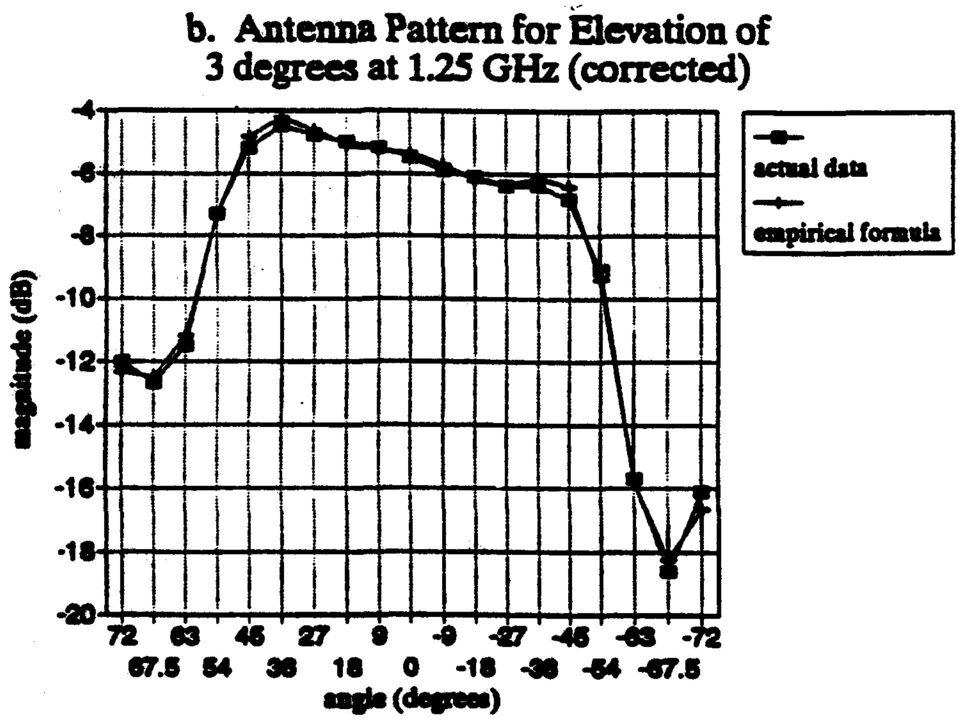
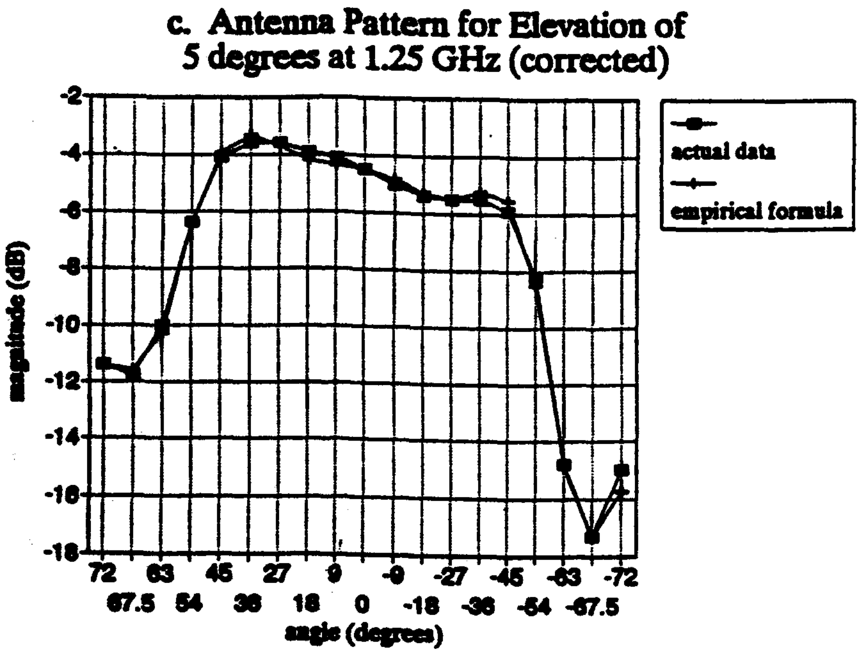


