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Preliminary Study of the Reflection of Millimeter Radio Waves from Fairly Smooth Ground

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ELECTRICAL ENGINEERING RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS

Report No. 60

29 February 1952

PRELIMINARY STUDY OF THE REFLECTION OF MILLIMETER RADIO WAVES FROM FAIRLY SMOOTH GROUND

by

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Prepared under Office of Naval Research Contract Nonr 375(01)

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ABSTRACT

A number of measurements of the reflection coefficient have been reported for a particular wave length and a particular set of conditions[1]. Comparatively little data are available on the reflection characteristics of millimeter radio waves or of the variation of the reflection coefficient with wave length.

This paper describes reflection studies made at wave lengths of 26.5, 9.0, 3.2 and 0.86 centimeters on a relatively smooth field at the Off Campus Research Center of The University of Texas. It is planned that these same measurements be made in the near future over a smooth water surface.

For the particular path used, the ground appeared smooth at 26.5 and 9.0 centimeters, but evidenced considerable roughness at 3.2 centimeters and appeared very rough at 8.6 millimeters.

I. INTRODUCTION

The Electrical Engineering Research Laboratory of The University of Texas has recently undertaken studies of the propagation of millimeter radio waves for the Office of Naval Research. As the first part of the measurement program under this contract the reflection characteristics of various surfaces are being studied.

This report describes measurements made over a 1000 foot path adjacent to the laboratory building. It is planned to use these same techniques for a path of similar length over an inland lake and for an overwater path along the Gulf Coast.

Although the primary object of these measurements is to determine the reflection characteristic of millimeter radio wave, the measurements at lower frequencies provided an opportunity to study variations of the reflection coefficient with frequency.

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1. For Example, See, Kerr, D., "Propagation of Short Radio Waves, Volume 13 Massachusetts Institute of Technology Radiation Laboratory Series, McGraw-Hill. For particular references see pages 418-437.

II. FACTORS AFFECTING THE STRENGTH OF REFLECTED SIGNALS

The following interdependent factors are significant in determining the strength of radio signals reflected from the ground:

a. The angle-of-incidence on the ground

b. The frequency

c. The polarization

d. The ground roughness and dielectric properties

e. The antenna characteristics

f. The path length

The first three of these factors are taken as variables in the measurement described in this report.

The ground roughness was not a variable as only a single path was used for the tests of this report. The roughness of the path will be varied, however, by repeating the tests over other paths.

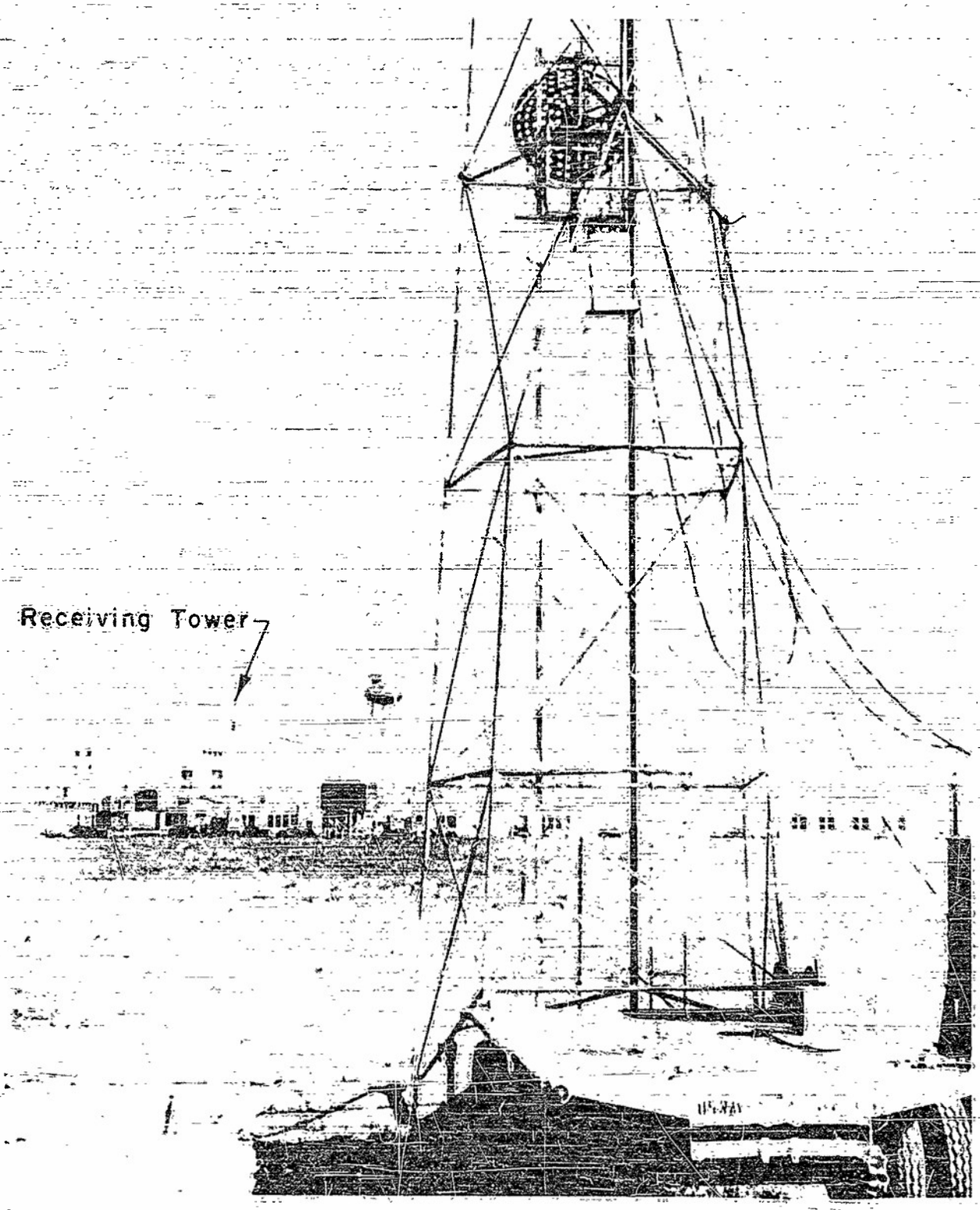
It is obvious that an antenna could be used with a radiation pattern narrow enough to materially reduce the illumination on the reflecting plane. This would mean, of course, that a correction would have to be applied to the apparent reflection coefficient in order to get a number which could be called the reflection coefficient of the path. Such a correction would be difficult to make without first making a number of simplifying assumptions. To avoid this difficulty, the antennas used in making these measurements were chosen such that approximately even illumination was obtained over a number of Fresnel Zones of the reflecting surface.

