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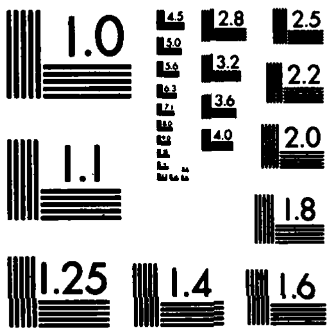

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AD-A135 041

SUPPLEMENT TO FINAL REPORT

Title: A STUDY OF THE DEPENDENCE OF RADAR BACKSCATTER CROSS SECTION ON WIND SPEED AND WAVE SLOPE FROM THE MARSEN EXPERIMENTAL RESULTS
(A contribution to studies of radar backscattering from the sea surface)

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

An analysis of the radar cross section data acquired from the NORDSEE tower during the MARSEN Experiment by the Naval Research Laboratory was made. A dependence on both wind speed and sea state was expected, based on observations and results obtained during the Gulf of Mexico Experiment. The range of variation of wind speed and wave slope during MARSEN were substantial. However, within a narrow range of wind speeds

the range of variation of wave slope was insufficient to demonstrate a radar cross section dependence on it. The results contained herein display appreciable randomness at each slope value; this tends to mask a likely dependence of radar cross section on slope. These results do not conflict with those obtained in the Gulf of Mexico, some of which are included for comparison, they are just too limited in range to add independent support.

ABSTRACT

An analysis of the radar cross section data acquired from the NORDSEE tower during the MARSEN Experiment by the Naval Research Laboratory was made. A dependence on both wind speed and sea state was expected based on observations and results obtained during the Gulf of Mexico Experiment. The range of variation of wind speed and wave slope during MARSEN were substantial. However, within a narrow range of wind speeds the range of variation of wave slope was insufficient to demonstate a radar cross section dependence on it. The results contained herein display appreciable randomness at each slope value; this tends to mask a likely dependence of radar cross section on slope. These results do not conflict with those obtained in the Gulf of Mexico, some of which are included for comparison, they are just too limited in range to add independent support.

INTRODUCTION

During September and October of 1979, the Naval Research Laboratory conducted extensive microwave backscatter measurements from the German Research Platform NORDSEE, as part of the MARSEN Experiment. Overall details of these NRL radars; their characteristics and supporting measurements can be found in the paper by Plant, Keller and Cross (1983). A previous study of tower radar data acquired in the Gulf of Mexico showed that the radar cross section is affected by wave slope as well as wind speed, with both mechanisms being modified by the stability or instability of the air-sea temperature difference.(Weissman, 1983) Of special interest in this study of the MARSEN data is corroboration of the Gulf of Mexico results, and the opportunity to study a wider range of wind speeds (up to 14 meters/sec), and wave slopes.

The Gulf of Mexico data that had been analyzed corresponded to a radar pointing or "look" direction with respect to the wind of 0°, within $\pm 22.5^{\circ}$. The grazing angle was 45° from horizontal. For this MARSEN data, the look direction was the same (within $\pm 30^{\circ}$) and the data from grazing angles of 25° and 35° was selected because it had the widest range of parameter variations.

DISCUSSION OF RESULTS

Theoretical studies and modeling of the electromagnetic backscatter from the ocean surface (Chan and Fung, 1977; Valenzuela, 1978) have recognized the dual importance of the short capillary wave dependence on wind speed and the long gravity wave spectrum dependence as well. The radar cross section then depends on the wind sensitive capillary wave spectrum and the long wave slope, and this has been modeled as a "net" wind speed dependence. However, the large volume of analyzed data, for a range of radar and illumination parameters, displays considerable "scatter" or spread when plotted against wind speed (or friction velocity); this opens the possibility of additional influences on the backscatter cross section, besides the wind speed alone. A fact that complicates the modeling effort is that the wave slope (of the large waves) often shows a steady increase with wind, making it difficult to separate these two mechanisms. The data points that have been analyzed and categorized are based on 21 minute averages. For the grazing angles of 25 and 35 degrees, approximately 150 data points have been studied and differentiated into wind speed and slope regimes. The data is plotted in Figures 1 to 6, where it is grouped into wind speed "bands", usually 1 meter/sec wide. The backscattered power (arbitrary units) is plotted versus RMS slope in all these figures. Within these groups, the maximum slope to the minimum slope is often approximately 1.5. However the variation in backscatter level is often significant, and a net increase or decrease with respect to slope is difficult to prove, although Figures 1,3 and 4 do give indications of an increase with wave slope.

