Grazing reflection from Woods "Physical Optics", page 40

Path difference is $2H \cos\theta$ where H is vertical height of bump and θ is angle between ray and vertical. This applies to all angles of θ.

Let $\theta = 0$. Assume a surface which has random roughness with mean values as given. Then the mirror efficiencies will be approximately (estimates only)

H	$\mathcal{E}$
$1/4\ \lambda$	50
$1/8\ \lambda$	80
$1/16\ \lambda$	95
$1/32\ \lambda$	99

When $\theta = \theta$ the value of H for same efficiency must be divided by $\cos\theta$ or

$\mathcal{E}$	H
50	$\lambda/(4\cos\theta)$
80	$\lambda/(8\cos\theta)$
95	$\lambda/(16\cos\theta)$
99	$\lambda/(32\cos\theta)$

Thus as $\cos\theta$ approaches 90°, or grazing incidence, the value of H may be very large and still have excellent efficiency

Reflection Coefficient & Roughness.

"Reflection & Absorption of 9 cm Waves", L. H. Ford and R. Oliver, Proc. Phys. Soc. (London), Vol 58, May 1946, p 265-280.

Specular Reflection will occur if
$H \cos \theta \ll \lambda$ where
H is average height of irregularities
θ is angle of incidence (angle to vertical)
λ is wavelength.

When $H \cos \theta / \lambda$ is about 1/5, the coefficient of reflection is 0.5 approx.
When $H \cos \theta / \lambda$ is about 1/2, the coefficient of reflection is improbably as large as 0.1.

Also see "Radio Wave Propagation" by Burrows and Attwood, Academic Press 1949.

The Reflection and Absorption of Radiation at 9cm Wavelengths.

by L.H. Ford & R. Oliver,

Proceedings of the Physical Society
1st May, 1946, Vol 58, Part 3, No 327, p 265-280

Abstract from Conclusions on pages 278 & 279

(3) The change in phase on reflection is about 180° for vertical polarization at angles of incidence appreciably greater than Brewster's angle, and negligible at angles of incidence appreciably less than Brewster's angle

(4) The change in phase on reflection is about 180° for horizontal polarization at all angles of incidence

(9) The depth of the surface irregularities multiplied by the cosine of the angle of incidence must be a small fraction of the wavelength. When this fraction is about 1/5, the reflected ray may be reduced to about 1/2 its proper value, and when the fraction is 1/2 a reflection coefficient greater than 0.1 is improbable.

M. I T report # 664 by Van Vleck

"Atmospheric Absorption of Microwaves"

Figure 3 gives .01 DB/nautical mile at 25 cm

$\frac{\Delta v}{c} = .02$ cm^{-1}. $\frac{\Delta v}{c} = .05$ cm^{-1}

Published in Physical Review

April 1st, 1947 Vol 71, page 413-433

10-6-49

Since the wave trains which create the interference are of finite length it is obvious that if the path difference is greater than the length of the train no interference can occur. The various lobes in pattern are similar to orders in a grating. By using very large orders or high lobes some information may be had upon the actua length of wave train. Likely a collector with poor resolving power will b needed for this experiment so that it can look high up and low down at same time.

Visit to Evans Laboratory March 10th 1950.

Talked to Blackwell and Crenshaw at some length. They thought the variation in intensity from pulse to pulse was probably due to apparatus difficulties. This was due to fact the oscillator didn't come up on exactly the same frequency each time. The narrow pass band of 50 cps would exclude some pulses. Furthermore, to get the results they did have, it was necessary to manipulate the tuning every few minutes. Some days this trouble was very bad and no echoes were secured. There was no obvious difference in the random ness of the echoes secured over water to the east or land to the west. Therefore it was concluded that there was no appreciable duct phenomena over the sea. Likewise there was no obvious difference between summer and winter. Data was secured intermittently from Jan 1946 thru Nov. 1947. Echoes over land to west were always weaker due to poor reflection coefficient of land. The lobe structure was also poorly defined and phenomena seemed to be approaching free space transmission. They thought some sintillation might occur but it could not be detected due to above trouble with the apparatus.

(over)

Sintillation is due to fact the light ray is bent by atmospheric refraction in a random manner. Since the aperture of your eye is small the ray may move out of the aperature at times. This will cause the image to twinkle. Conversely, the aperture of a telescope is large. Thus the ray will always be present but merely move around over the aperture. This will cause the image to dance.

Please get copies of following publications from the Navy Hydrographic Office at Suitland, Md.