The path length of 1,000 feet was chosen so that grazing angles up to 5° could be obtained with the towers available and so that the effect of wave curvature would be small.

III. METHOD OF MEASUREMENT

The method used for obtaining the reflection coefficient was that of measuring height-gain curves as both the transmitter and receiver were raised simultaneously to heights of 50 feet. The simultaneous and synchronous movements of the transmitter and receiver were chosen in order to keep the center of reflection at the same point.

From these data, curves were drawn through the maxima and minima of the interference patterns. The reflection coefficient at a given height was taken as the quotient of the difference and the sum of the maxima and minima curves at that height. The transmitter and receiver were kept at the same level on the height runs by means of a bridge circuit in which the resistances were controlled by the elevator heights. A picture of the transmission path with the transmitting tower in the foreground and the receiving tower in the background is shown in Figure 1.



General Photograph Of Path Showing Transmitting Tower In Foreground And Receiving Tower In Background

Fig. 1

IV. PATH CHARACTERISTICS

The general profile of the path is shown in Figure 2(a) and a more detailed profile of the center 10 feet is shown in Figure 2(b). It is noticed that the path could be represented approximately throughout most of its length by a single plane with the intersection of the plane and towers being taken as zero height. The antennas were pointed parallel to this plane and the angles-of-incidence were computed relative to it.

The general ground coverage is shown in Figure 3. Some short, dead, grass stalks were standing and a sparse matting of grass stalks was on the ground.

V. ANTENNA CHARACTERISTICS

The antennas used in the measurements were as follows:

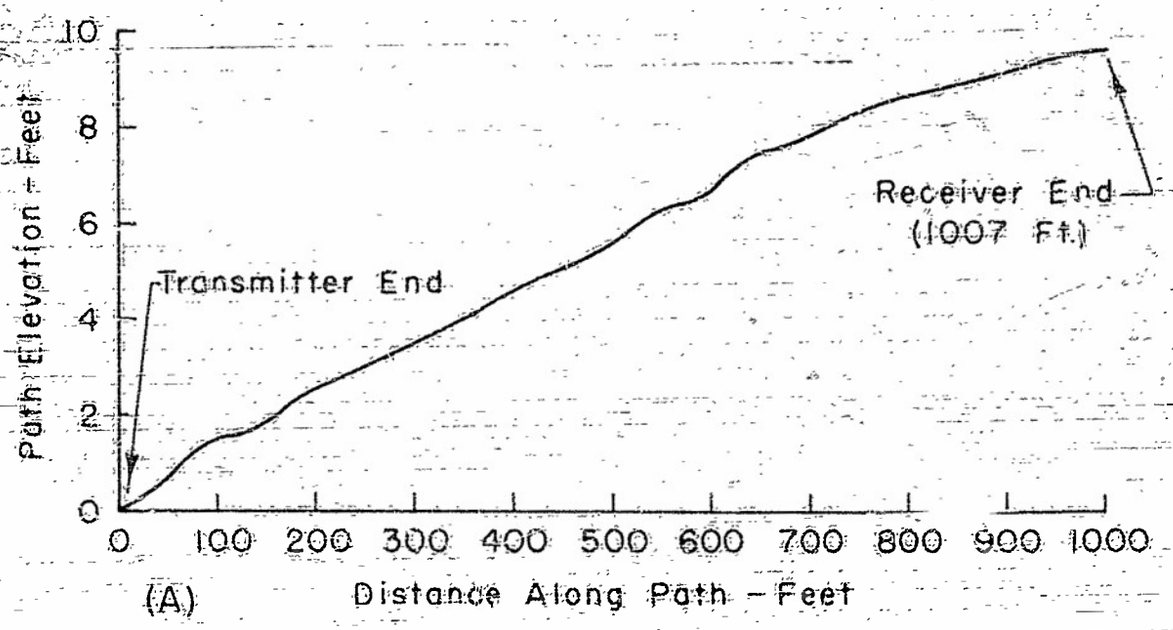
Wave Length CM	Polarization	Angle Between Halfpower Points	Antenna Type
26.5	Horizontal	14.4°	40" Parabolic Reflector
26.5	Vertical	21.0°	40" Parabolic Reflector
9.0	Horizontal	13.8°	18" Parabolic Reflector
9.0	Vertical	15.2°	18" Parabolic Reflector
3.2	Horizontal	15.8°	4" x 4" Horn
3.2	Vertical	18.6°	4" x 4" Horn
.86	Horizontal	14.8°	1" Circular Horn
.86	Vertical	20.0°	1" Circular Horn

The radiation patterns for these antennas are shown in Figure 4. A picture of the antennas is shown in Figure 5. Identical antennas were used at the two ends for each measurement.

A number of other antennas with narrower beams were also tested, but these tests contributed little additional information to that found with the antennas listed above.