It is concluded that these MARSEN results <u>tend</u> to support the conclusion obtained from the Gulf of Mexico data: that the radar cross section will increase appreciably with large wave slope. However the properties of this data are not adequate to provide an independent proof. A re-analyzed data set from the Gulf of Mexico is shown in Fig. 7. This data corresponds to stable air-sea temperature conditions, the friction velocity lies between 0.22 and 0.24, close to a 7.5 m/s wind speed. This graph shows the clear dependence on slope that has been discussed in the previous report.

REFERENCES

Chan, H.L. and A.K. Fung, "A theory of sea scatter at large incidence angles", J. Geophys. Res., 82, 24, 3439-3444, 1977

Plant, W.J., W.C. Keller and A. Cross, "Parametric dependence of ocean wave-radar modulation transfer function" accepted for publication in J. Geophys. Res., 1983

Valenzuela, G.R., "Theories for the interaction of electromagnetic and oceanic waves-a review", Boundary Layer Meteor., 13, 61-85, 1978

Weissman, D.E., "The dependence of the radar modulation transfer function on environmental conditions and wave parameters" Final Report, Contract N00014-83-M-0081, August 1983

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Figure 2 : MARSEN: Radar Cross Section (arbitrary units) vs. RMS Slope $10.3 \leq U \leq 10.9$ m/s

Figure 3 : MARSEN: Radar Cross Section (arbitrary units) vs. RMS Slope $11.0 \leq U \leq 11.9$ m/s

Figure 4 : MARSEN: Radar Cross Section (arbitrary units) vs. RMS Slope $12.0 \leq U \leq 12.9$ m/s

Figure 5 : MARSEN: Radar Cross Section (arbitrary units) vs. RMS Slope $13.0 \leq U \leq 13.8$ m/s