"Wind, Sea + Swells; Theory in Forecasting" #HO601

"Wind, Waves + Swells; Principles + Forecasting" HO11275

"Breakers + Surf" HO234

Grote Reber

3-13-50

Hydrographic Office tel G153
Suitland Md.
Sea & Swell charts

H0601 Wind Sea & Swells 1947 50¢
Theory of Relation in Forcasting

✓ H0602 Wind Waves at Sea, $2.80
Breakers & Surf 1947

H011275 Wind Waves & Swells 40¢
Principles & Forcasting 1944

Suitland, Md.

Div. of Distribution X12

H0234 Breakers & Surf 1944 40¢

~~code x12~~

~~Talk to Division of Oceanography Mr. Wilgus~~

calm, low, med & high.
0-1 ft 1-3 ft 3-8 ft 8-up.

✓ ~~North~~ East Pac. H0-10,712-D
Sea & Swell Atlas.

Mr. Bates
Division of Oceanography

9/14/48

U.S. Hydrographic Office

HO-602 - Wind waves at sea, breakers & surf - 1947 ($2.80)

HO-10,712-II - Sea & swell atlas of northeast Pacific

HO 9-15-48

HO code 153
ext. 12
Div. of Distribution

rec'd 9-29-48

Reber
501

5-25-50

Talked to Ament at NRL for 20 minutes. He is on G 130 x 172. He said during May 1946 they made various experiments off the northeast coast of Oahu. The receiver was on a tower 106 feet high above sea, with other receivers at 50, 30 and 15 feet. The transmitter was in an airplane which height varied from 400 to 1000 feet. The propagation was in a direction from N.E. to S.W. a north east wind was blowing 8 to 10 knots so they were propagating off the backs of the waves. For this type of one way experiment where reciprocity exists the direction into or with the wind makes no difference. However for radar work considerably less back scatter is obtained when working to backs of waves.

At 10 cm the first six lobes showed ratios of maxima to minima of 13 to 20 DB, at 3 cm the ratio was 6 to 8 DB.

A 10 knot wind on a 1000 mile fetch will raise waves more than a foot high.

Apparently some 700 mc experiments were made eastward from the Annex station across Chesapeake Bay. They got quite a spray of points, when the reflection coefficient was computed, even at this frequency. There are some MIT reports describing results at S and X band.

5-25-50

If the earth were flat the angular distance between maxima would be

$$\Delta\alpha = \sin^{-1}\frac{\lambda}{2h}$$

Where $\lambda = 25$ cm and $h = 250$ ft $= 7610$ cm

$$\frac{\lambda}{2h} = \frac{25}{2\cdot 7610} = 1.642\times10^{-3} \text{ radian}$$

$$\Delta\alpha = 57.3 \times 1.642\times10^{-3} \times 60 = 5.65 \text{ minutes of arc.}$$

If the source were as large as 3 minutes of arc the interference lobes would be swamped out and an effect such as Piddington describes would result.

Since the frequency is so high the ionosphere cannot have any effect. However the lower atmosphere may have humidity gradients which could be very rough and rapidly changing. These would break up the interference pattern in the manner described. Furthermore, they would be more pronounced at 25cm than at 100 mc. The effect is agrivated by operating from the shore of a hot continent.

A combination of these two effects probably explains Piddington's trouble and not oxygen or roughness of the sea.

Sunset at Attu   9-9+10-50

3 cm and 10 cm apparatus both using mirrors 6 feet in diameter were operated on Alexai Point. They were about 30 feet above sea level. The sun set behind some mountains at the base of Murder Point and across Massacre Bay. These mountains were about 1500 feet high and about 7½ miles away. Their apparent angle above the horizon was thus about 2½ degrees.

When the sun set behind the mountains, a good interference pattern was secured at 10 cm but not at 3 cm or at 0.8 cm which used a mirror 2 feet in diameter. The apparatus was on a polar axis which kept the mirror pointed at the center of the sun. For an interference pattern to occur, two waves must be present. Since both waves must originate in the sun and come over the tops of the mountains at 2½° above the sea; the reflected wave from the sea will make an angle of 5° or more with the direct wave at the reciever. Since the mirror is kept pointed at the direct wave, the reflected wave will be 5° or more off axis. This will cause the reflected wave to be considerably attenuated and reduce the amplitude of the interference pattern. At 10 cm the beam is about 3⅓° wide at 3DB down. Thus it is probably about 8DB down at 5° off center. Even with this attenuated reflected wave a decent interference

pattern is secured (about 30% amplitude change).
At 3cm the circumstances are much less favorable. The beam is about 1° wide at 3DB down. Thus it is probably over 20DB down 5° off center. This extremely weak reflected wave will not be sufficient to create a good interference pattern, and the sun will simply die out gradually as it is obscured by the hills. This is what was observed with a very faint (less than 10%) ripple as an interference pattern.