Figure 22. Curve Fit For Elevation Angles a. 0 Degrees, b. 3 Degrees



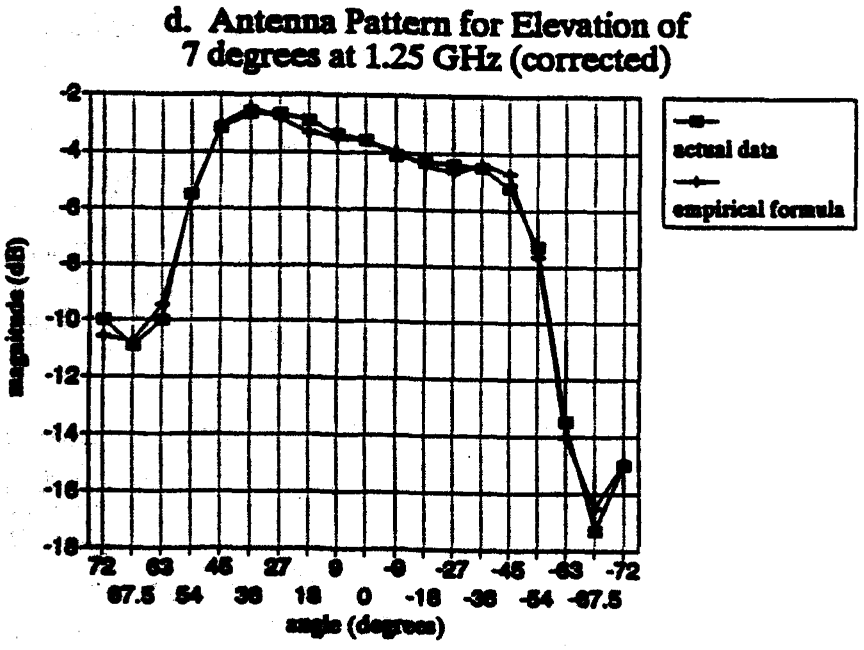
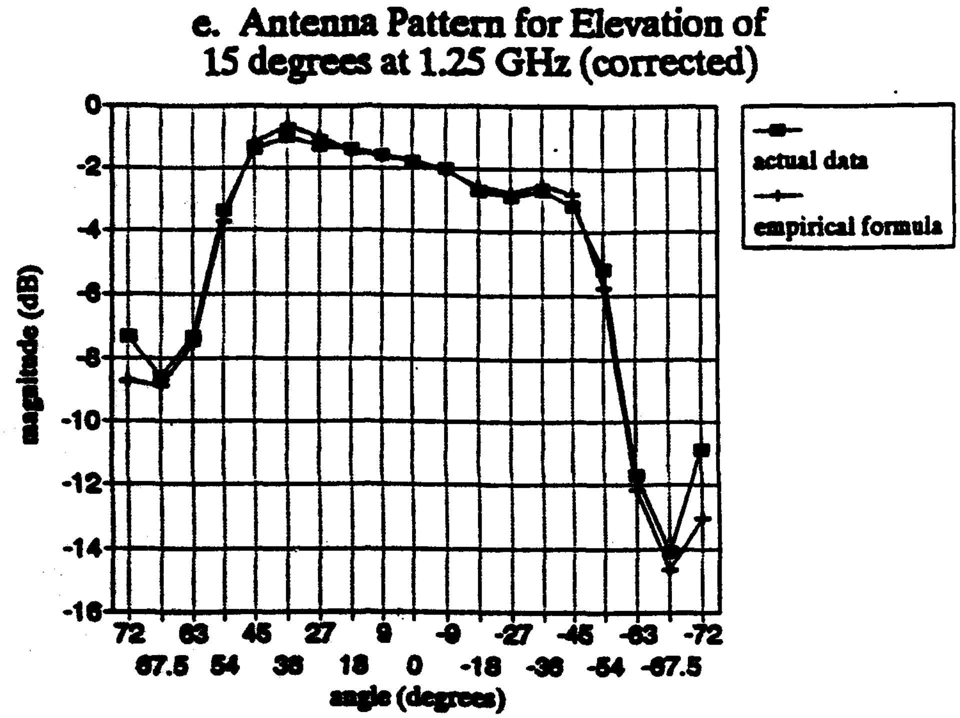