VI. ORIGINAL DATA

A sample of the original data for each frequency is shown in Figure 6. No difficulty was experienced in plotting the envelope of the maxima and minima signals for the 26.5 cm wave length. Some difficulty was experienced in obtaining the calibration of minimum signal due to the square law dector used



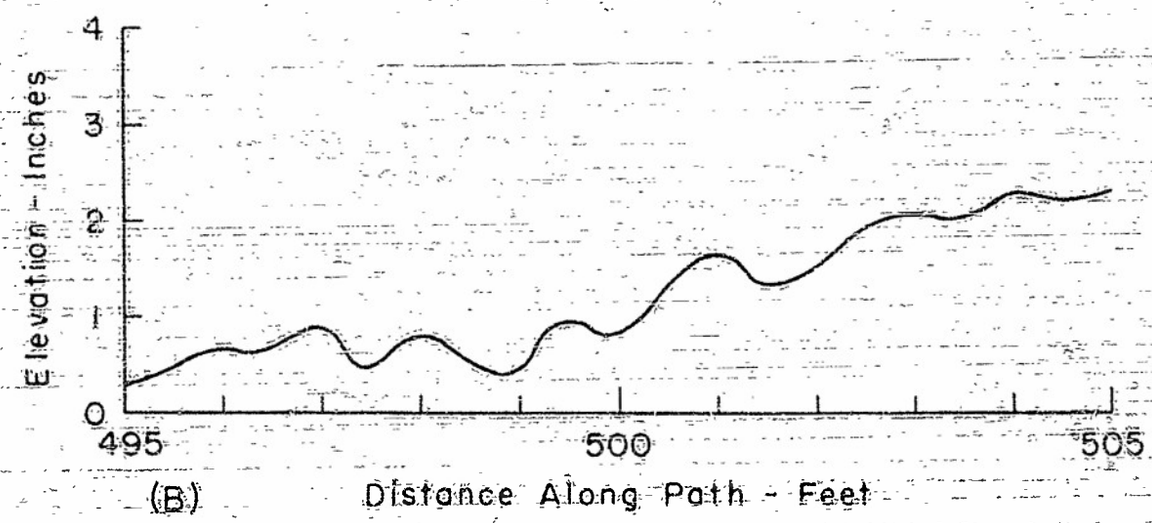
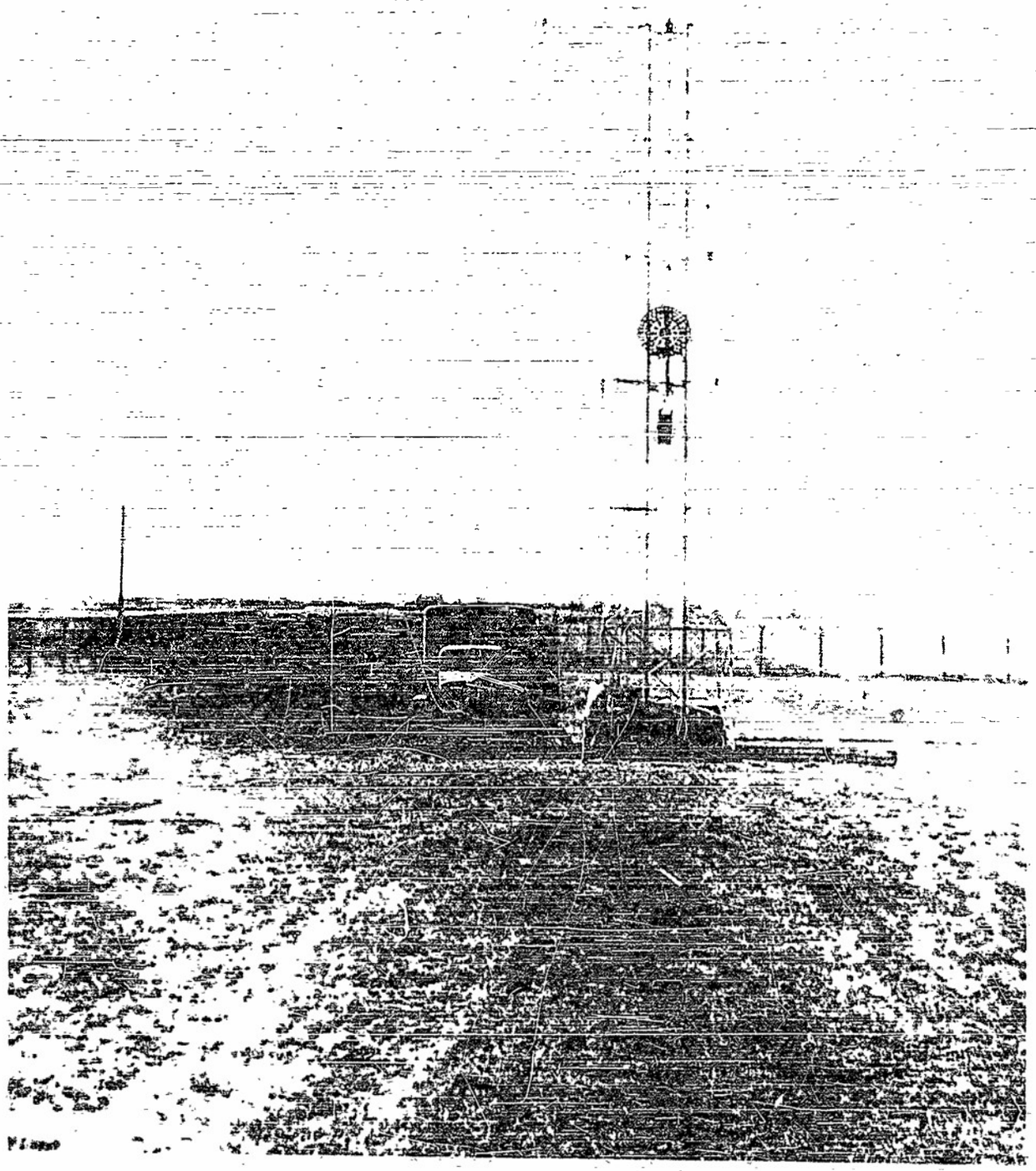
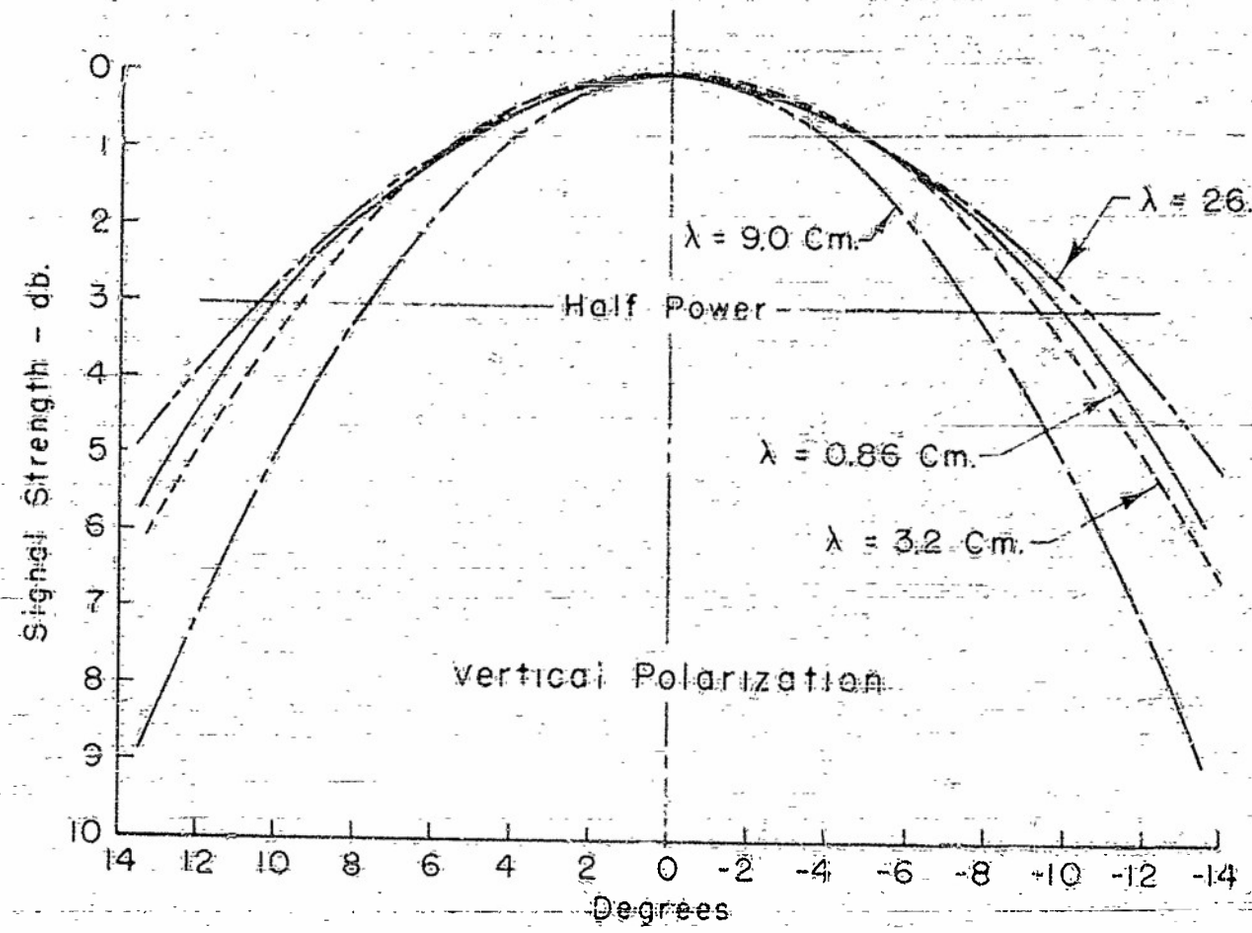