The sea in Massacre Bay had a swell of about 2 feet with waves a foot or more high and a few white caps. It was quite choppy. Apparently even so rough a sea is a good reflector at 10 cm wavelength.

12-19-50

Later calculations showed the reflections were from steel matting at a distance of about 6 feet below mirror instead of sea at 30 feet below mirror. This was determined by measuring the period of oscillation and computing rate at which sun set. The geometry also showed that Massacre Mountains cut off sun as a straight edge before an angle small enough to reach the sea was secured.

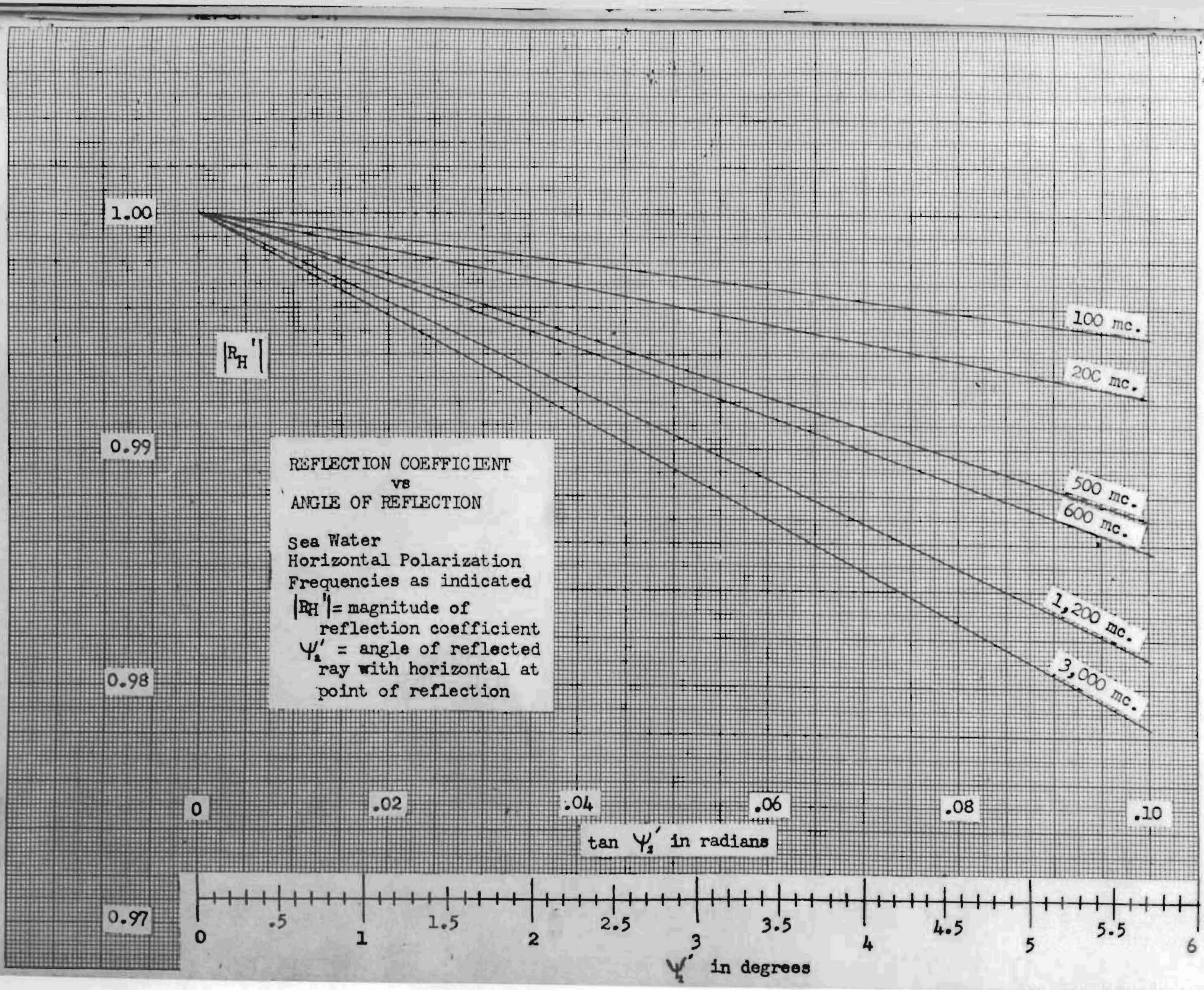
January 10, 1952

Visited Library of Congress. They don't have H.O. Misc # 11,117 "Waves in the North Pacific Ocean". However I found an old card dated about 1878 filed under Hydrographic which was entitled "Waves in North Pacific Ocean". This is different from former as it contains histograms for 1924-1938.

