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140-GHZ CAPTURE ANTENNA MULTIPATH EXPERIMENT.(U)
AUG 78 H B WALLACE

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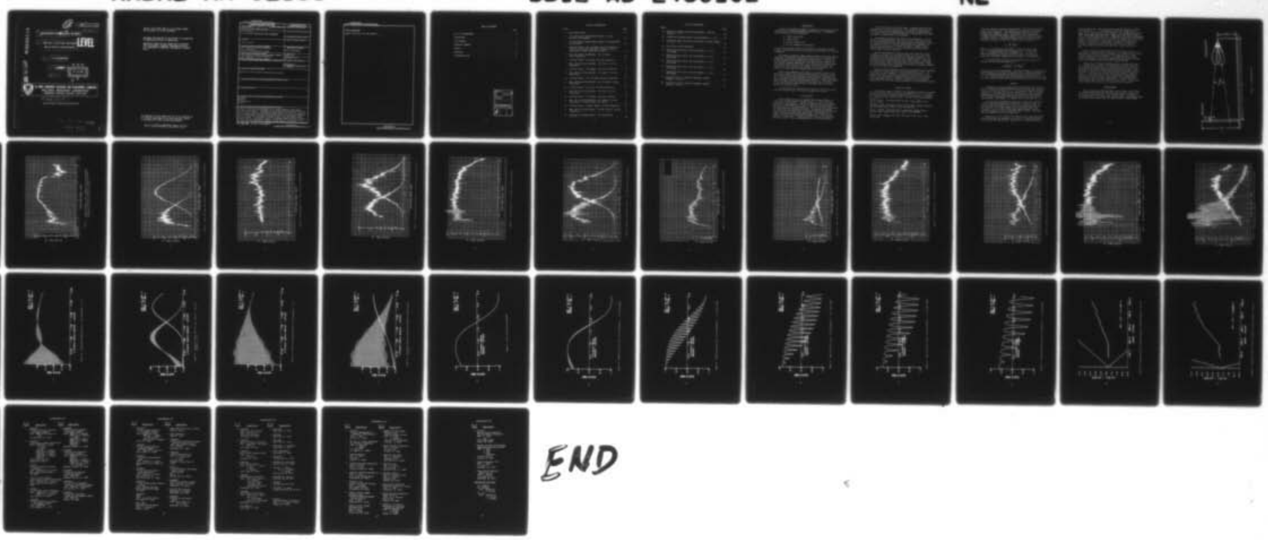

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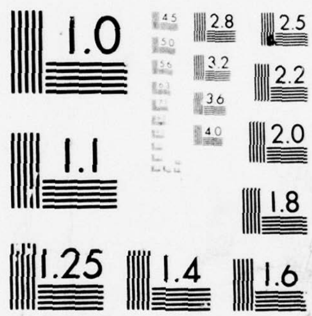

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Capture

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part of a study of the feasibility of a 140-GHz beamrider, measurements were made of the effect of multipath on the antenna power patterns of simulated missile capture antennas. The upper and lower lobes of two conically scanning capture antennas were simulated using 50.8-mm and 152.4-mm horn-lens antennas. Vertical field probes were made at a range of 100 m over high weeds, mowed grass and asphalt. A theoretical model for specular ground reflection compared favorably with the experimental results. On the basis of this model, it is concluded that the capture of a beamrider missile would be difficult at ranges

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greater than 200 m over some terrain.

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INTRODUCTION

The BRL has conducted a number of studies in-house concerning the feasibility of a 140-GHz beamrider antitank system. The beamrider system performs four basic functions:

- target acquisition,
- target track,
- missile capture, and
- missile guidance to the target.

In the "capture" mode, while the main beam is continually tracking a target, a beamriding missile is launched into the beam of a "capture" transmitter.

The capture transmitter beam contains encoded positioning information which is detected by a receiver in the tail of the missile and decoded to provide error signals for missile control. The missile is not tracked at any time but tries to seek the 3-db crossover of the conically scanned transmitter. The capture beam is aimed toward the tracking beam, which is also coded, so that the missile will intercept it and switch over to tracking its 3-db crossover. The missile will then ride the tracking beam to the target.

Part of the tradeoffs in the design of a capture system is the size of the "basket" the missile can be initially injected into and the effects of multipath reflection on the conically scanning beam null. By going to a small antenna, the basket can be made very large but the energy reflected from the ground increases. The ground reflection will change the power patterns of the upper and lower lobes of the capture beam causing either an elevation shift in the null position or multiple nulls.

This experiment was designed to get a general idea of the magnitude of multipath effects for various antennas and terrains.

TEST SCENARIO

A 100-m range was set up to measure the multipath effects on a conically scanning beam at 140-GHz (Figure 1). Three different earth covers were measured: high weeds, mowed weeds, and an asphalt road flat to approximately ± 1.3 cm. A conically scanning antenna smaller than 0.91 m was not available at the time for these experiments so single horn-lens antennas were used. The antenna was mounted on a precision altazimuth mount to permit positioning the transmitted beam to simulate the upper and lower lobes. The transmitter was placed 1.82 m above the ground and the beams had a 3-db crossover parallel to the ground. A 10-mW CW IMPATT oscillator was initially used as a source. Later measurements used a 0.5 W pulsed IMPATT.

At the other end of the 100-m range, a superheterodyne receiver was placed on a vertical positioner. The positioner could move the receiver from just above ground level to a height of approximately 4 m. The receiver was maintained parallel to the ground at all times and aimed in azimuth with a 7x riflescope.

Two different antennas were used for the transmitter - a 50.8-mm and a 150.4-mm horn-lens. The receiver used a 50.8-mm horn-lens. All of the measurements were made using vertical polarization. Prior to running the test, the one-way beam patterns were measured with the receiver elevated to 12 m above the ground. Figures 2 and 3 show the measured patterns (x's) and computer generated patterns (solid lines) of the two antennas.

Prior to measuring the simulated upper and lower lobes of the transmitter, the receiver was moved from the top of the positioner to ground level while the transmitter continually tracked it. This provided a baseline measurement of power and multipath. Since the positioner used a manually cranked winch, some noise was introduced into the receiver output from oscillation of the positioner. Aiming was difficult above the 3-m position and resulted in improper pointing in some of the pattern measurements.

After the tracking pattern was made, the transmitter was positioned to simulate the upper lobe and a power measurement was taken. The lower lobe was then simulated. A calibrated RF attenuator in the receiver was used to measure received power relative to the received power at the time when the transmitter was pointed at the receiver in its uppermost position. Figures 4 through 17 are the patterns measured for the 50.8- and 150.4-mm antennas over the different terrains.

THEORETICAL MODELS

The equations used to calculate the multipath will not be discussed here as they can be found in many other references.[1,2,3,4] It should be pointed out that the ground reflections were assumed to be specular, i.e., the ground was perfectly smooth. Actually the ground roughness

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[1] David K. Barton, "Low-Angle Radar Tracking," Proc. IEEE, Vol 62, No. 6, Jun 74.

[2] Richard A. McGee, "Multipath Suppression by Swept Frequency Methods," BRL Memorandum Report 1950, Nov 68. (AD #682728)

[3] Cecil L. Wilson, "Pointing Errors in Sequential Lobing Antenna Systems," BRL Technical Note 1463, May 62. (AD #609009)

[4] Miles V. Klein, Optics, New York, John Wiley & Sons, Inc., 1970, pp 184-189.

serves to diminish the effects of multipath by diffusing the reflected energy over a broad area. The higher the RF frequency, the rougher a given terrain appears. Also any vegetation cover will tend to attenuate the reflected signal. These facts can be readily seen by comparing the 50.8-mm antenna patterns over high weeds and asphalt (Figures 10 and 15). Generally specular reflection applies if the RMS height variation in the first Fresnel zone of reflection is

$$\sigma_n < \frac{1}{8} \frac{\lambda}{\sin \theta},$$

where σ_n is the RMS height variation, θ is the reflection angle, and λ is the wavelength of the propagated beam.[1] In this case θ_{max} = 3.3 degrees (receivers + 4m height), λ = 2.14 mm, so if $\sigma_n < 4.61$ mm specular reflection can be assumed. This case will be met for the asphalt surface but not for the two earth surfaces.

The antenna power patterns were simulated using a $[J_1(x)/(x)]^2$ function for the 50.8 mm antennas and a

$$\frac{2}{3}\left(\frac{\sin x}{x}\right)^2 + \frac{1}{3}\left(\frac{\sin x}{x}\right)^3$$

function for the 150.4-mm antenna. Very good agreement was obtained for both antennas as can be seen in Figures 2 and 3. Figures 18 through 21 show the expected multipath for the forward scattering coefficient ρ = -0.5. Relative power is the expected power received relative to the free space power received when the transmitter and receiver are coaligned.

RESULTS

A comparison of the measured data and theoretical model indicates that the forward scattering coefficients for the ground with vegetative cover is less than or equal to -0.1. This assumes a totally specular reflection. If a model was developed taking into account the surface roughness and diffuse reflection, ρ_o would increase in the model but other reflection parameters would be introduced which would reduce the multipath. Over asphalt, ρ_o appears to be on the order of -0.5.

An interesting phenomenon was noted when comparing the multipath in the CW and the chirped pulse measurements. Figure 15 shows 15 cycles of multipath between the 1- and 2-m vertical positions, for the CW source. The number agrees with the multipath model used. In Figure 17 only 13 cycles of multipath appear between 1 and 2 m when the pulsed source had a chirp from 139 to 140 GHz. The reason for this difference is not yet understood.

Based on ρ_o = -0.5 a series of elevation error curves were generated to determine the capability of a missile to find the intended null point of the capture beam. Figure 22 is a representative error curve generated for a 150.4-mm conically scanning antenna at a range of 100 m with $\rho_o = 0$. As the missile flies lower in the capture beam, the receiver would find the difference (Δ_p) between the contributions of the upper and lower lobes. Where Δ_p is zero should be the null. Since the transmitter is at a height of 1.82 m and is boresighted parallel to the ground, the null is at the same height without multipath present. If the missile is below the null, Δ_p is positive which would tell the missile to move upward. Conversely, if the missile is high, a negative Δ_p would tell the missile to move downward. All of the calculated error curves are for a receiver with an RF AGC.

Figure 23 shows the error curve at 100 m with $\rho_o = -0.5$. A second null is appearing due to multipath. At a range of 200 m (Figure 24) there are five nulls having positive slope, any one of which could be sought out by the missile. As we progress out in range (Figures 25 through 27) more nulls appear until the possible tracking nulls are outside the beam of the main tracking antenna.

Figures 28 and 29 show the computed path of a perfect missile, i.e., instantaneous response, when injected into capture beams from 152.4-mm and 50.8-mm antennas. In these simulations the free space boresight of the capture antenna was parallel to the ground. The missile was injected into the antenna beam before multipath affected the nulls. The missile will only follow nulls lying on a positive slope. It can be seen that for the 152.4-mm and 50.8-mm antennas the missile would fly outside the envelope of the tracking beam at approximately 300 m and 220 m, respectively. The 3-db envelopes of the capture beams are indicated by the solid lines. These ranges would increase for reduced ρ_o or increased antenna diameters.

ACKNOWLEDGMENT

The multipath experiment described in this report is the result of a number of persons in the Millimeter Wave Research Group at the Ballistic Research Laboratory. The equipment used was designed by Mr. Donald Bauerle, Mr. Joseph Knox, and the author. The computer model of multipath was developed with assistance from Mr. Richard McGee.