Fig. 2 - Profile And Detail At Center Of Path



Photograph Of Ground Coverage Showing
Transmitting Tower With L-Band
Antenna In Background

Fig. 3



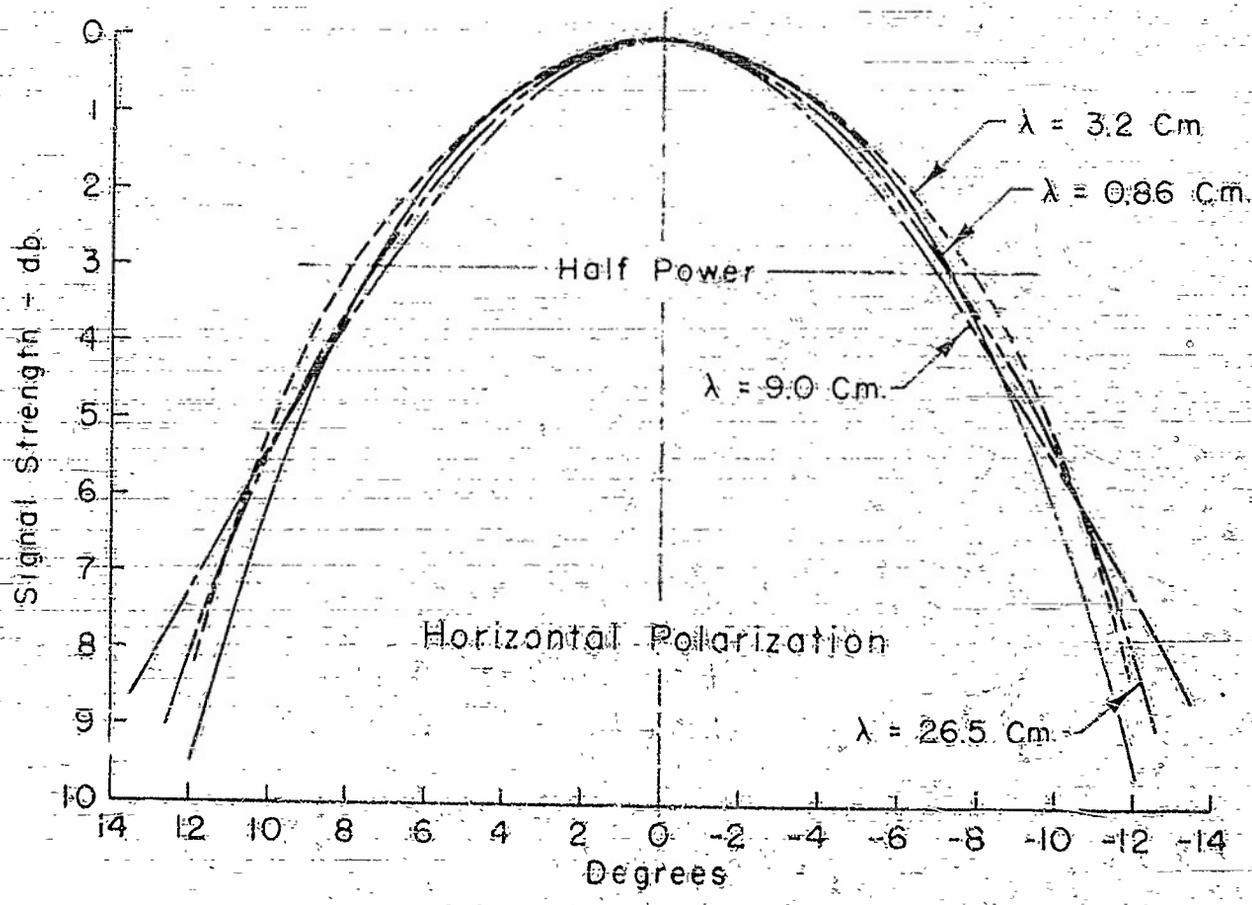
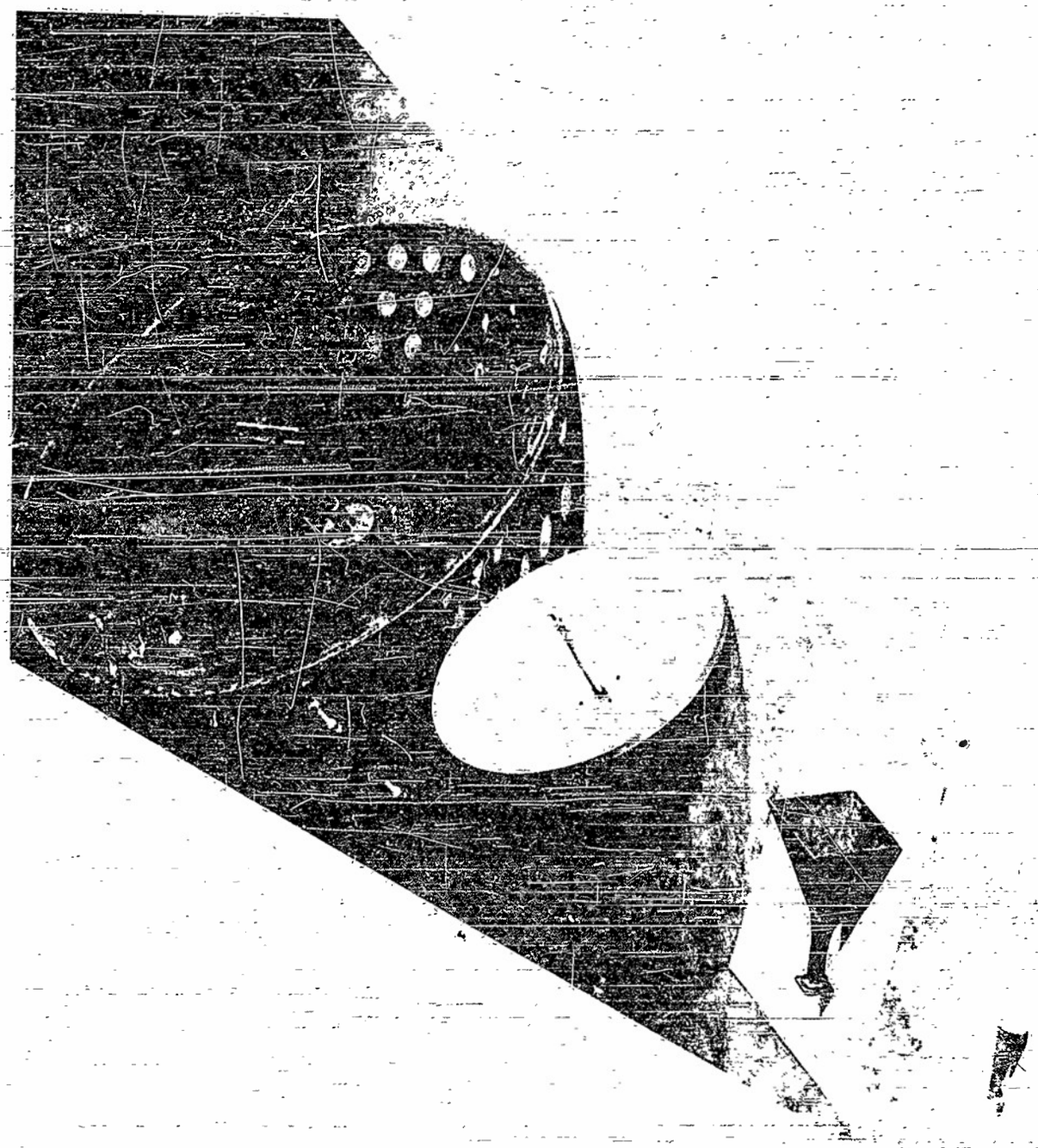