These are from Radiation Lab
Report C-11 dated Sept 28, 1943
by Hutner, Dodson, Hill, Parker
and Howard. The title is
"Field Intensity Formulas"

Bureau of Standards Library
Number 23 dated Oct 18, 1946

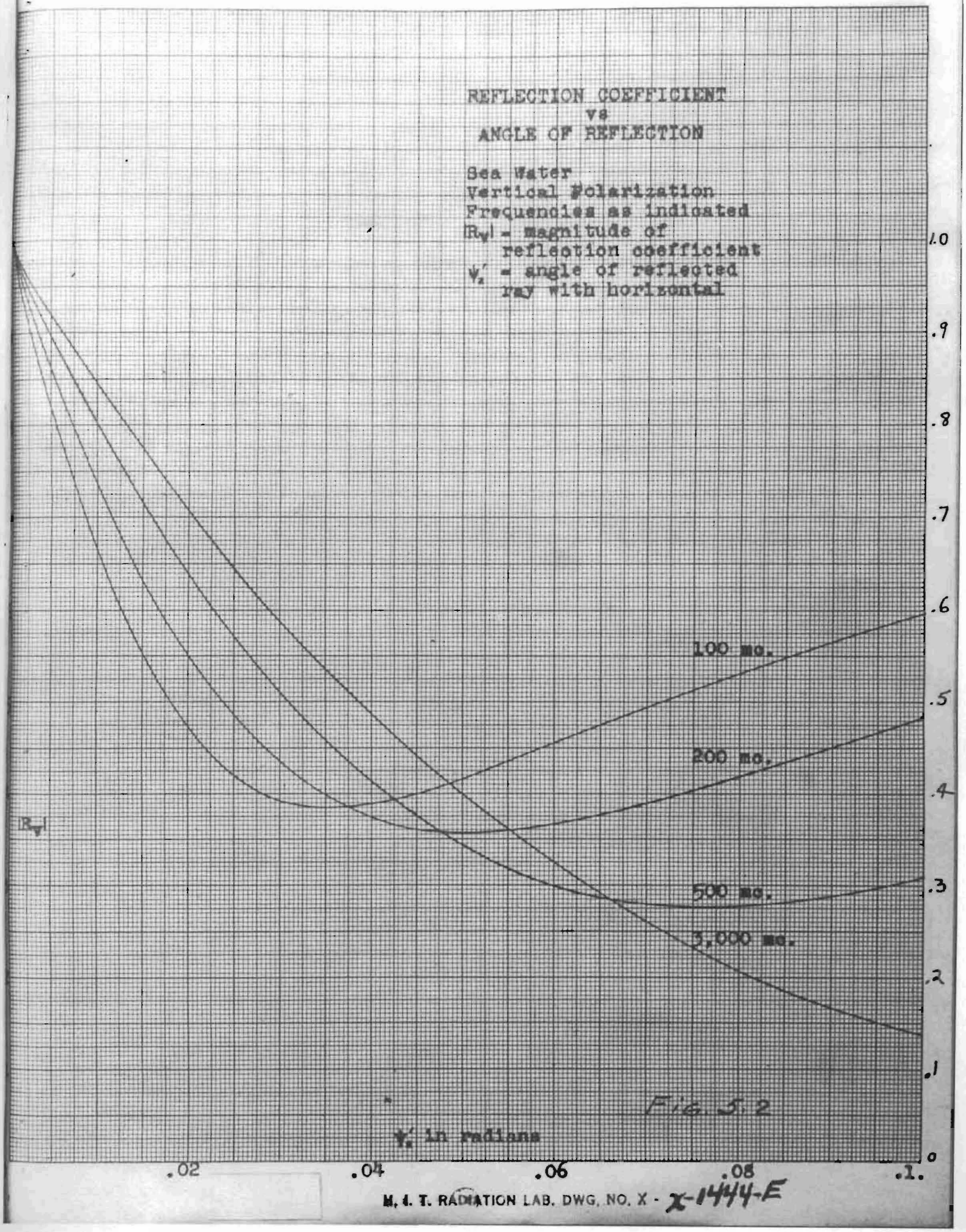
Note. Brewsters angle is proportional to $(\text{wavelength})^{-1/2}$ or $\theta = k/(\lambda)^{1/2}$. When λ is in meters and θ in degrees $k = 3,5$ for 200 mc and below; $k = 3,4$ for 500 mc; $k = 2,0$ for 3000 mc