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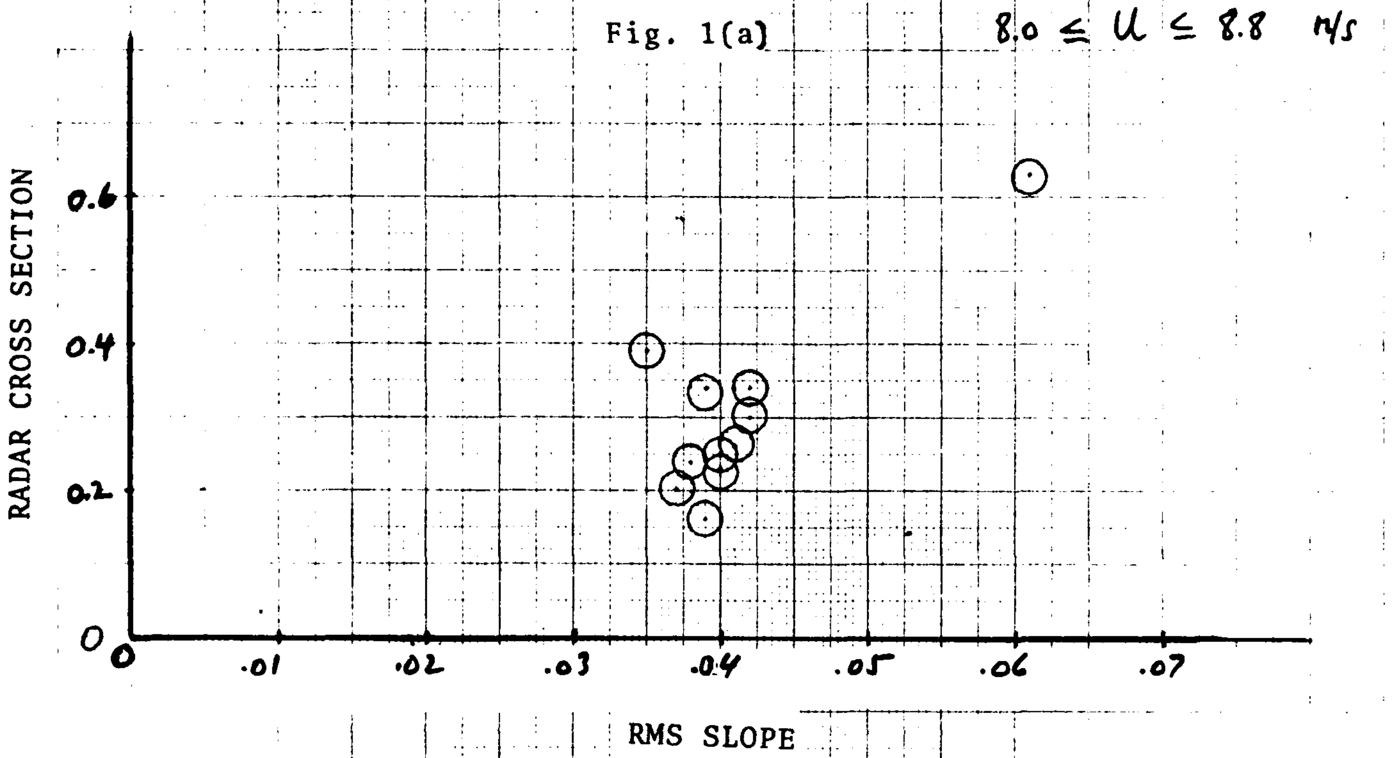
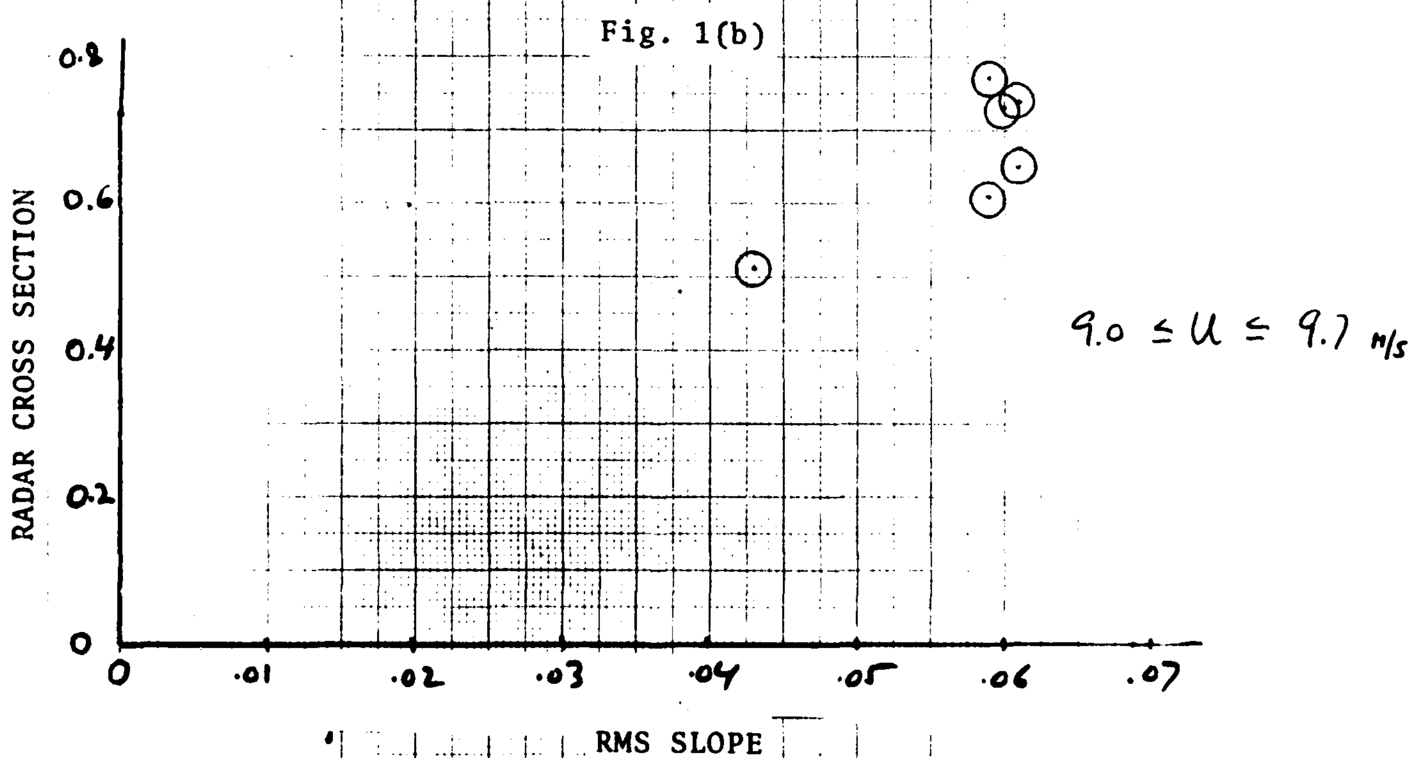
MARSEN Radar Cross Section
vs. RMS Slope