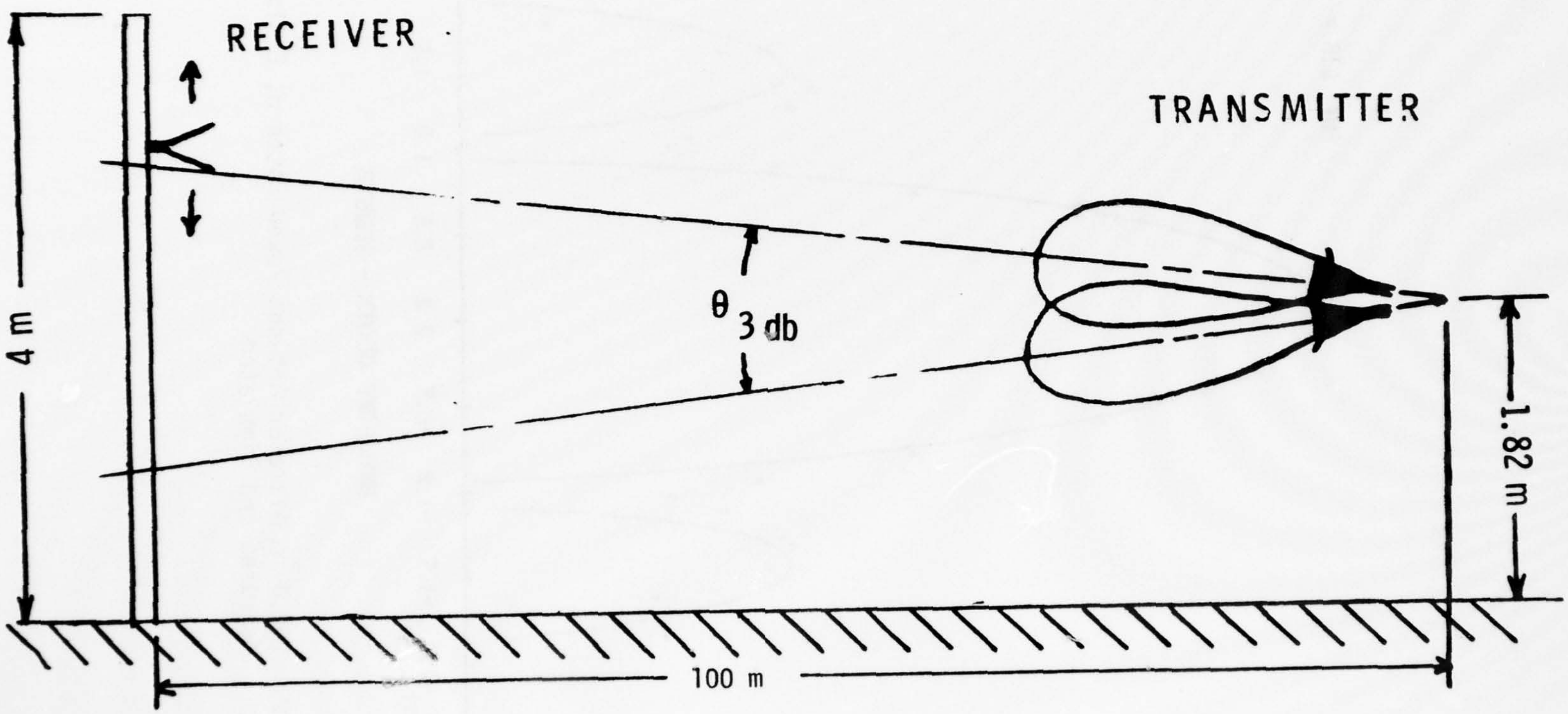

Figure 1. Experimental Setup

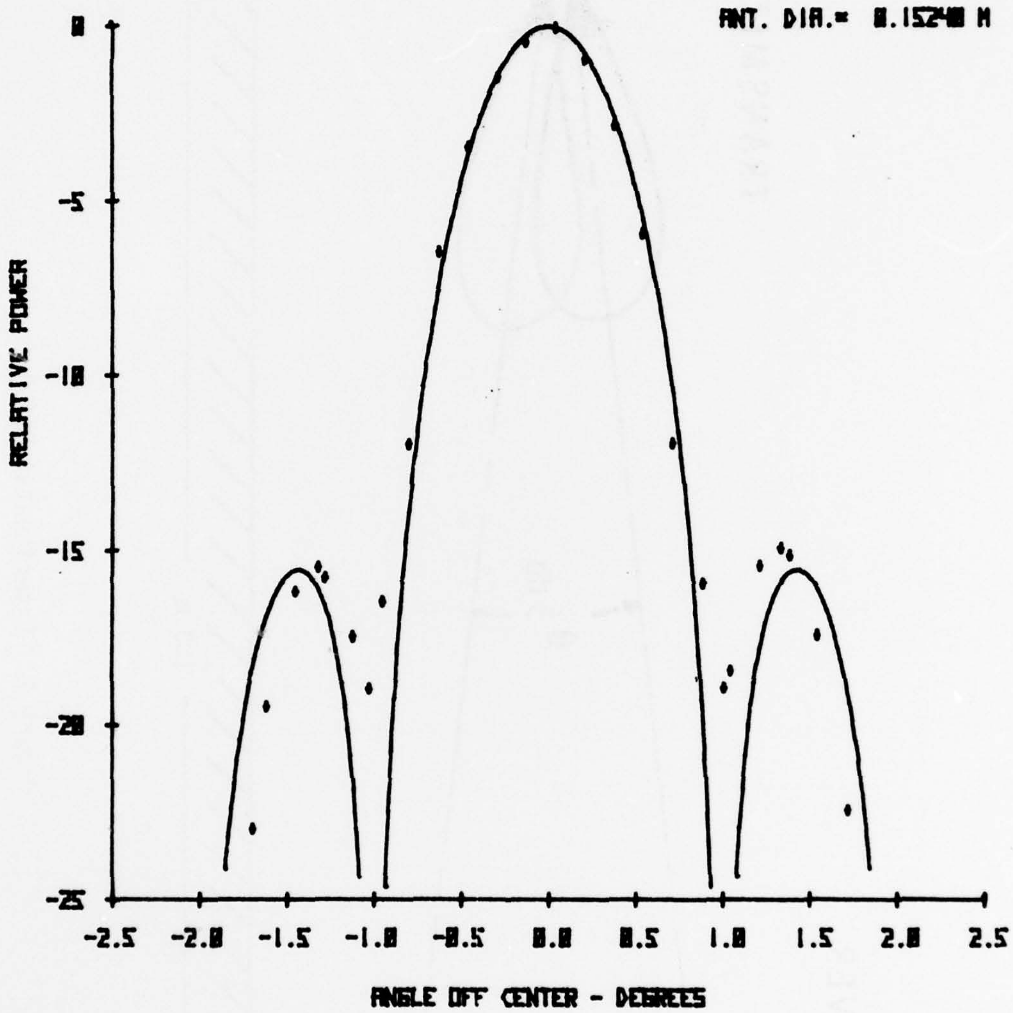

Figure 2. 152.4-mm Diameter Antenna Power Pattern, E-Plane
Measured and Simulated

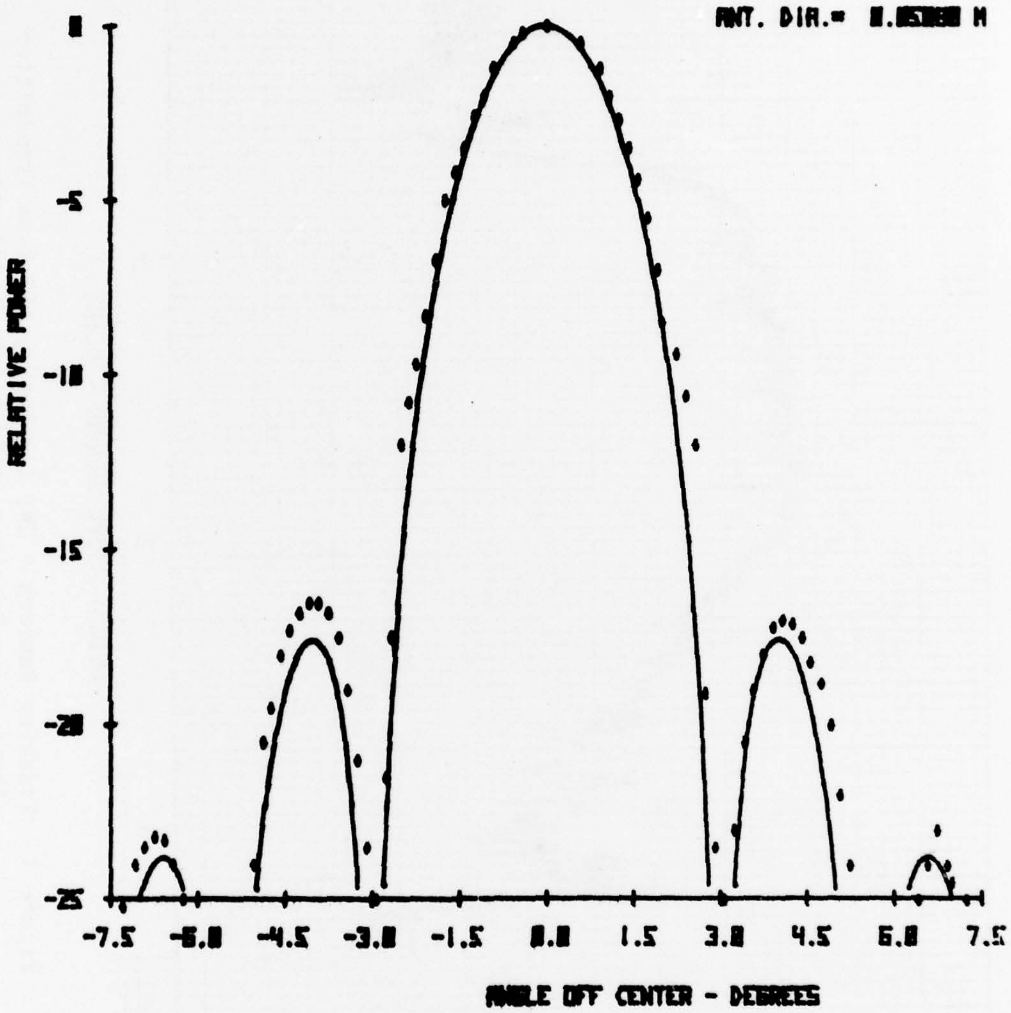

Figure 3. 50.8-mm Diameter Antenna Power Pattern, E-Plane Measured and Simulated

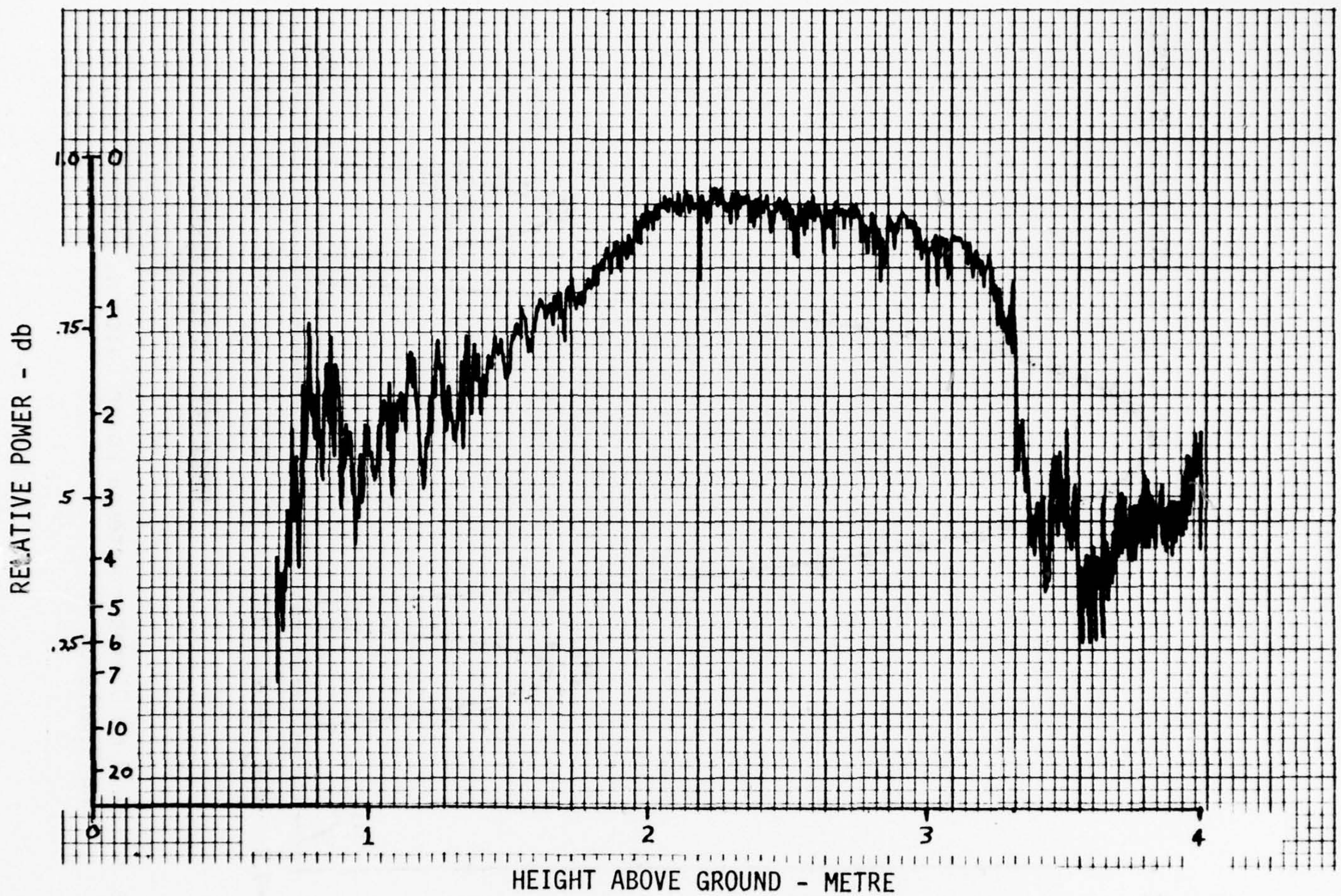

Figure 4. Tracking Pattern - CW, 1-m Weeds, 152.4-mm Transmitter (Above 3.3-m Receiver could not be aimed accurately, attenuation at lower levels due to weeds.)