REFLECTION COEFFICIENT
vs
ANGLE OF REFLECTION

Sea Water
Horizontal Polarization
Frequencies as indicated
$|R_H'|$ = magnitude of reflection coefficient
Ψ_1' = angle of reflected ray with horizontal at point of reflection

FIG. 5.1



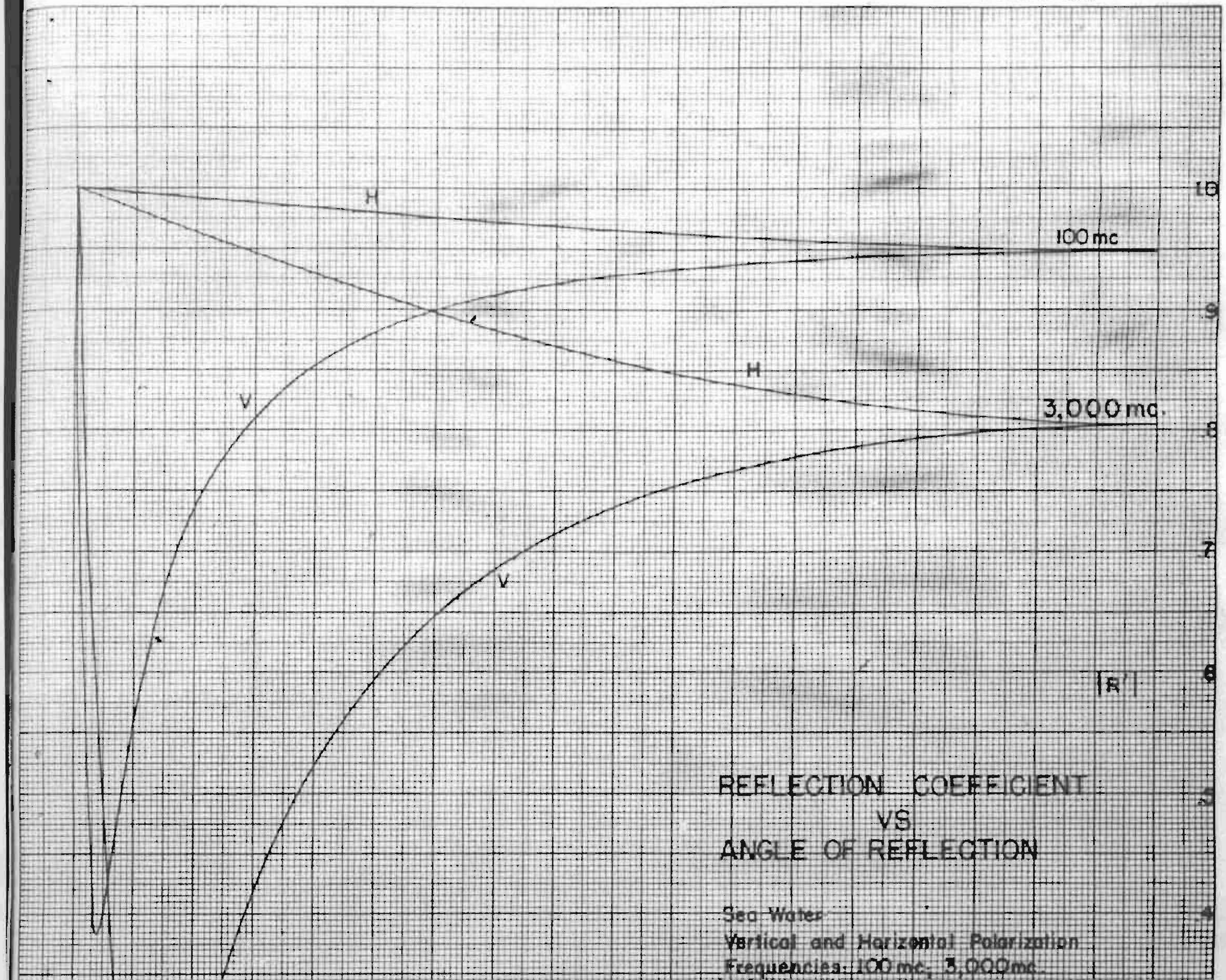
REFLECTION COEFFICIENT
vs
ANGLE OF REFLECTION