Fig. 4 - Antenna Patterns In Vertical Plane



Photograph Of Antenna Used

Fig. 5

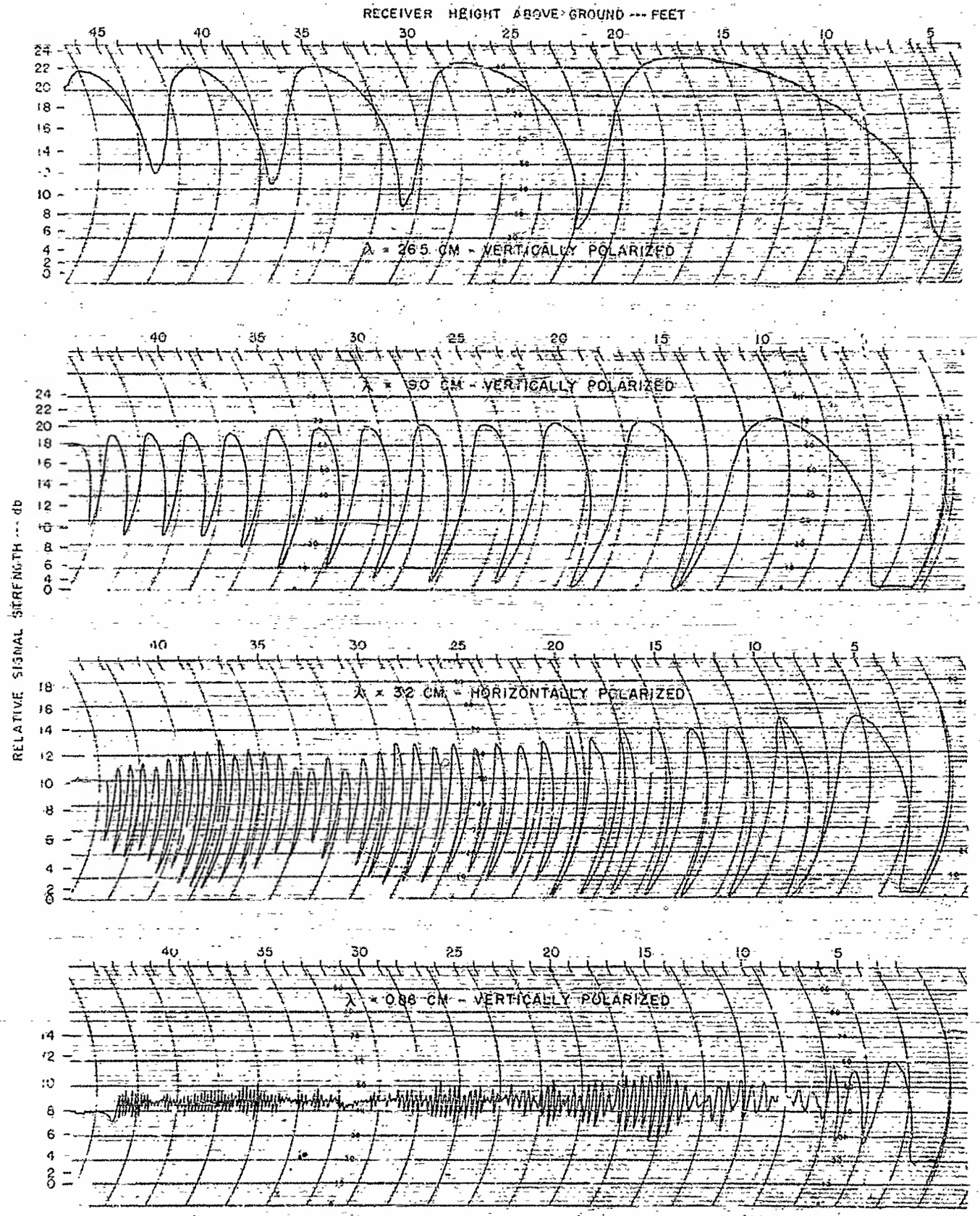


FIG. 6 - SAMPLES OF ORIGINAL DATA

on 10 cm. This difficulty was circumvented, however, by calculating a direct wave signal from the higher angle values and assuming that this value was the same at the low angle values.

The envelope of maxima and minima became somewhat irregular for the 3.2 centimeter measurements and was very irregular for the 8.6 millimeter measurements. The reflection coefficient was calculated from the envelope in each case, giving the irregular curves shown in Figure 7. A smooth curve was drawn through each of these curves and was used for the comparisons of the next section.

VII. COMPARISON OF REFLECTION COEFFICIENT CURVES

A set of reflection coefficient curves using the antennas described in paragraph V and radiating a horizontally polarized signal are shown in Figure 8. A set for the same antennas with vertical polarization are shown in Figure 9. The reflection coefficient curve for an infinite smooth plane with a dielectric constant of 4 is shown in each case for comparison. This curve is approximately the same for all frequencies used.

From these curves, it is evident that the reflection coefficient decreases appreciably as the frequency is increased, becoming very small for $\lambda = 8.6$ millimeters. The three lowest frequency curves apparently approach unity as the grazing angle approaches zero. It is difficult to extrapolate the reflection coefficient curves for the 8.6 millimeter waves to zero grazing angle as the reflection coefficient is changing rapidly in this region.

The reflection coefficient for vertical polarization is in general less than that for horizontal polarization.

VIII. CONCLUSIONS

(a). The reflection coefficient for 8.6 millimeters for the field test did not exceed 0.4 and dropped to less than 0.1 at angles of grazing above 2.5 degrees.

(b). The reflection coefficient increased with wave length and approached the theoretical curve at a wave length of 26.5 cm.

(c). The envelopes of maxima and minima of the height-gain curves and the resulting reflection coefficient curves were very regular for 26.5 and 9.0 cm wave lengths, but became somewhat irregular at 3.2 cm and were very irregular at 8.6 millimeters. Thus it would appear, for the path used, that the surface was smooth at 26.5 cm and rough at 8.6 millimeters.