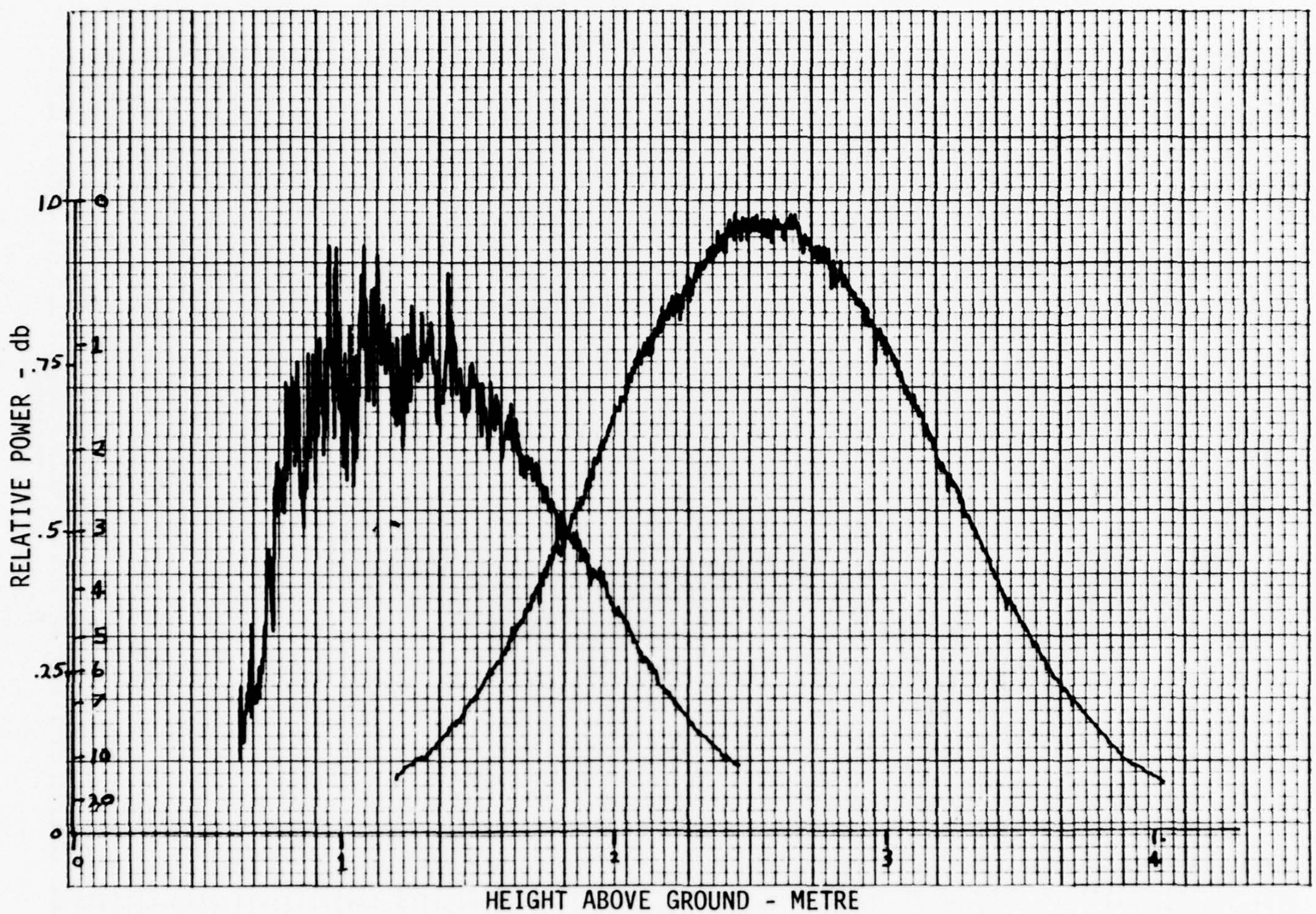

Figure 5. Upper and Lower Lobe Patterns - CW, 1-m Weeds, 152.4-Transmitter

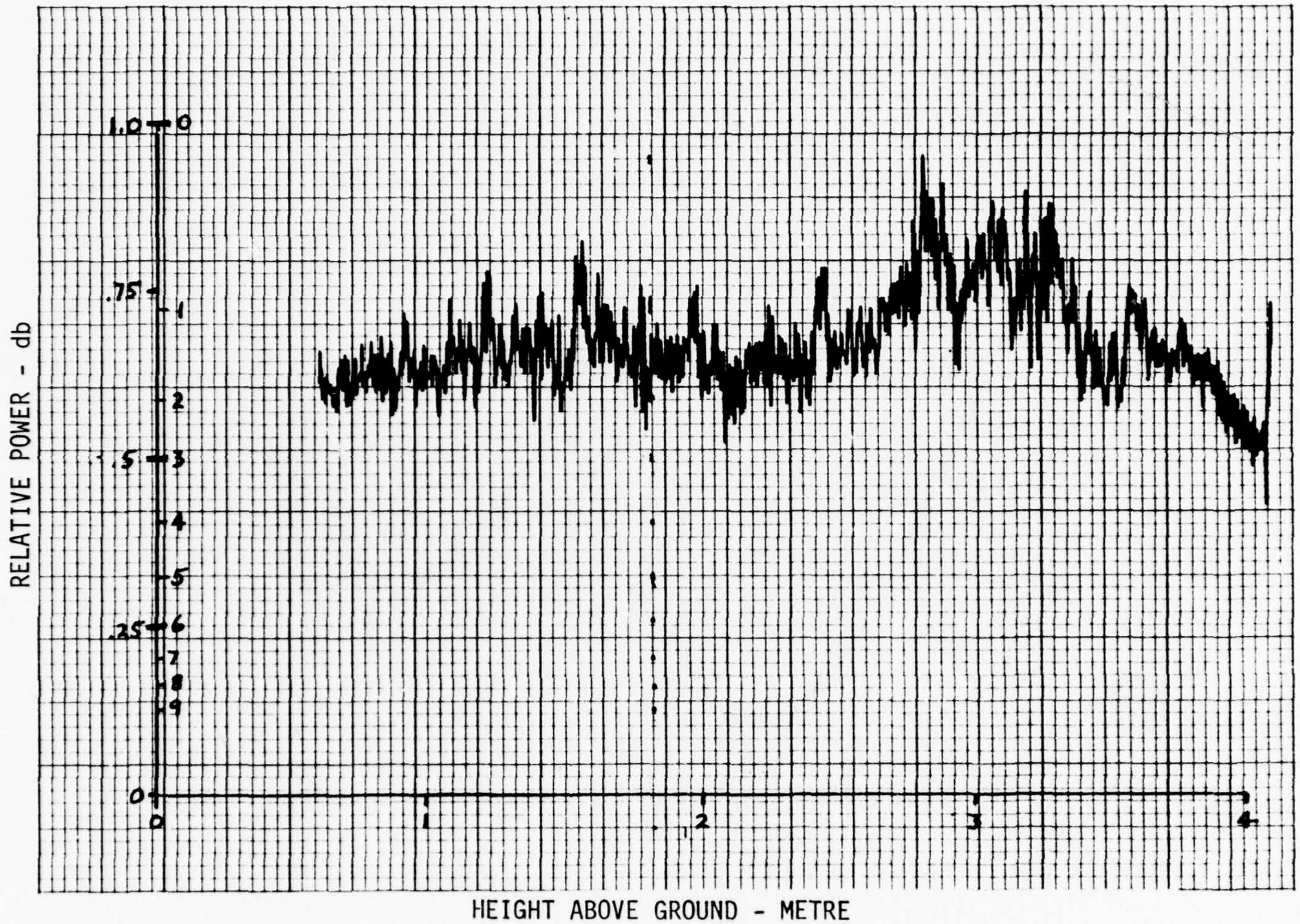

Figure 6. Tracking Pattern - CW, Grass, 152.4-mm Transmitter

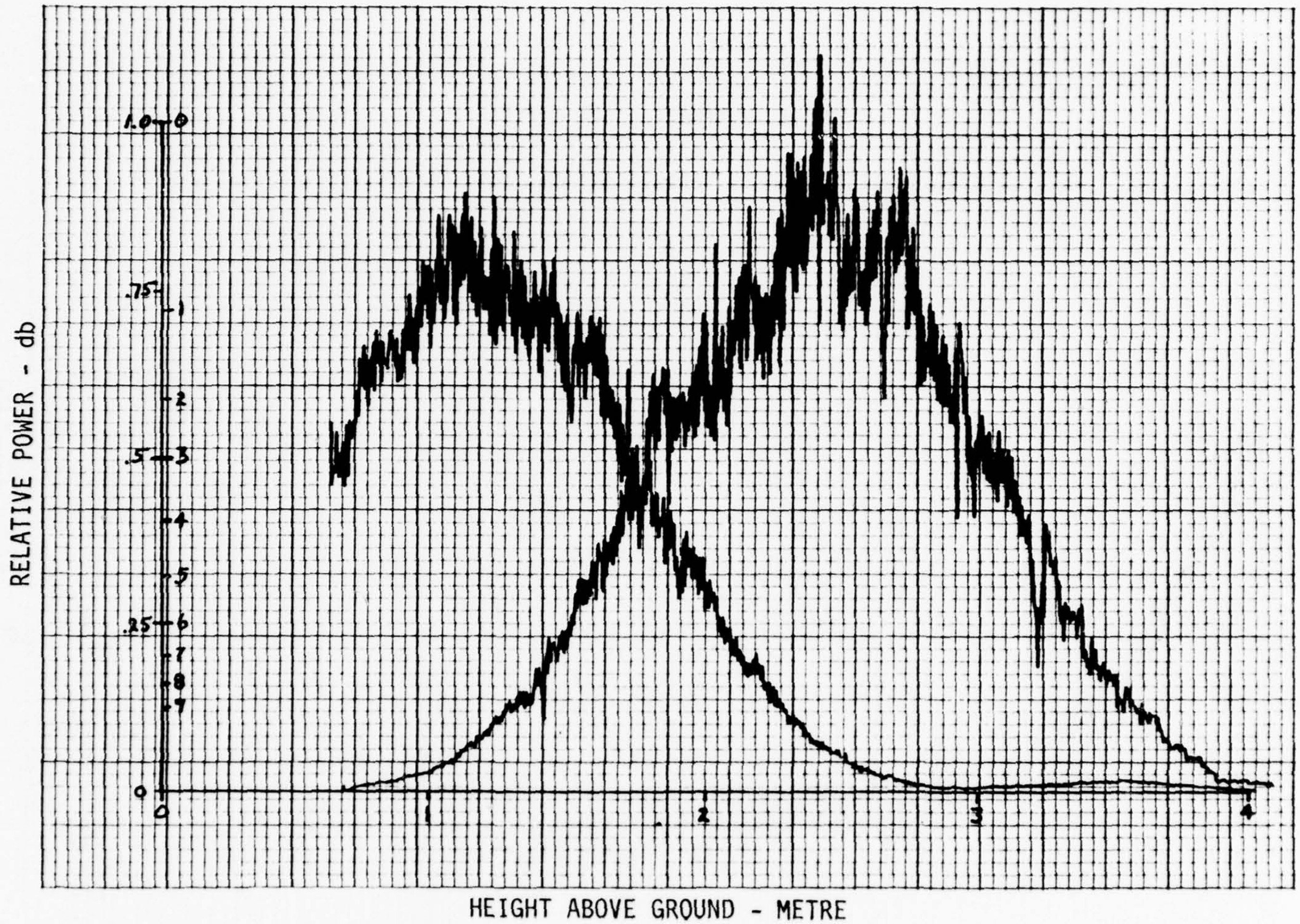

Figure 7. Upper and Lower Lobe Patterns - CW, Grass, 152.4-mm Transmitter

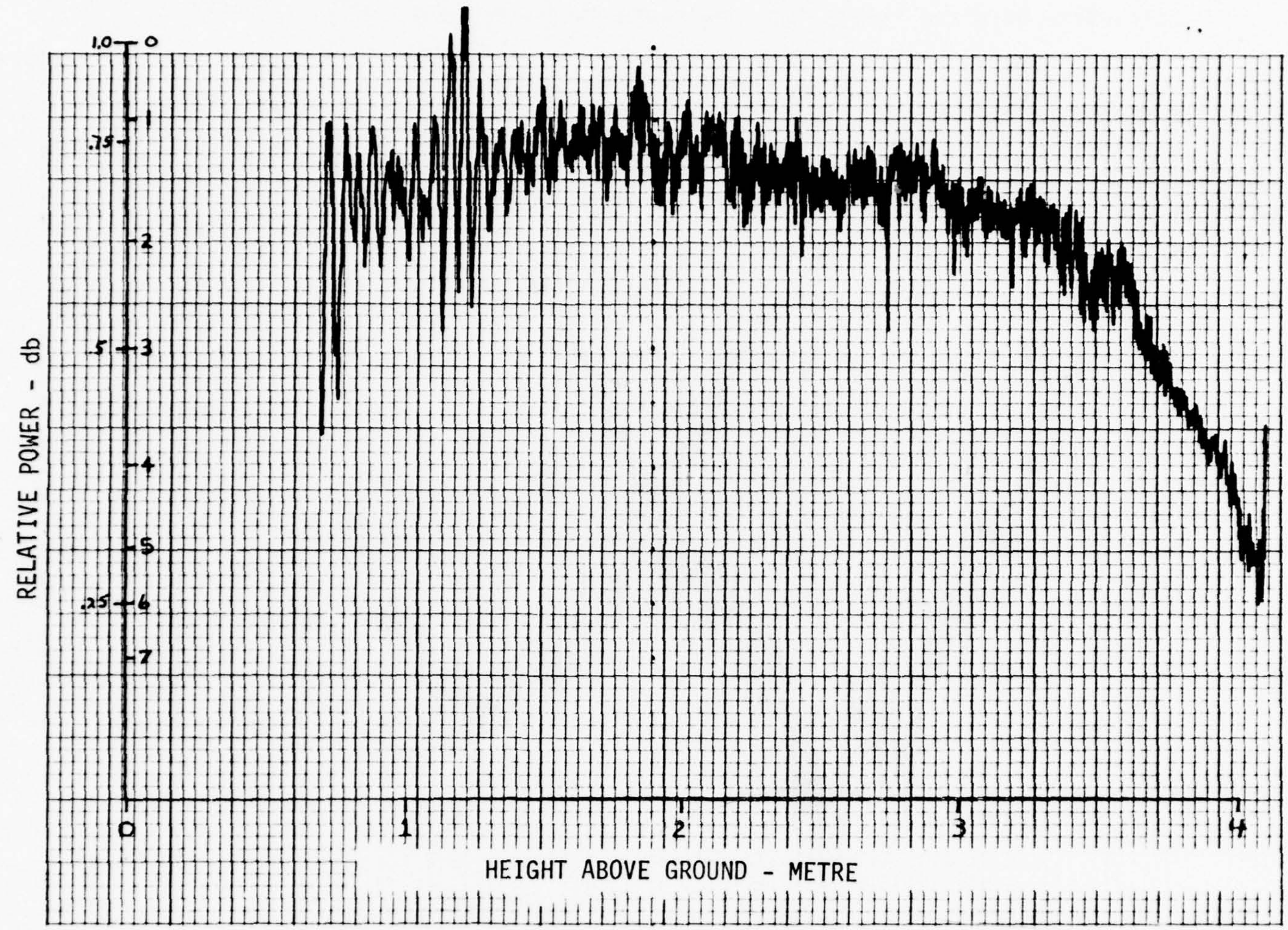

Figure 8. Tracking Pattern - CW, Asphalt, 153.4-mm Transmitter