Sea Water
Vertical Polarization
Frequencies as indicated
$|R_V|$ = magnitude of
reflection coefficient
ψ_2' = angle of reflected
ray with horizontal

Fig. 5.2

M. I. T. RADIATION LAB. DWG. NO. X - X-1444-E

FIGURE 5.3


REFLECTION COEFFICIENT
VS
ANGLE OF REFLECTION
Sea Water
Vertical and Horizontal Polarization
Frequencies: 100 mc; 3,000 mc
|R'| = magnitude of reflection coefficient
Ψ'_2 = angle of reflected ray with horizontal
100 mc
3,000 mc
H
V
H
V
|R'|
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
Ψ'_2 in degrees
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°

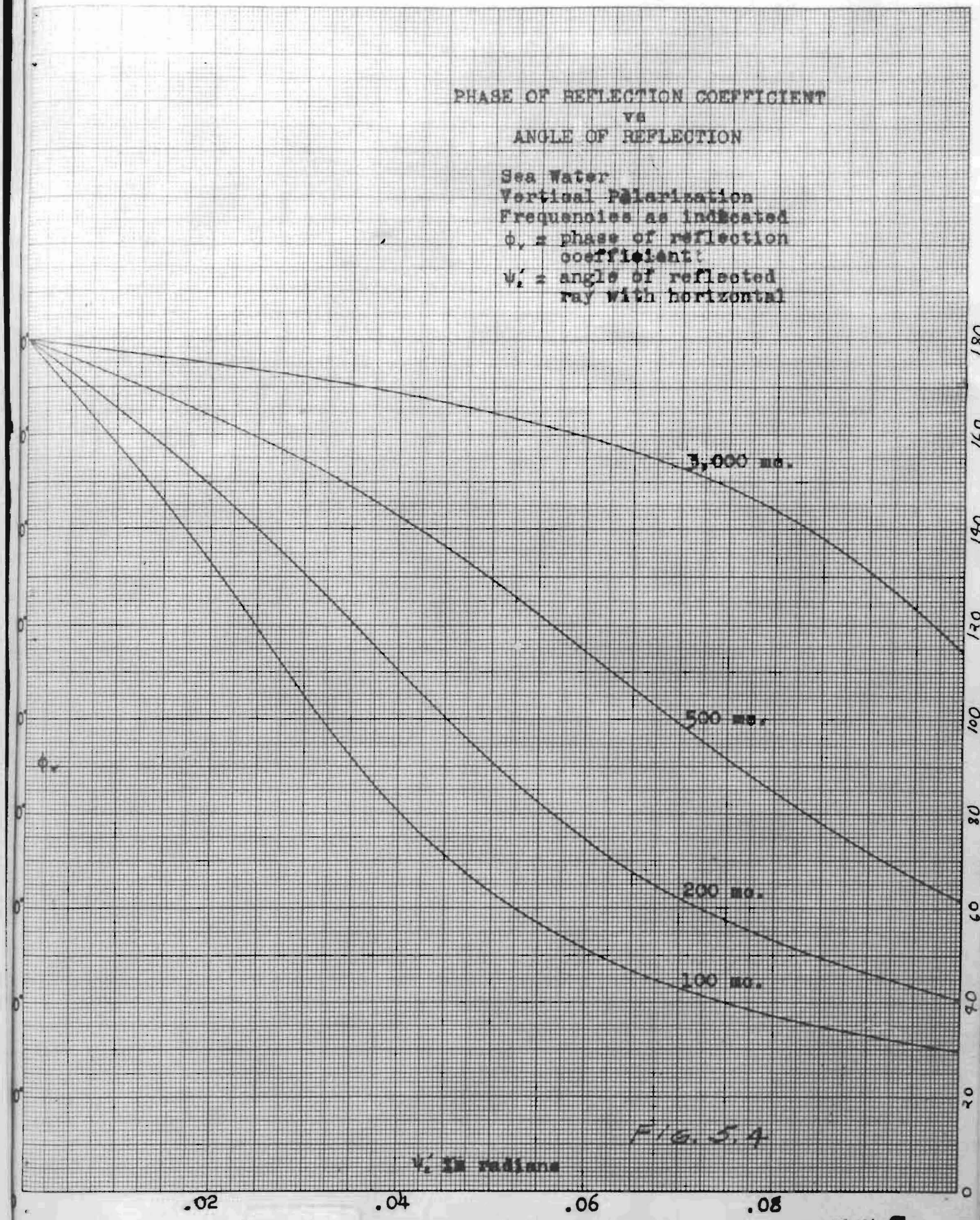
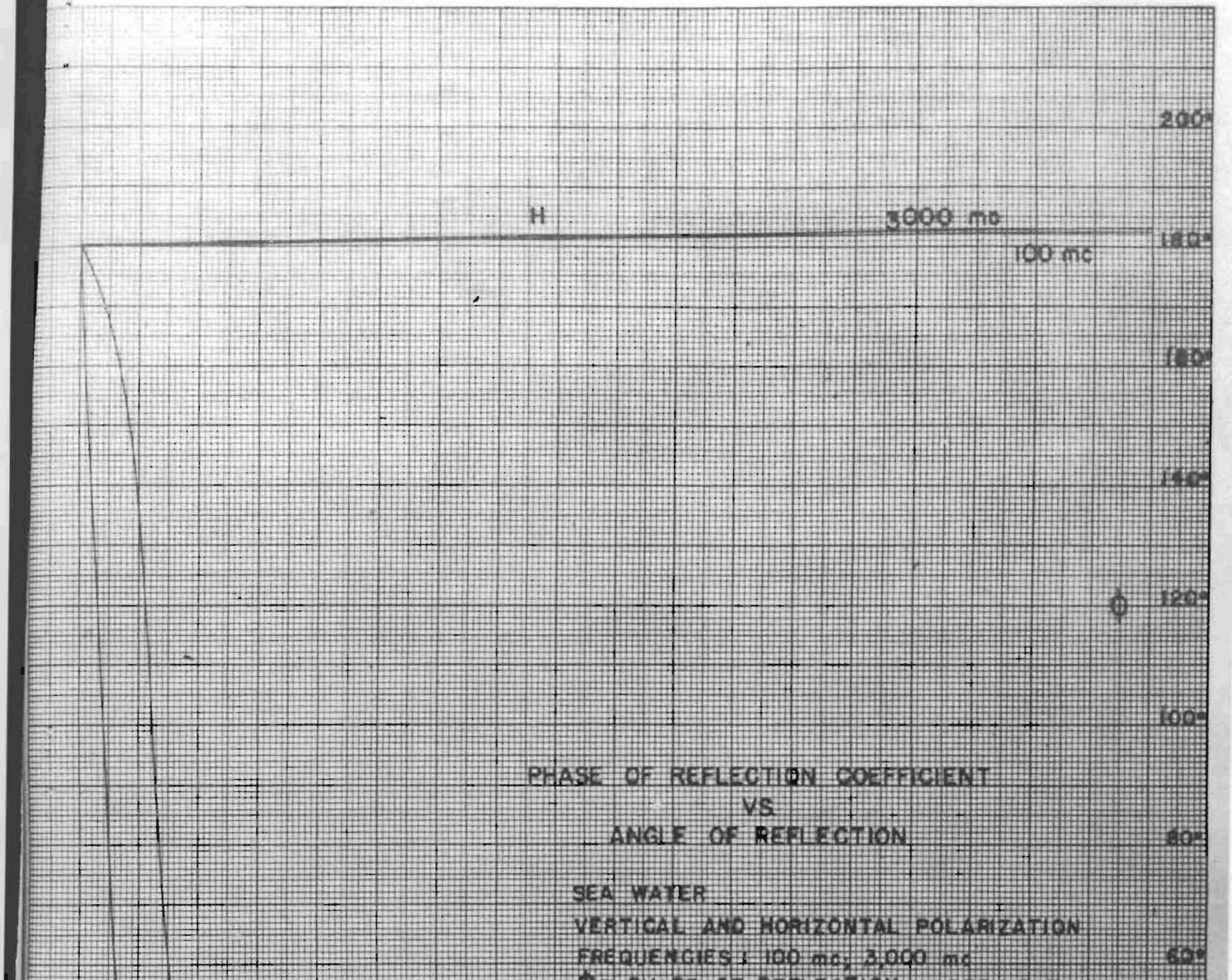