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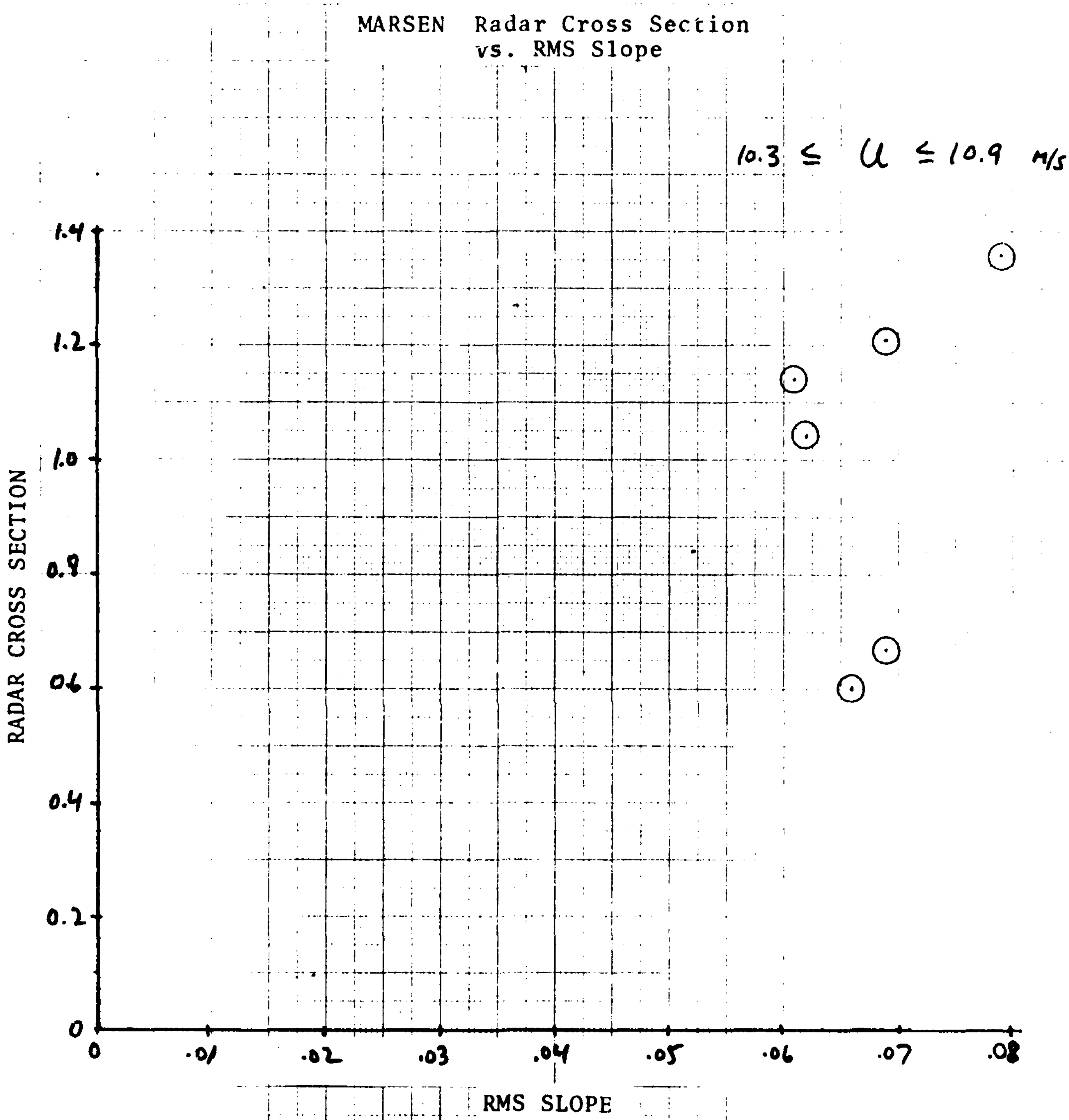
MARSEN Radar Cross Section
vs. RMS Slope
10.3 ≤ U ≤ 10.9 m/s
RADAR CROSS SECTION
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
.01
.02
.03
.04
.05
.06
.07
.08
RMS SLOPE