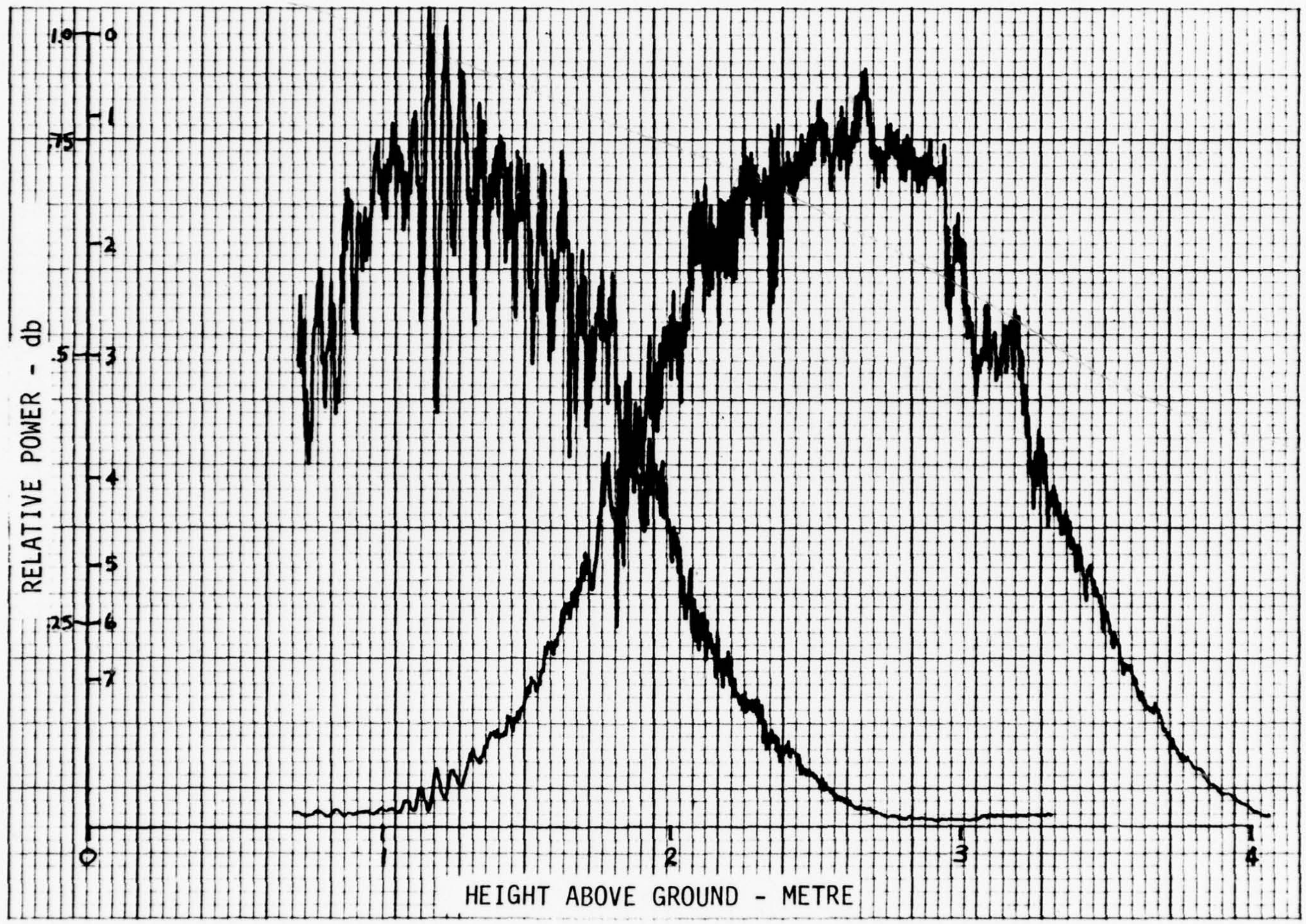

Figure 9. Upper and Lower Lobe Patterns - CW, Asphalt, 153.4-mm Transmitter

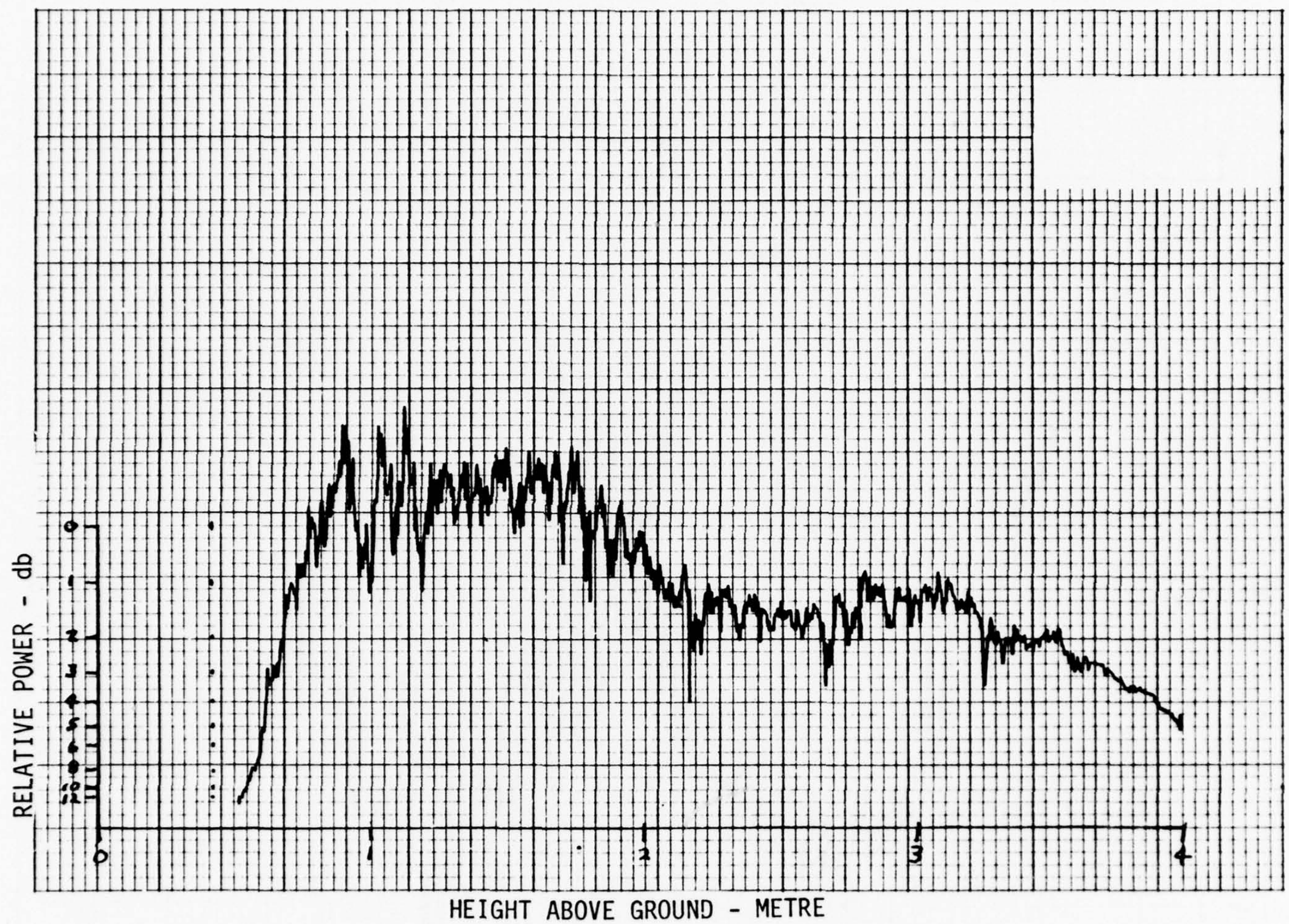

Figure 10. Tracking Pattern - CW, 1-m weeds, 50.8-mm Transmitter

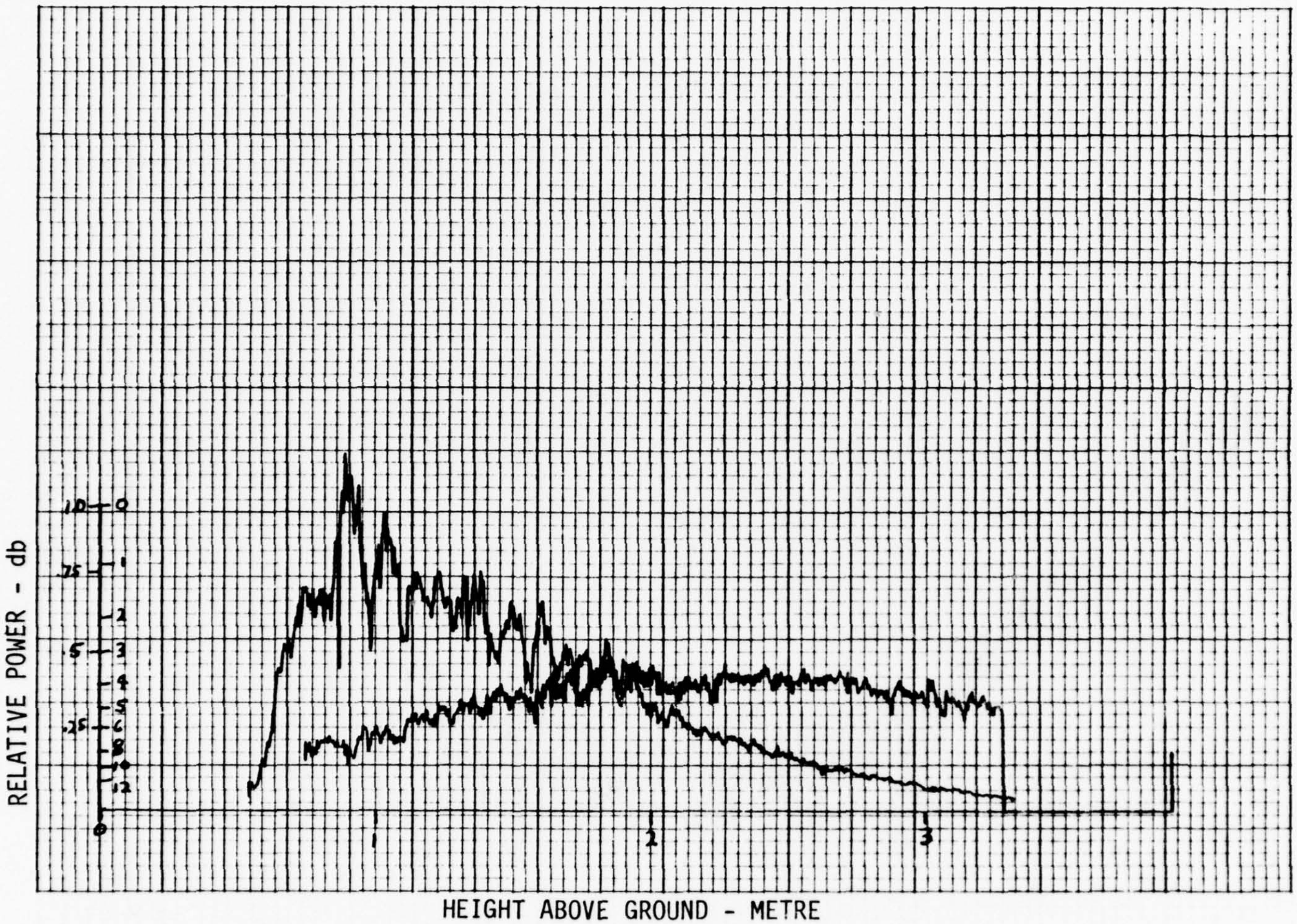

Figure 11. Upper and Lower Lobe Patterns - CW, 1-m Weeds, 50.8-mm Transmitter

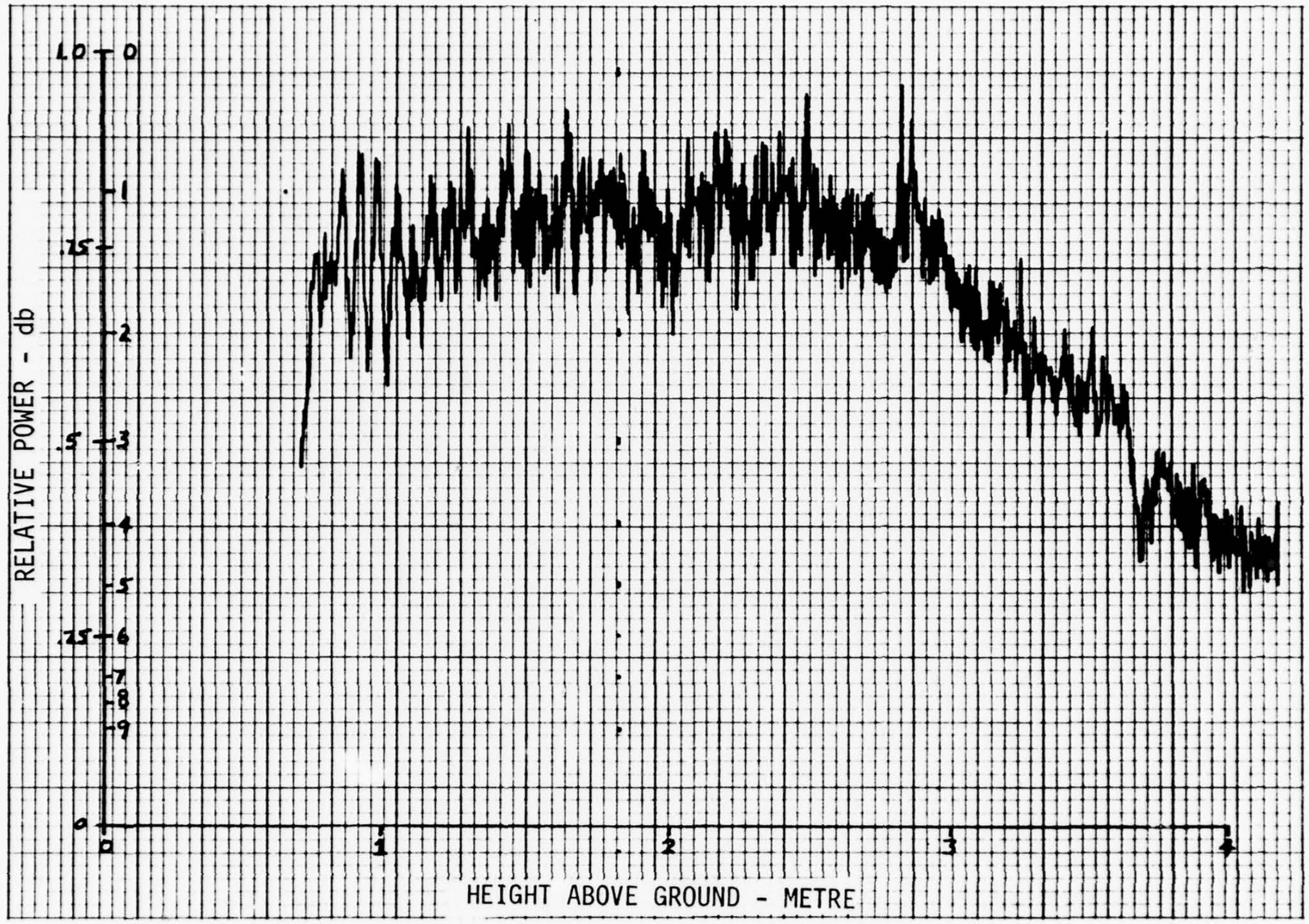