FIG. 5.4

M. I. T. RADIATION LAB. DWG. NO X X-1444-F

FIG. 5.5

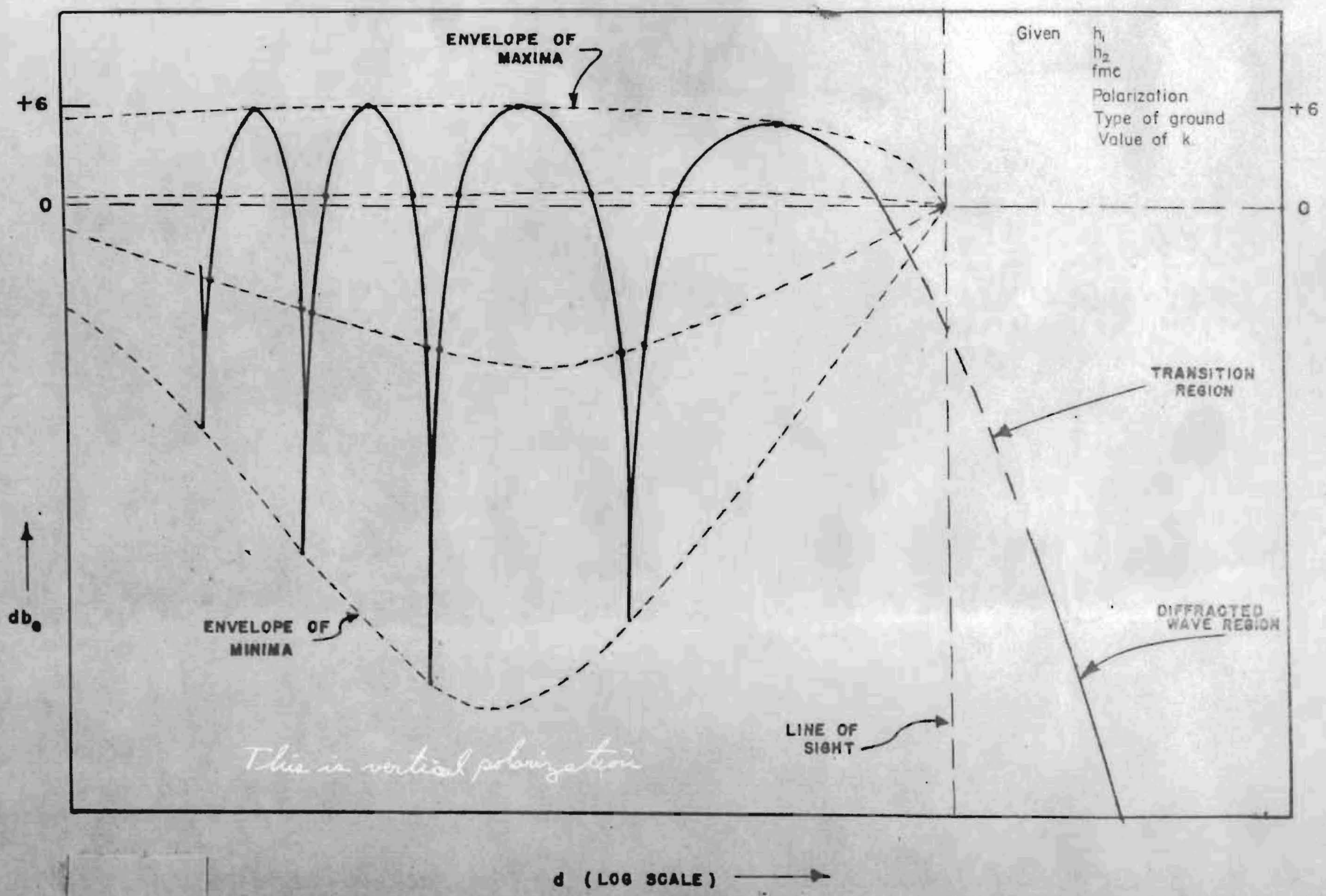


PHASE OF REFLECTION COEFFICIENT
VS.
ANGLE OF REFLECTION

SEA WATER
VERTICAL AND HORIZONTAL POLARIZATION
FREQUENCIES : 100 mc, 3,000 mc
Φ = PHASE OF REFLECTION COEFFICIENT
ψ_2' = ANGLE OF REFLECTED RAY WITH HORIZONTAL

REPORT C-11

M. I. T. RADIATION LAB. DWG. NO. X 3222-P



This is vertical polarization

FIG. 7.I

REPORT C-II

M I T. RADIATION LAB. DWG. NO. X 3222-T.