46 1510

Fig. 2

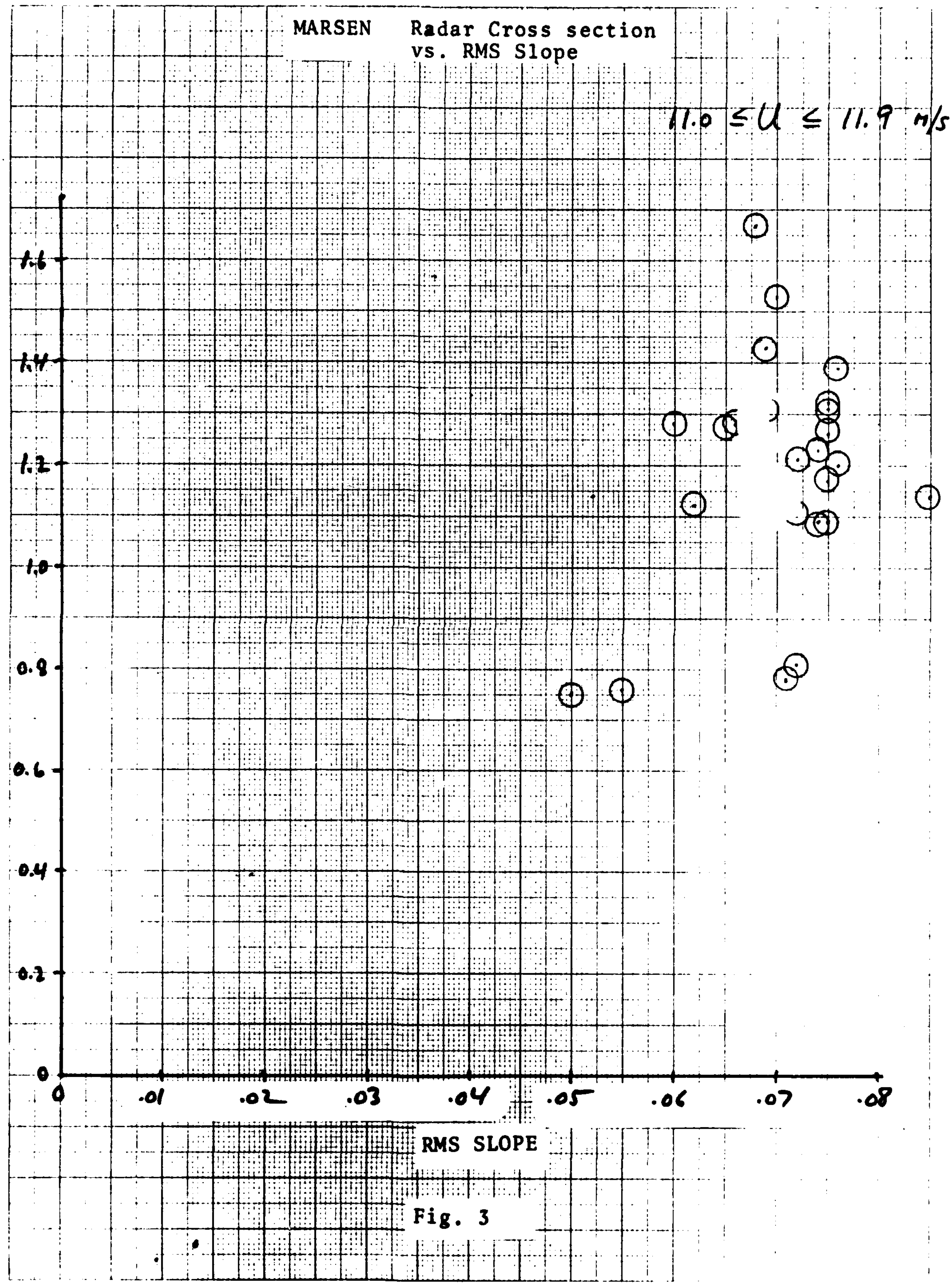
MARSEN Radar Cross section
vs. RMS Slope
11.0 ≤ U ≤ 11.9 m/s
RADAR CROSS SECTION
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
.01
.02
.03
.04
.05
.06
.07
.08
RMS SLOPE