Figure 12. Tracking Pattern - CW, Grass, 50.8-mm Transmitter

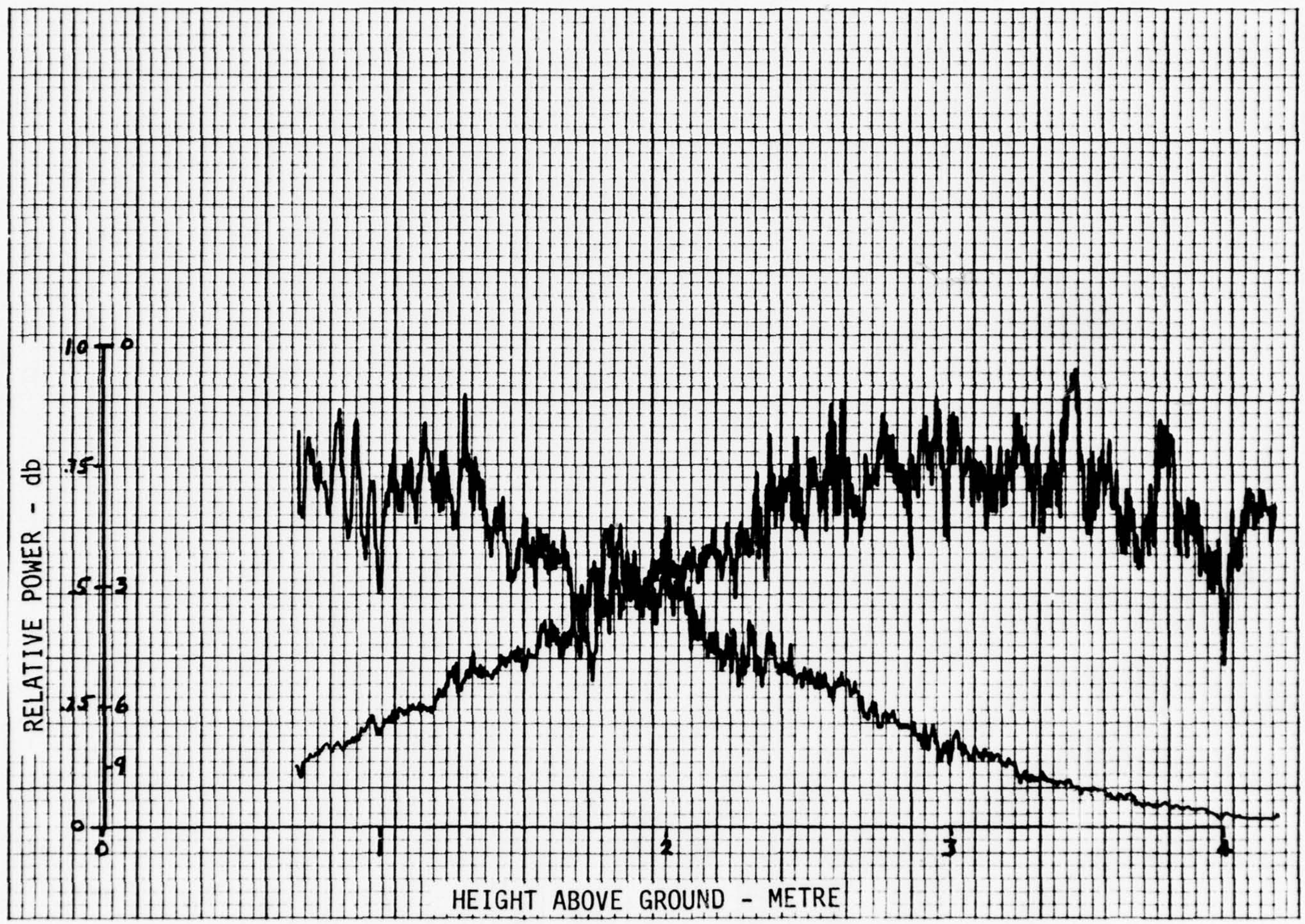

Figure 13. Upper and Lower Lobe Patterns - CW, Grass, 50.8-mm Transmitter

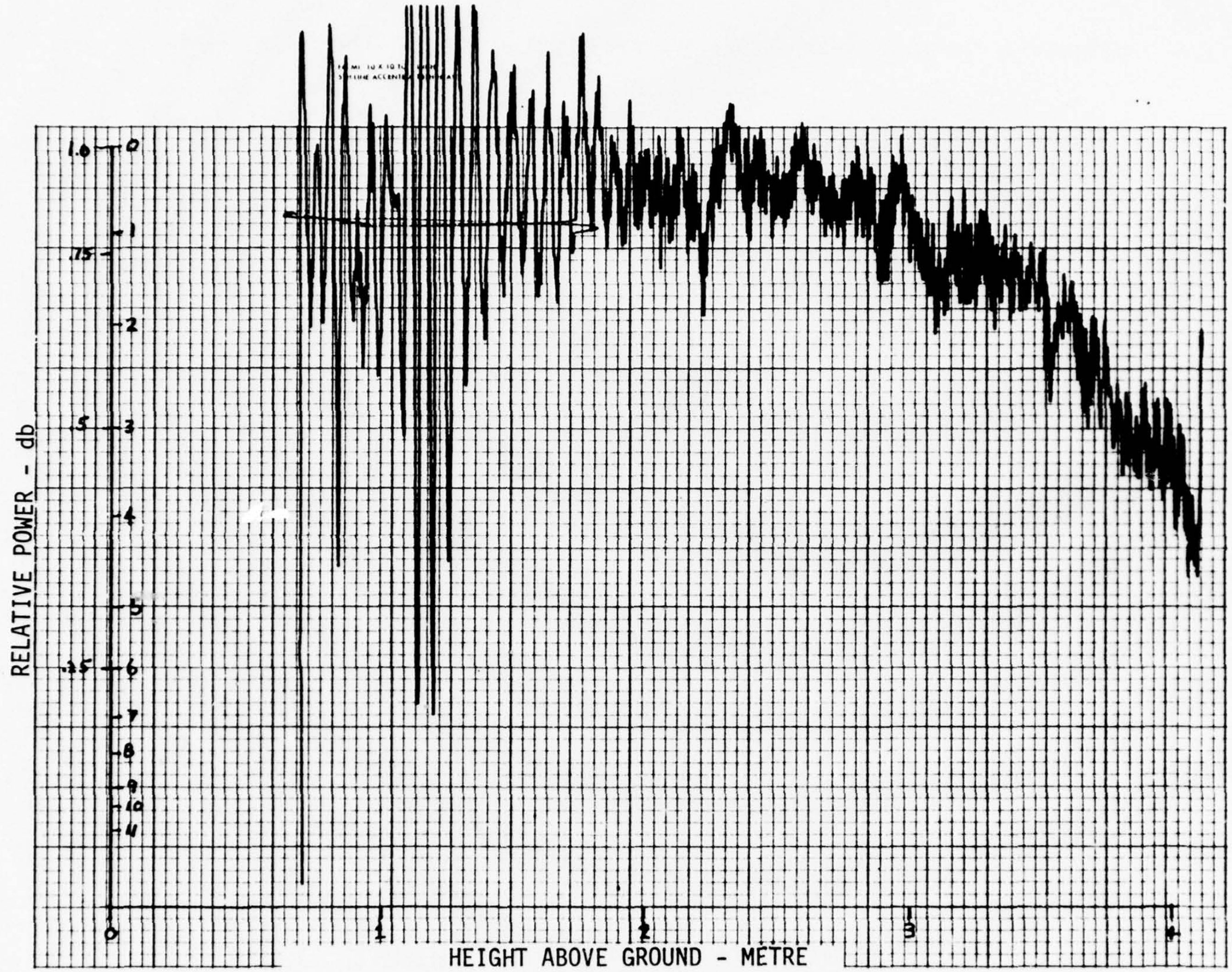

Figure 14. Tracking Pattern - CW, Asphalt, 50.8-mm Transmitter

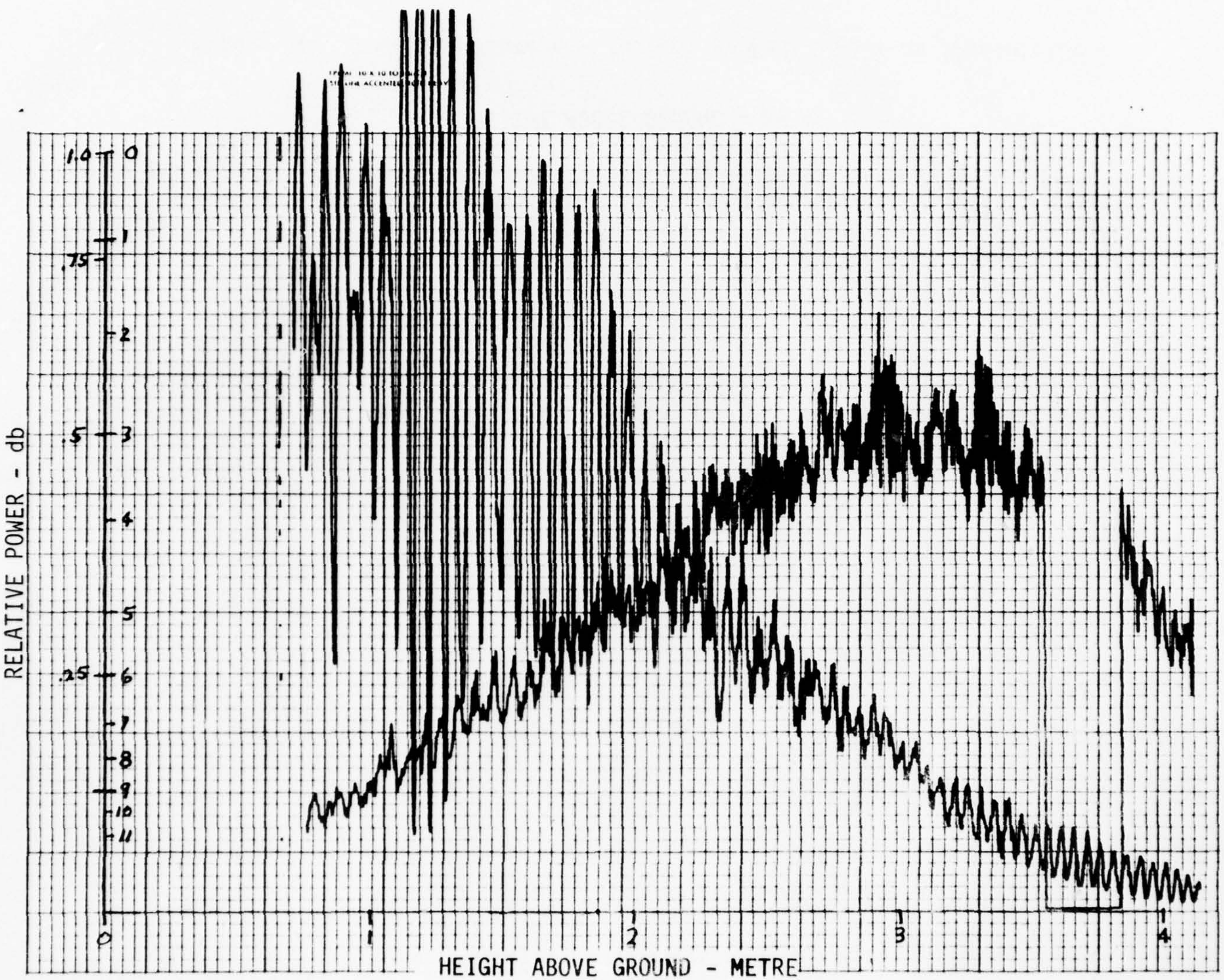

Figure 15. Upper and Lower Lobe Patterns - CW, Asphalt, 50.8-mm Transmitter. (LO lost from 3.5 to 3.85 m.)