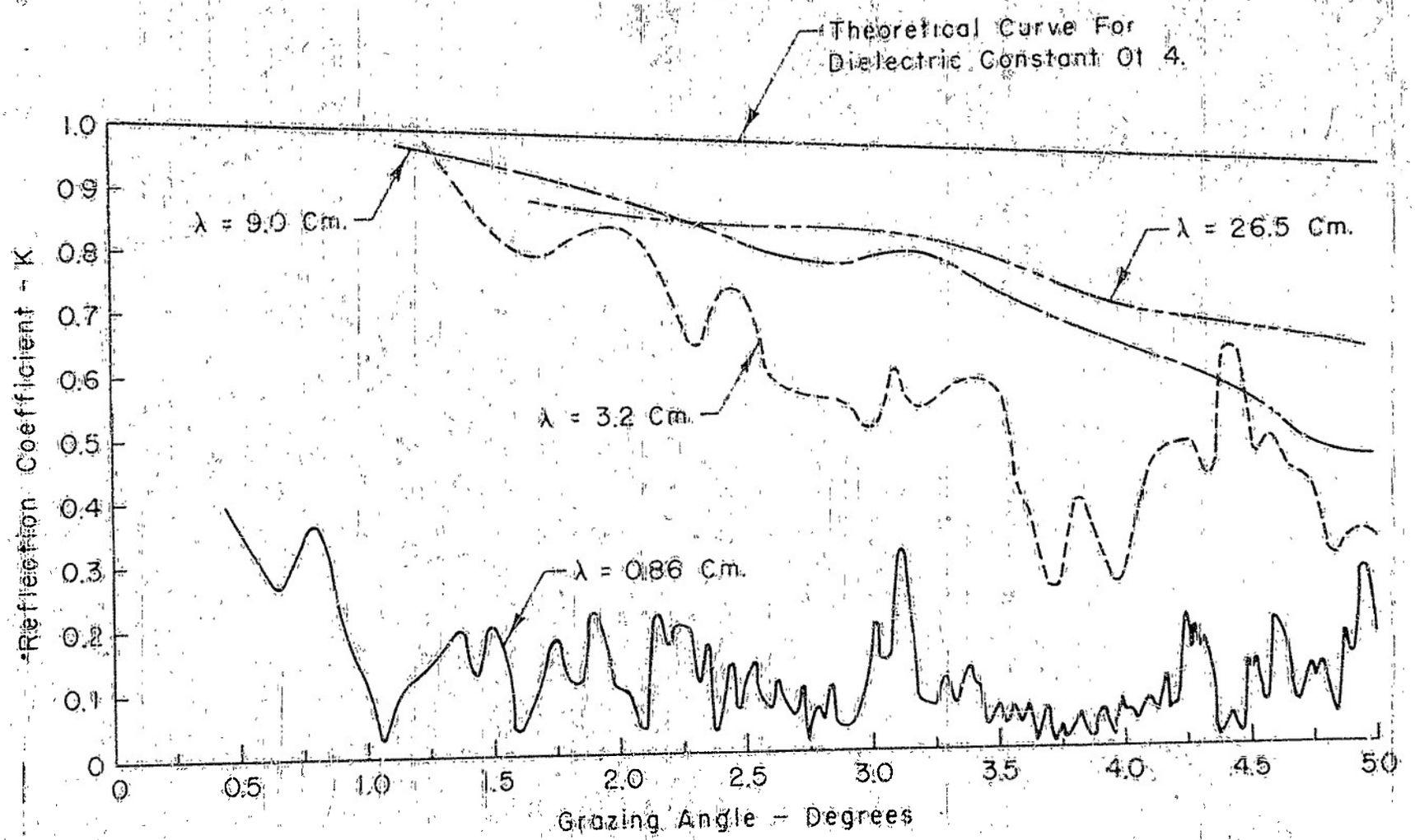


Fig. 7 - Reflection Coefficient Curves For Horizontal Polarization.