Fig. 3

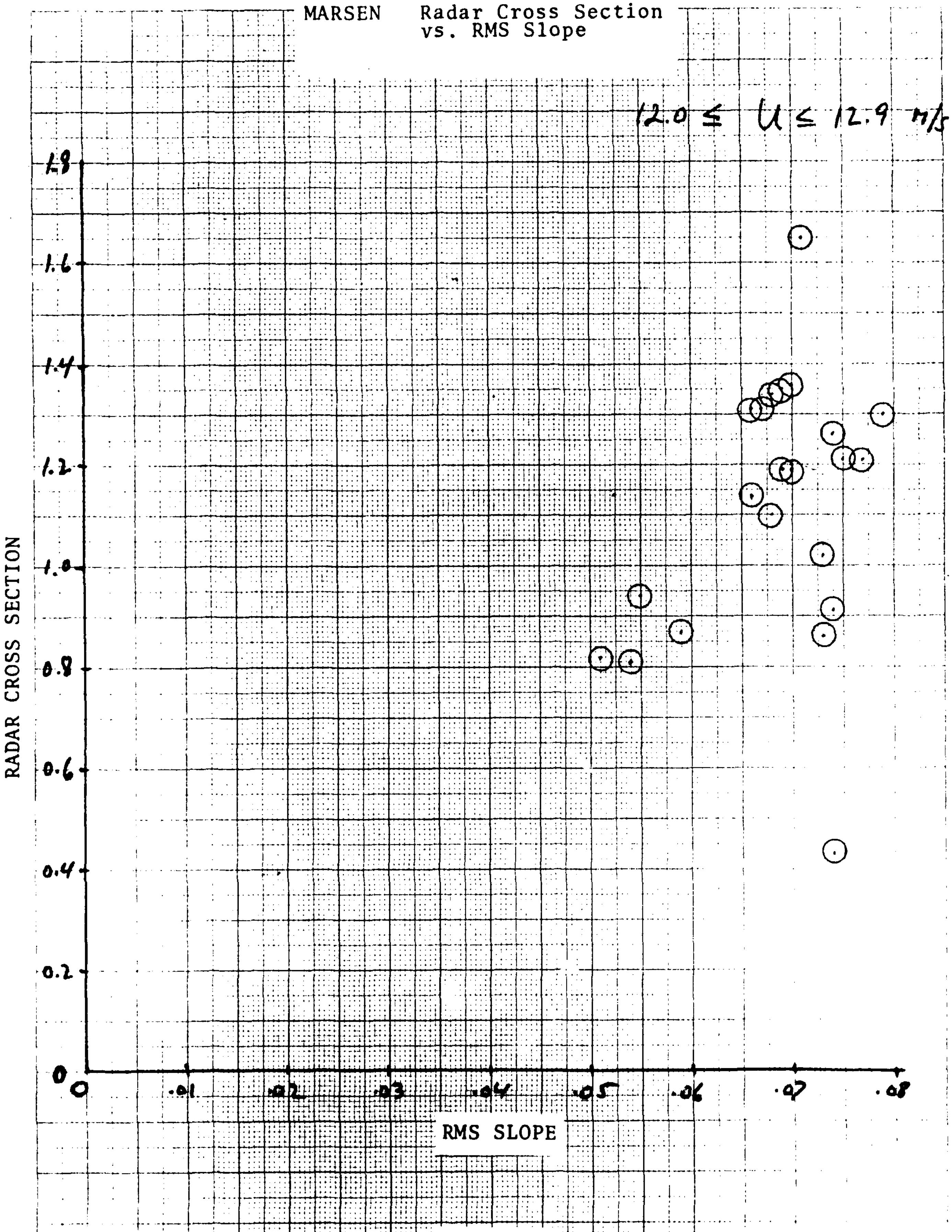
MARSEN Radar Cross Section vs. RMS Slope
12.0 ≤ U ≤ 12.9 m/s
RADAR CROSS SECTION
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
.01
.02
.03
.04
.05
.06
.07
.08
RMS SLOPE