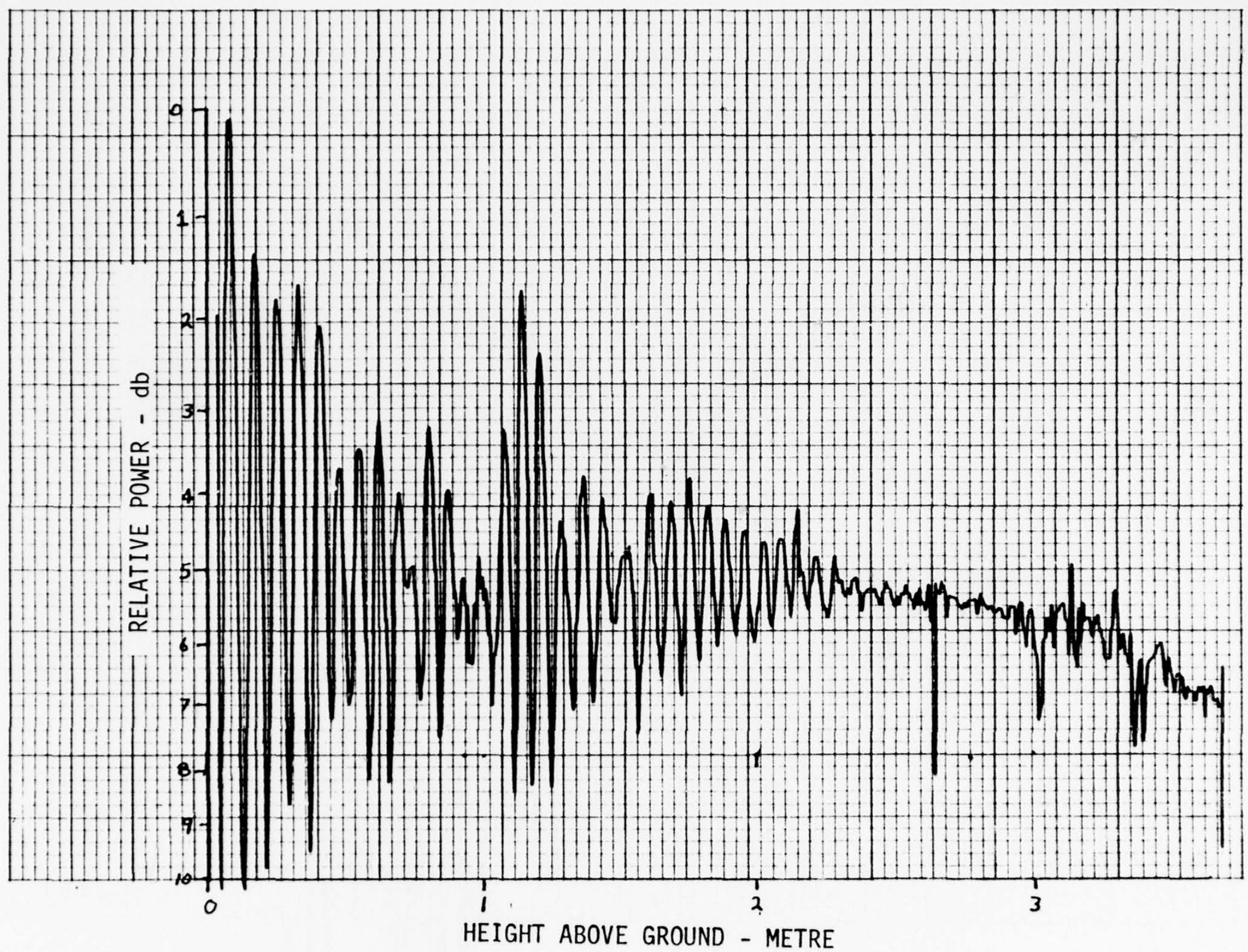

Figure 16. Tracking Pattern - Pulsed, Asphalt, 50.8-mm Transmitter

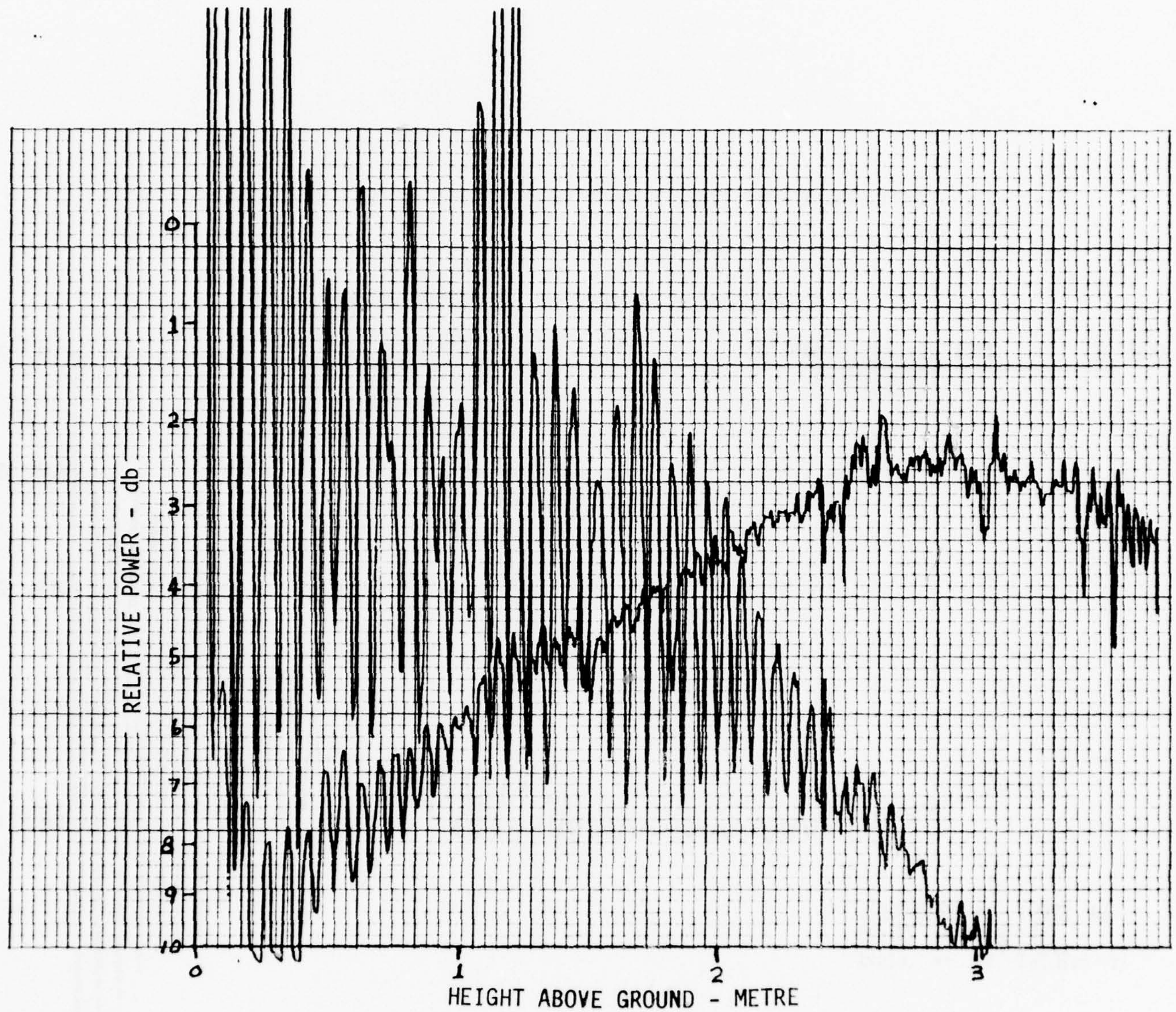

Figure 17. Upper and Lower Lobe Patterns - Pulsed, Asphalt, 50.8-mm Transmitter

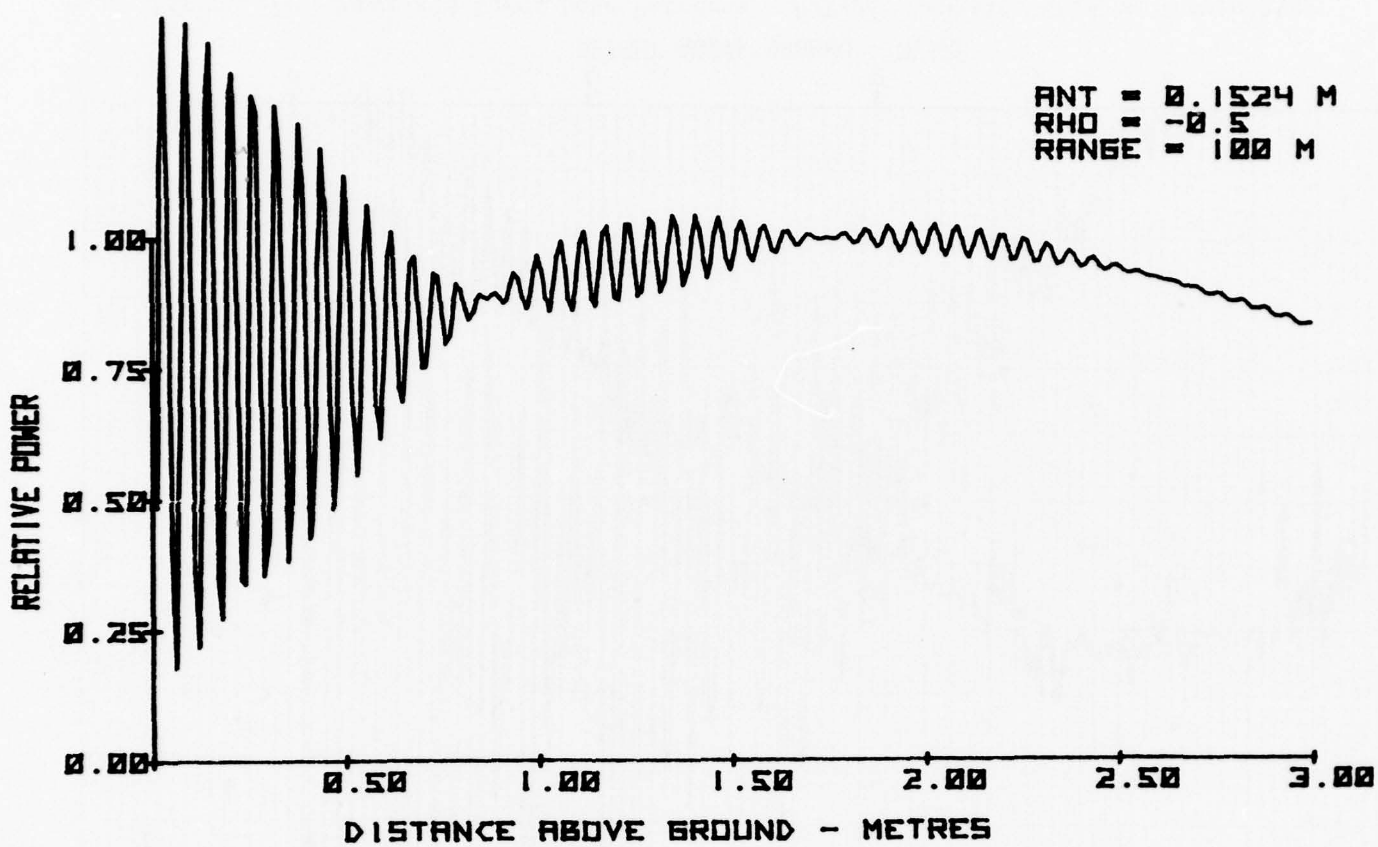

Figure 18. Theoretical Tracking Pattern - 152.4-mm Antenna, $\rho = 0.5$

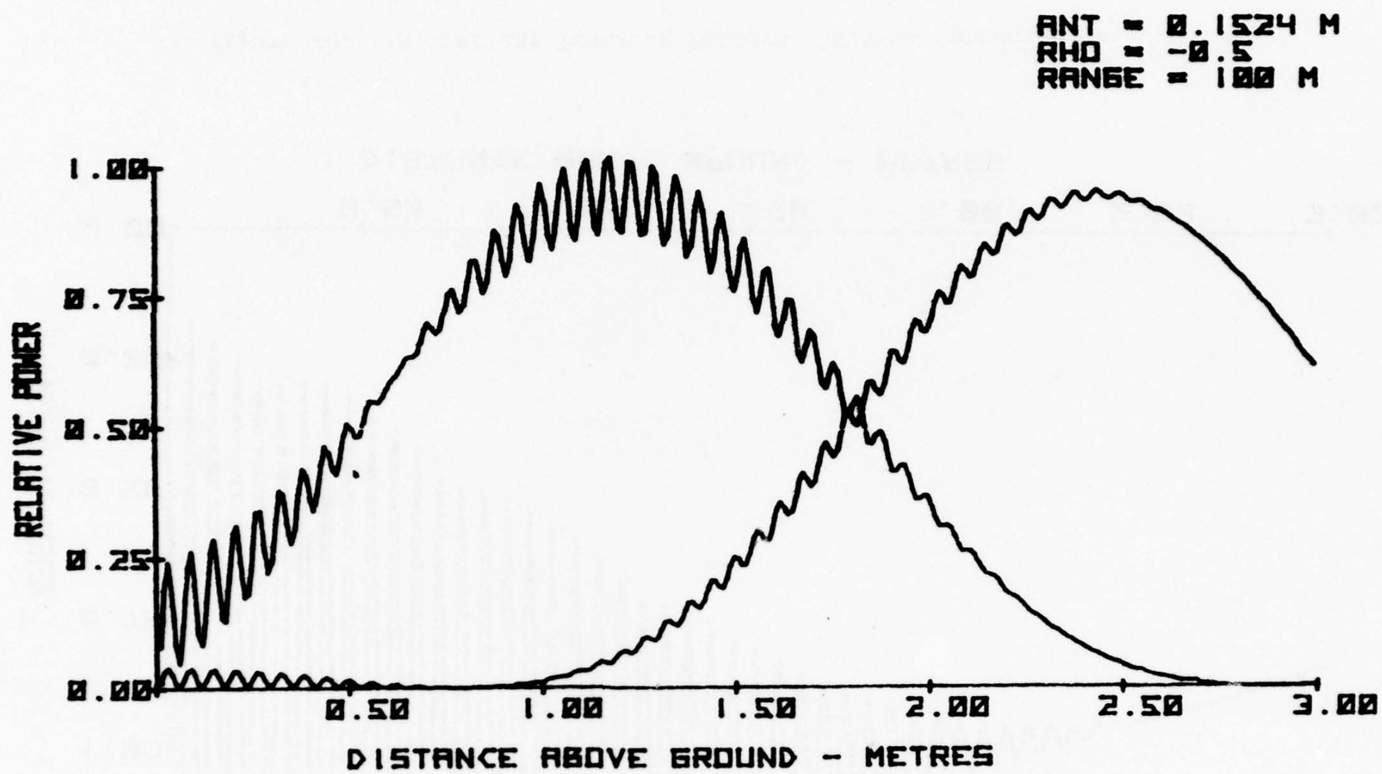

Figure 19. Theoretical Upper and Lower Lobe Patterns - 152.4-mm Antenna, ρ = -0.5.

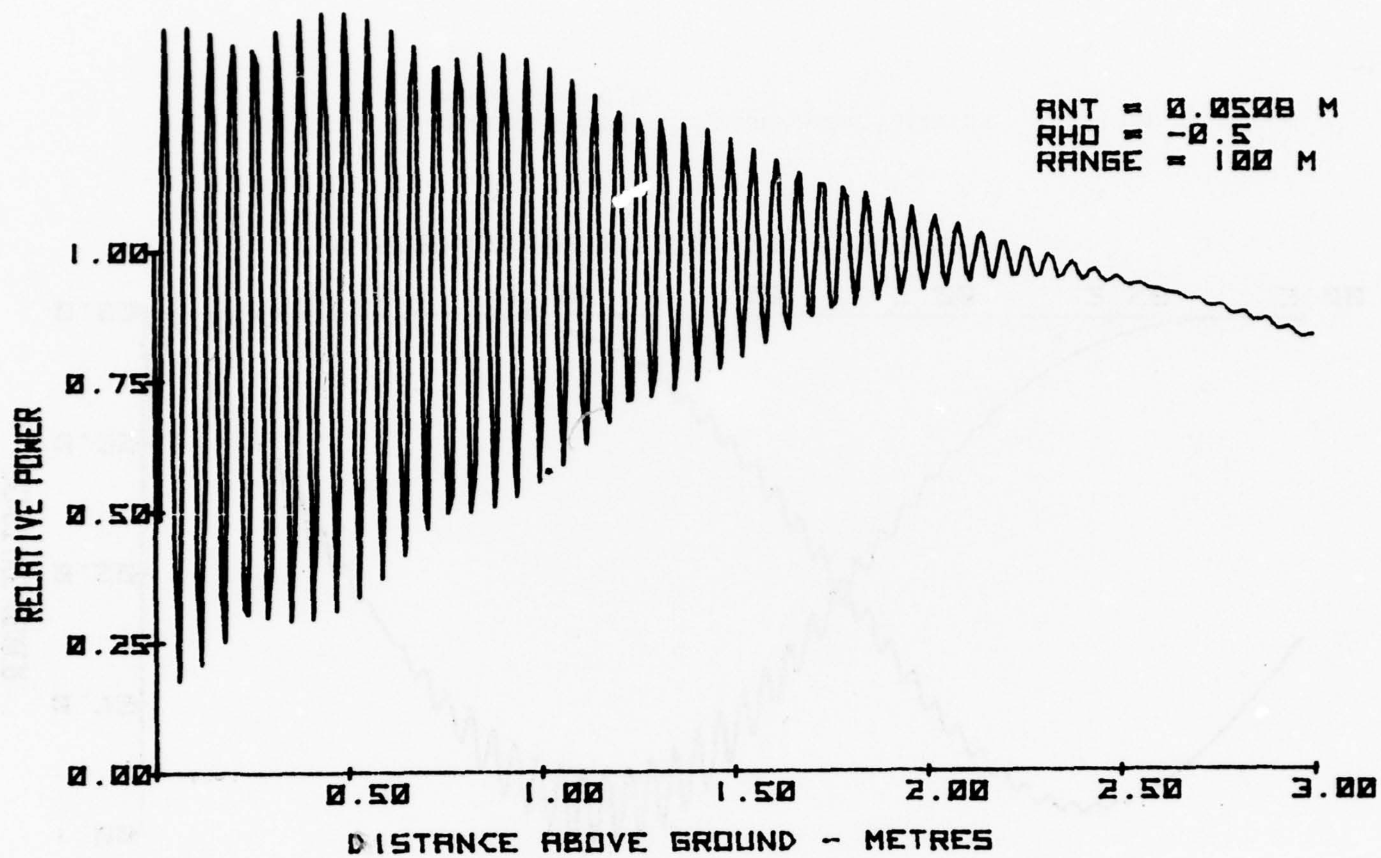

Figure 20. Theoretical Tracking Pattern, 50.8-mm Antenna, $\rho = -0.5$

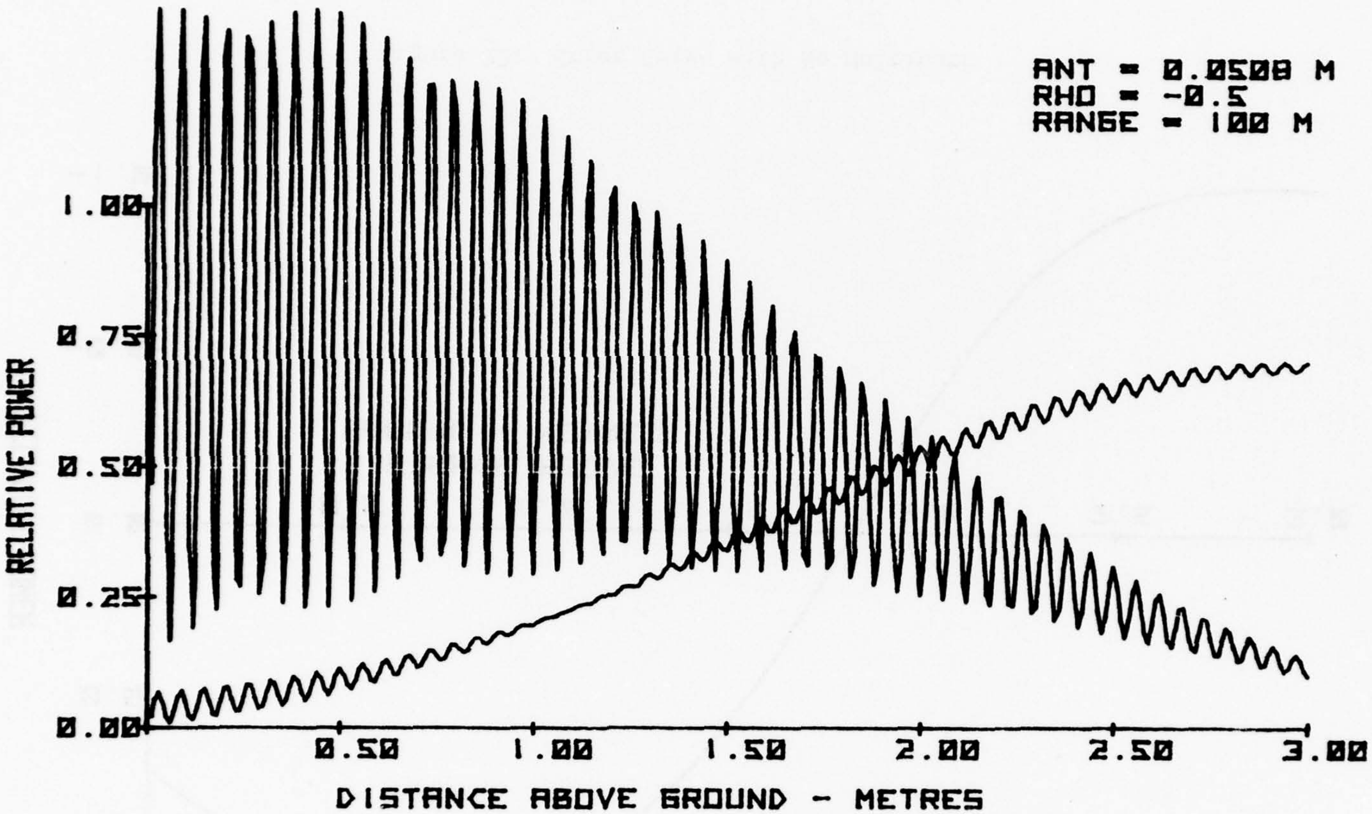

Figure 21. Theoretical Upper and Lower Lobe Patterns, 50.8-mm Antenna, $\rho = -0.5$.