Figure 22. Curve Fit For Elevation Angles c. 5 Degrees, d. 7 Degrees



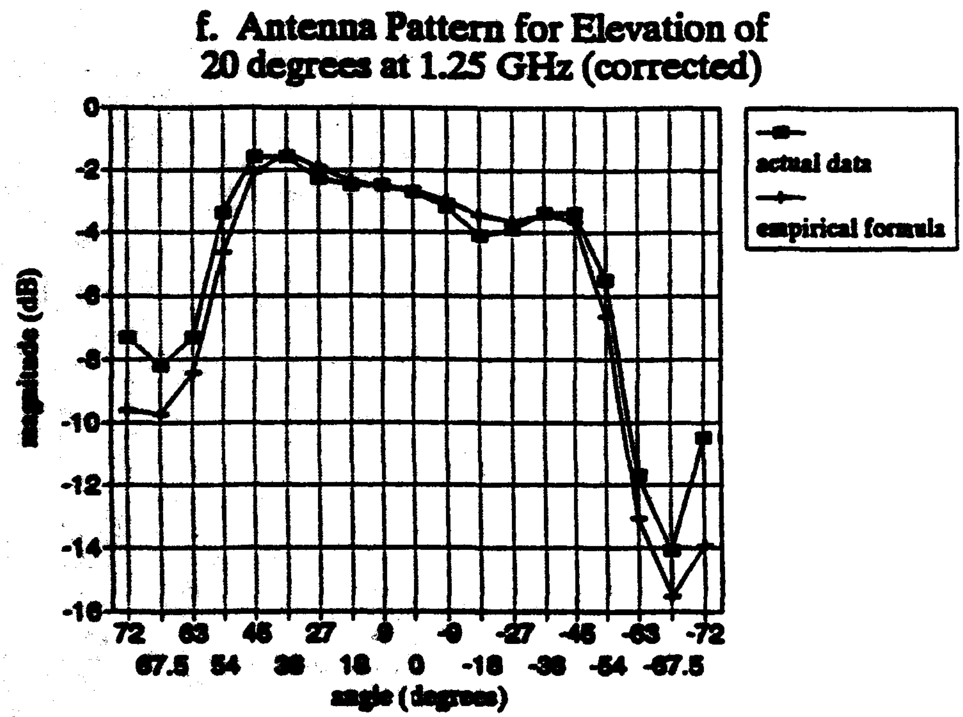


Figure 22. Curve Fit For Elevation Angles e. 15 Degrees, f. 20 Degrees

REFERENCES

(1) Jasik: "Antenna Engineering Handbook," McGraw-Hill Book Co., 1961, pg. 18-10 through 18-17

(2) RL/ERPE-91-049, In-House Report, "Scale Model Log Periodic Antenna Measurements Program," 8 Jul 91

MISSION

OF

ROME LABORATORY

Mission. The mission of Rome Laboratory is to advance the science and technologies of command, control, communications and intelligence and to transition them into systems to meet customer needs. To achieve this, Rome Lab:

a. Conducts vigorous research, development and test programs in all applicable technologies;

b. Transitions technology to current and future systems to improve operational capability, readiness, and supportability;

c. Provides a full range of technical support to Air Force Materiel Command product centers and other Air Force organizations;

d. Promotes transfer of technology to the private sector;

e. Maintains leading edge technological expertise in the areas of surveillance, communications, command and control, intelligence, reliability science, electro-magnetic technology, photonics, signal processing, and computational science.

The thrust areas of technical competence include: Surveillance, Communications, Command and Control, Intelligence, Signal Processing, Computer Science and Technology, Electromagnetic Technology, Photonics and Reliability Sciences.

END

FILMED

DATE: 11-94

DTIC