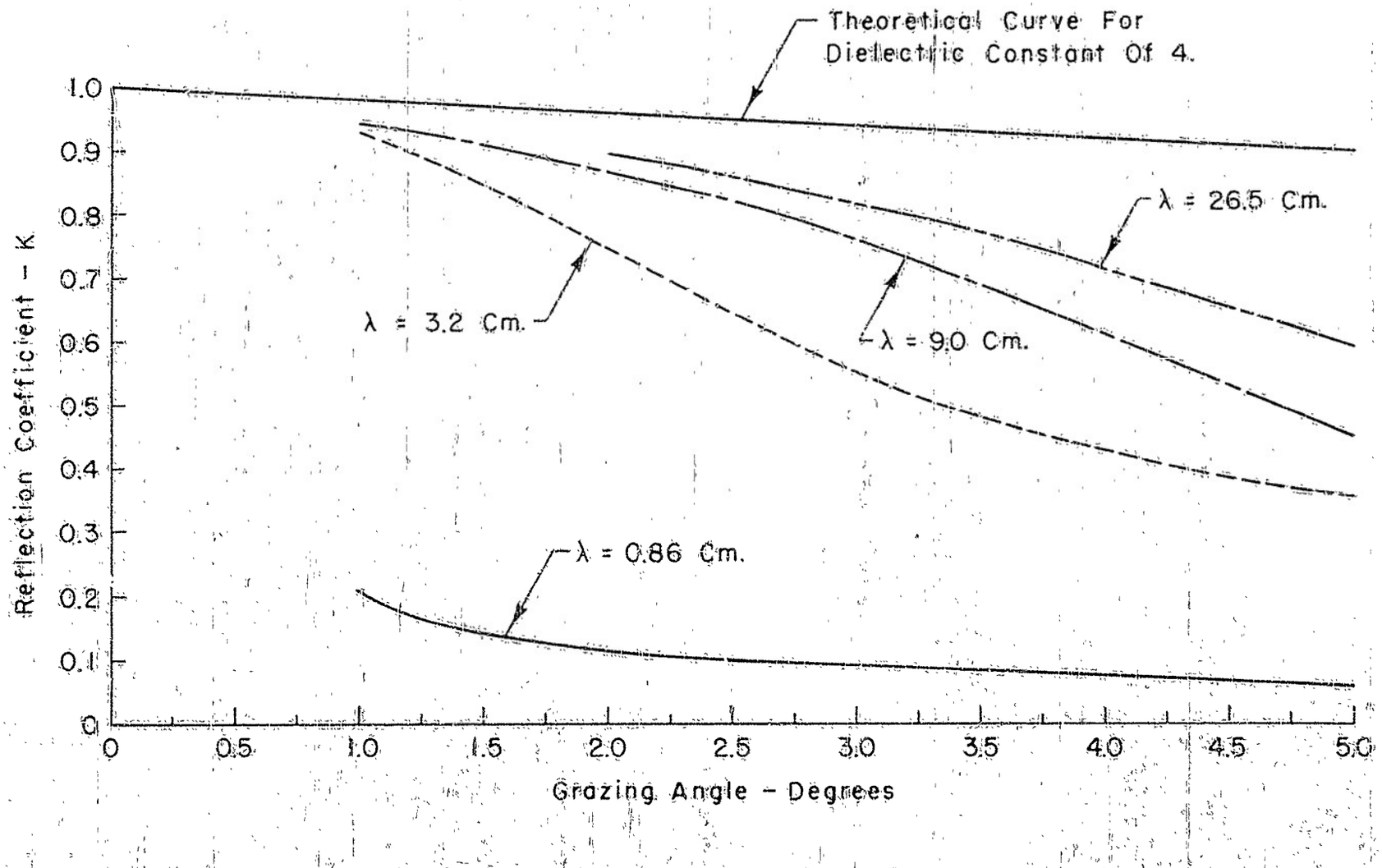


Fig. 8 – Smoothed Reflection Coefficient Curves For Horizontal Polarization

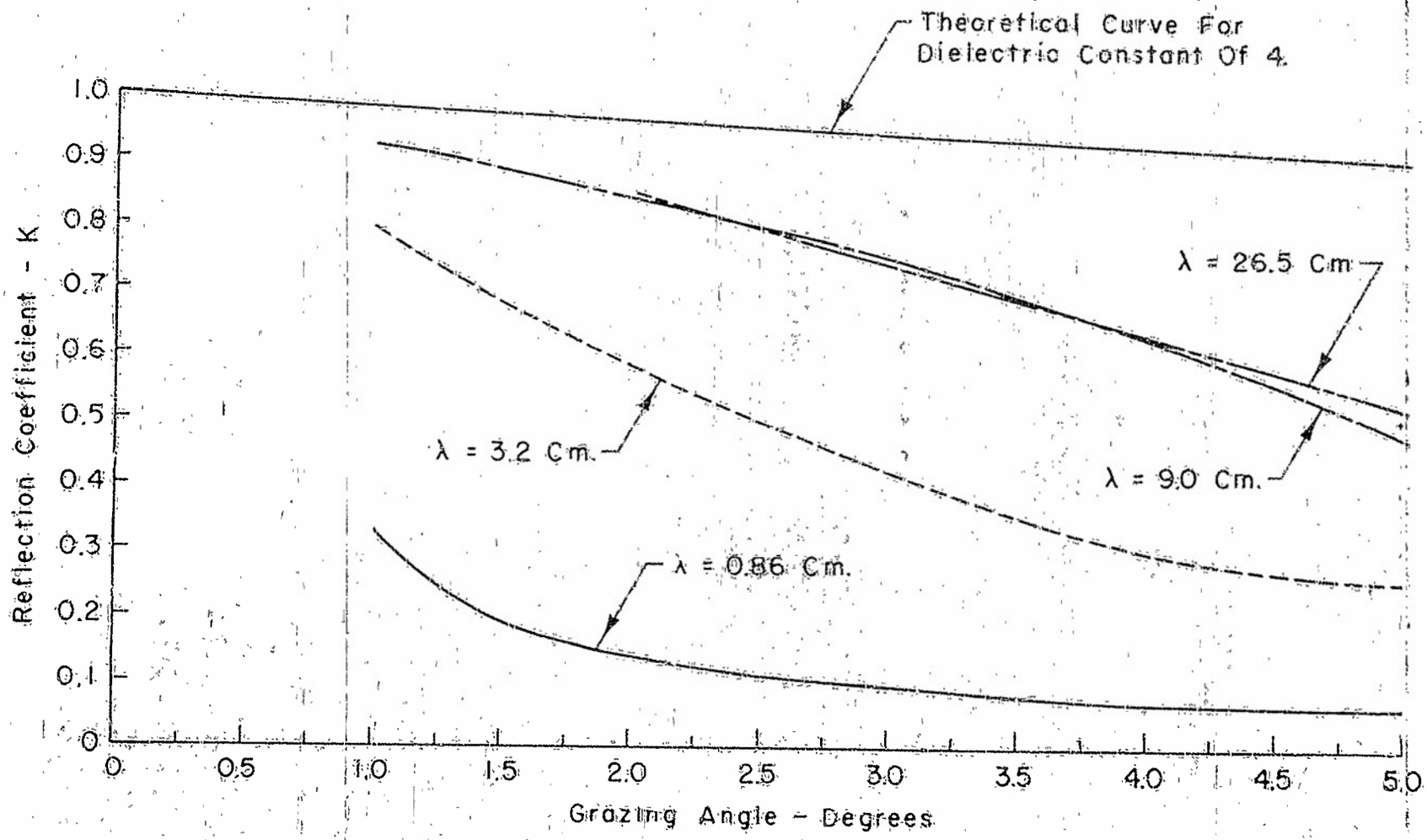


Fig. 9 - Smoothed Reflection Coefficient Curves For Vertical Polarization