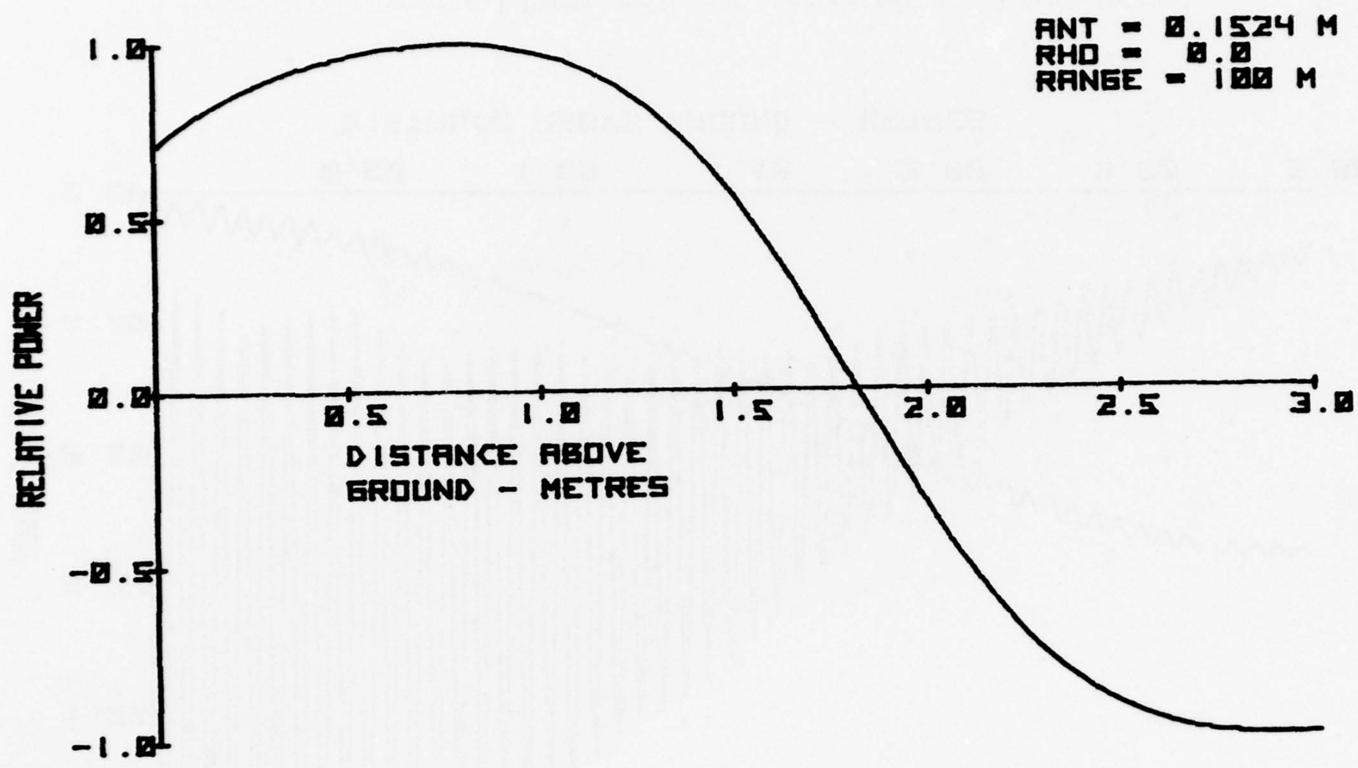

Figure 22. Error Curve with No Multipath

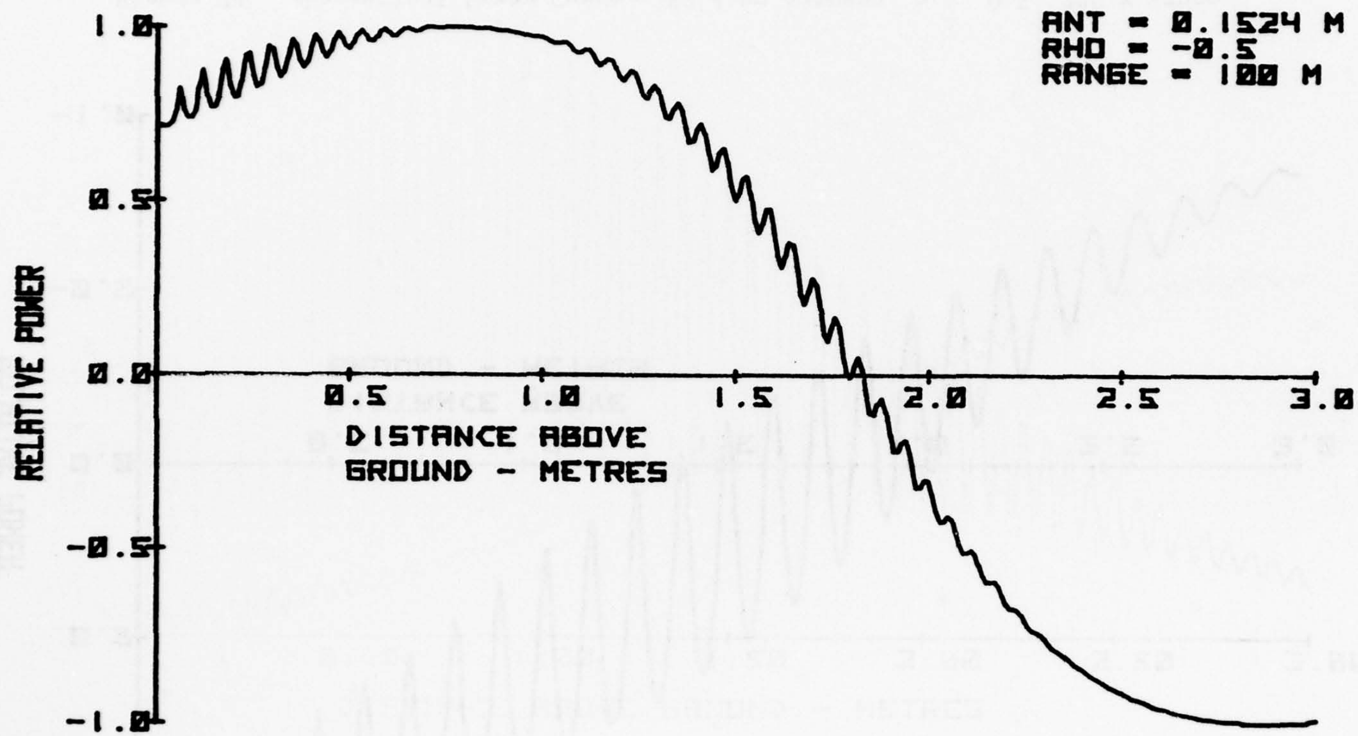

Figure 23. Theoretical Error Curve, 152.4-mm Antenna, ρ = -0.5, 100-m Range

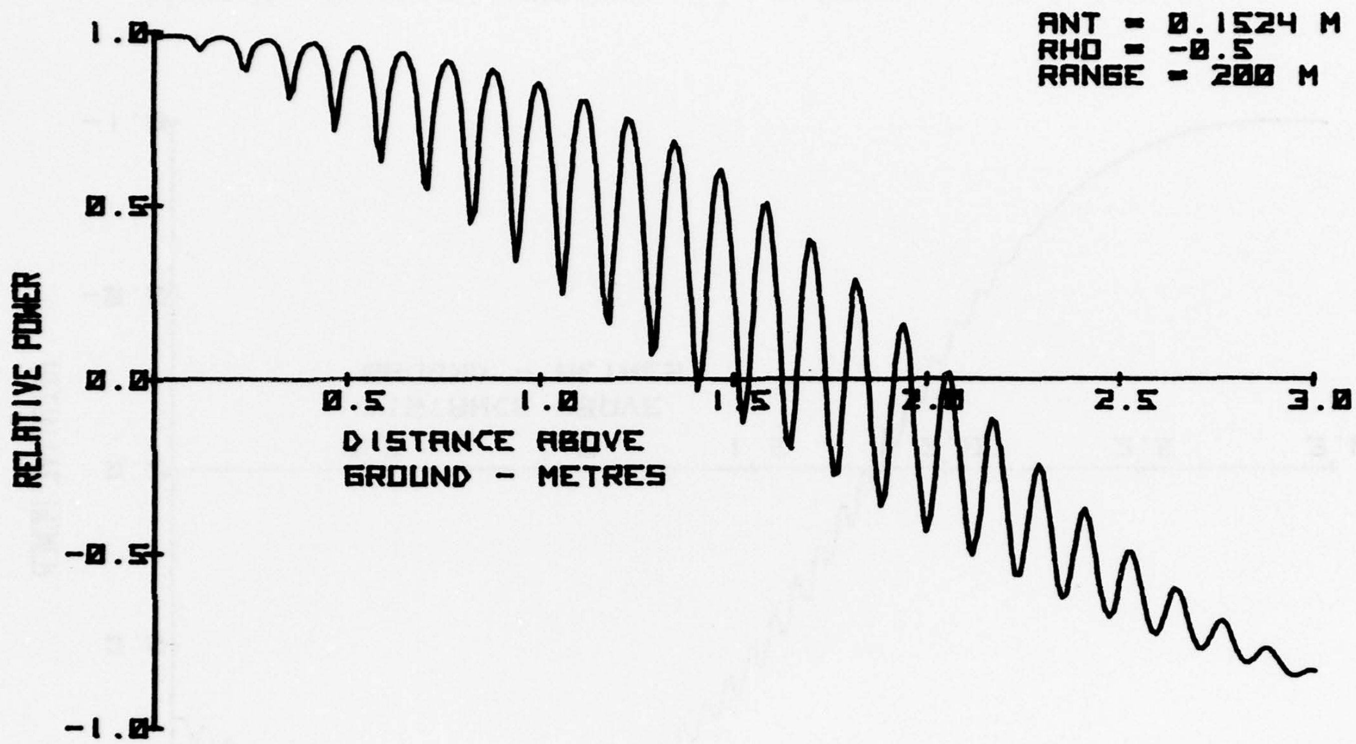

Figure 24. Theoretical Error Curve, 152.4-mm Antenna, ρ = -0.5, 200-m Range

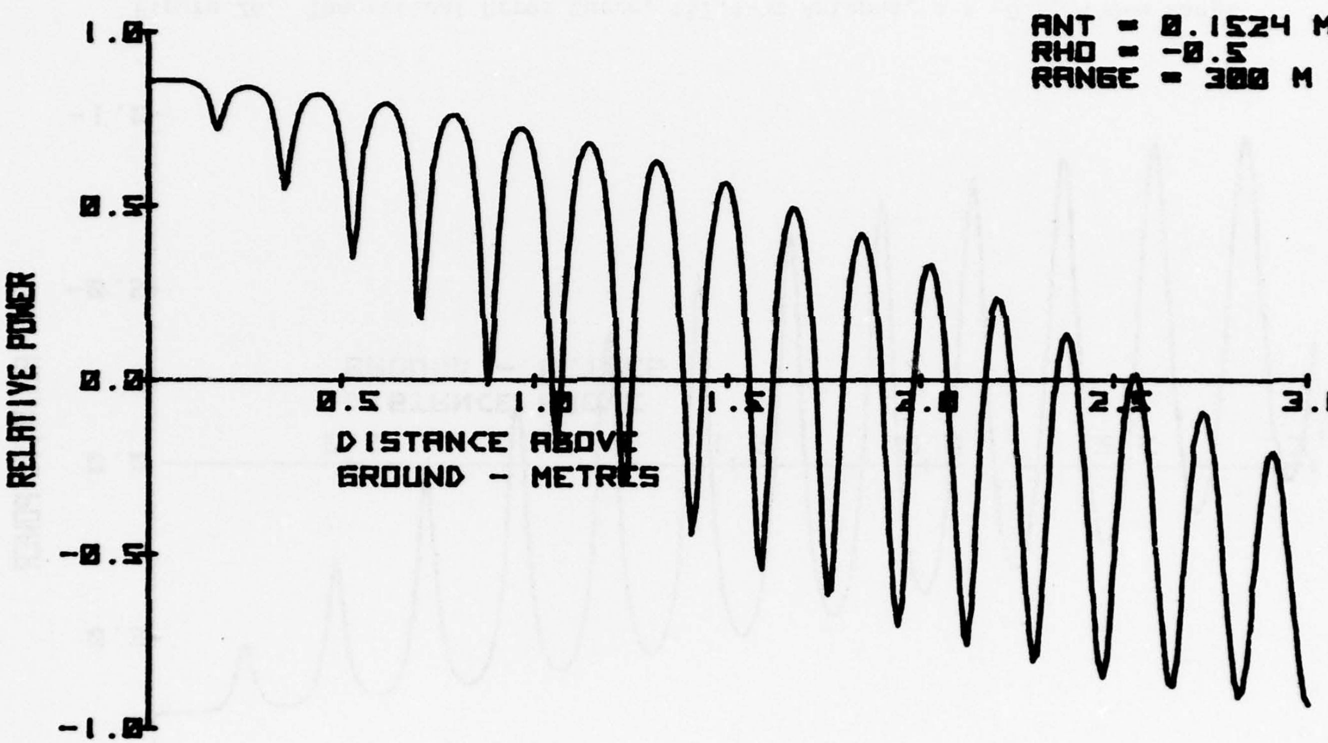

Figure 25. Theoretical Error Curve, 152.4-mm Antenna, ρ = -0.5, 300-m Range

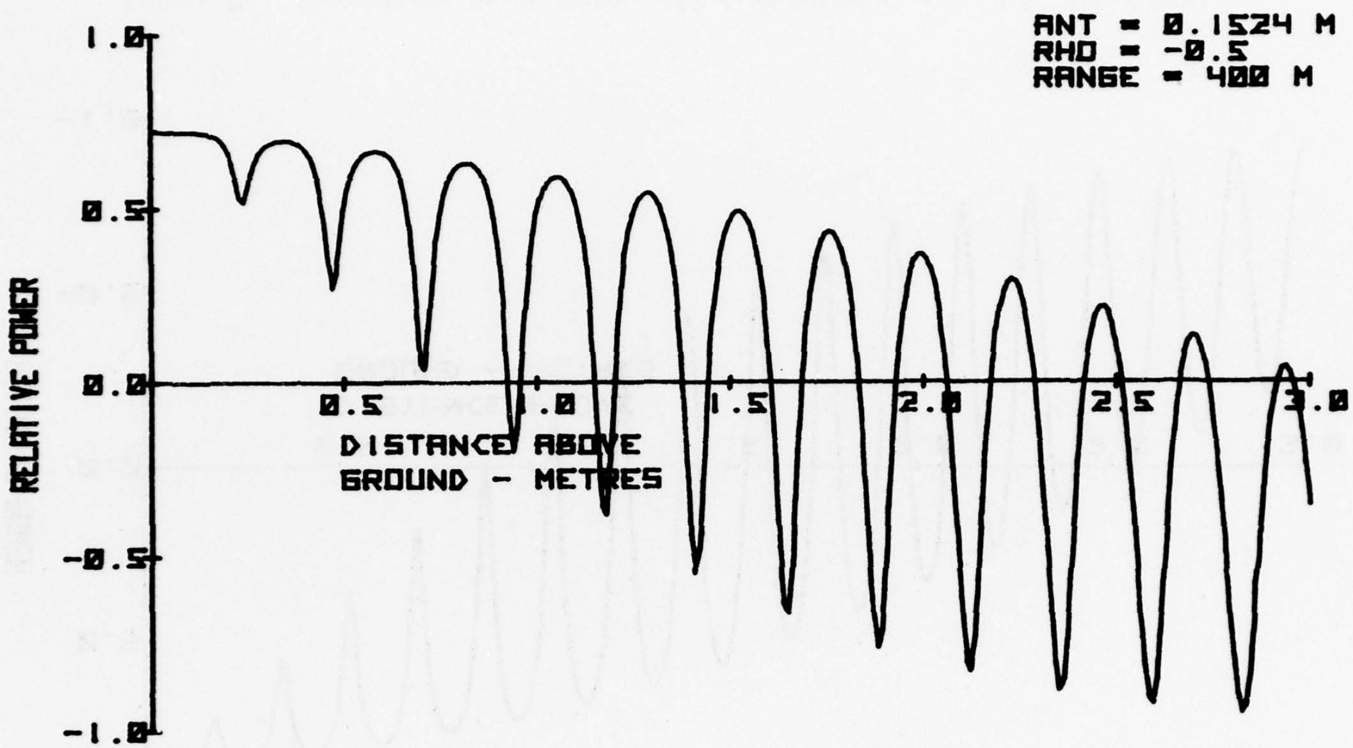

Figure 26. Theoretical Error Curve, 152.4-mm Antenna, ρ = -0.5, 400-m Range

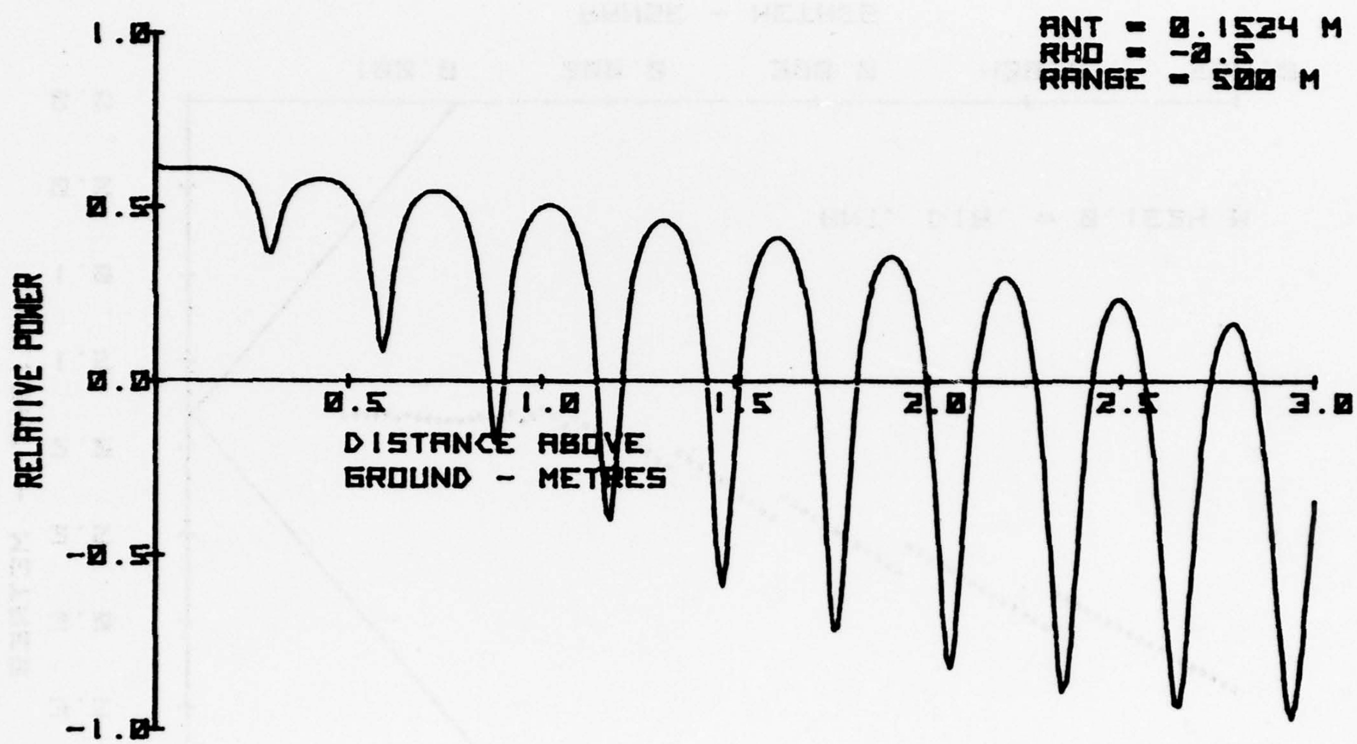

Figure 27. Theoretical Error Curve, 152.4-mm Antenna, ρ = -0.5, 500-m Range

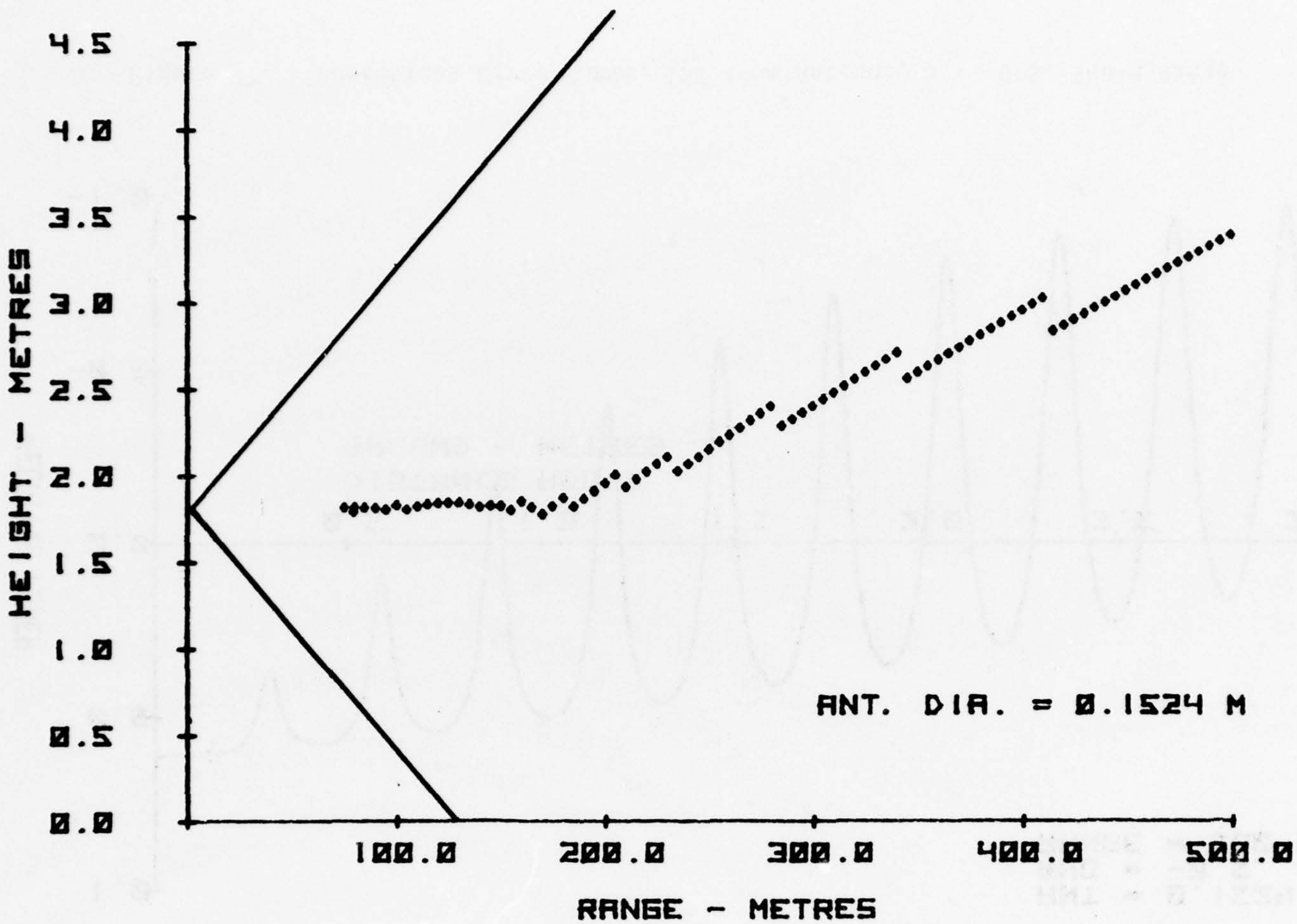

Figure 28. Theoretical Path of "Perfect" Beamrider, Antenna Diameter = 152.4 mm

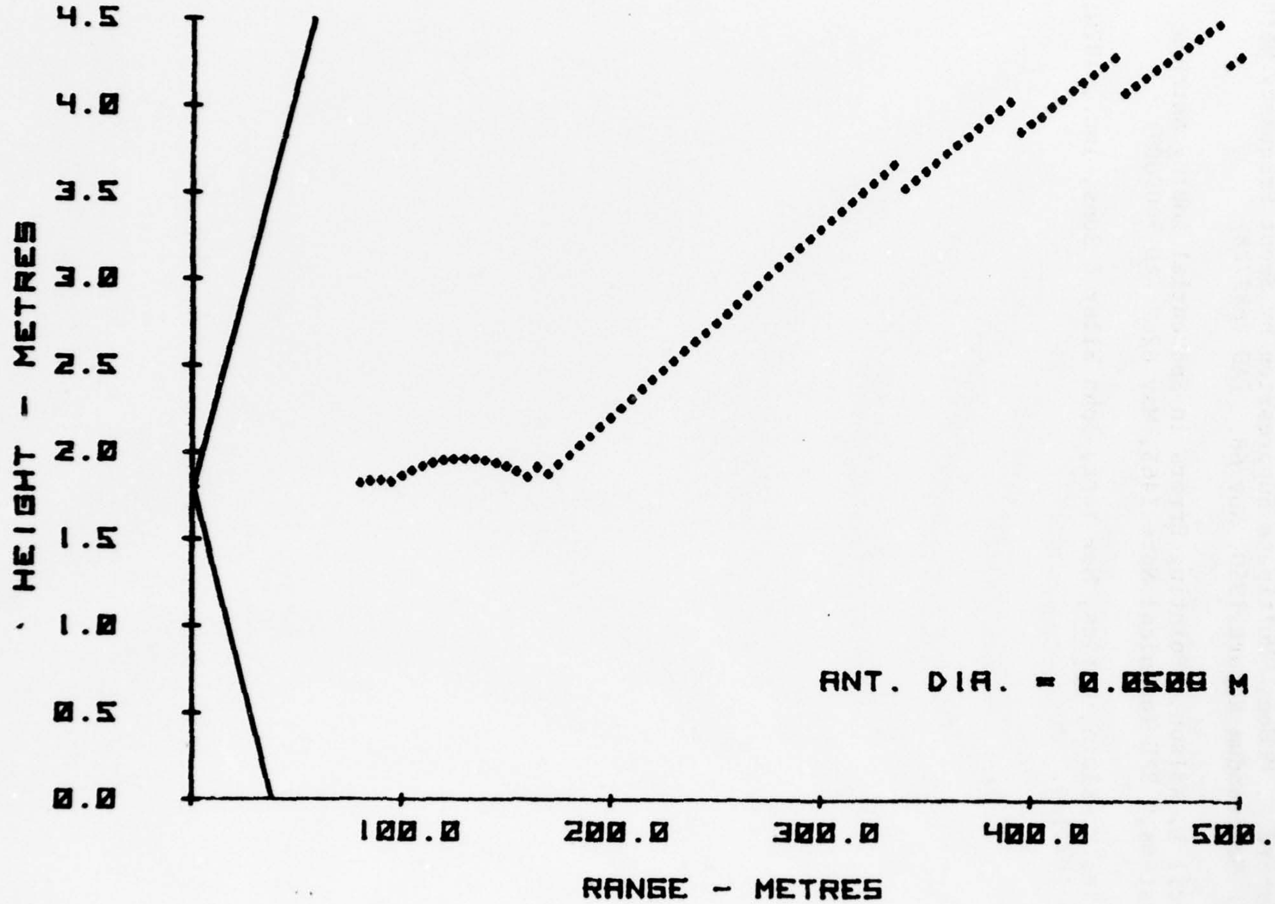

Figure 29. Theoretical Path of "Perfect" Beamrider, Antenna Diameter = 50.8 mm.

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1. David K. Barton, "Low-Angle Radar Tracking," Proc. IEEE, Vol 62, No. 6, Jun 74.

2. Richard A. McGee, "Multipath Suppression by Swept Frequency Methods," BRL Memorandum Report 1950, Nov 68. (AD #682728)

3. Cecil L. Wilson, "Pointing Errors in Sequential Lobing Antenna Systems," BRL Technical Note 1463, May 62. (AD #609009)

4. Miles V. Klein, Optics, New York, John Wiley & Sons, Inc., 1970, pp 184-189.

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