Fig. 4

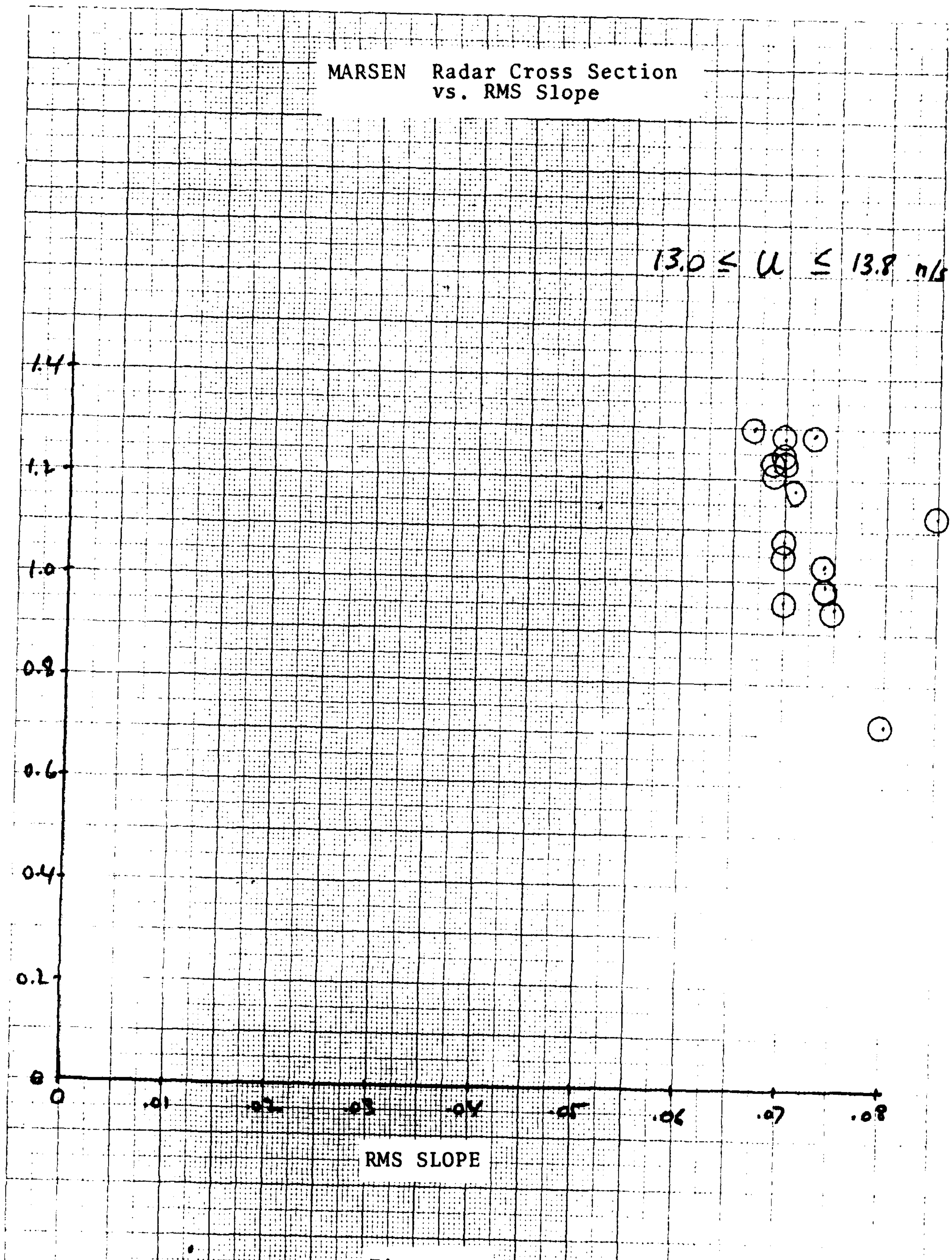
MARSEN Radar Cross Section
vs. RMS Slope
13.0 ≤ U ≤ 13.8 m/s
RADAR CROSS SECTION
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
.01
.02
.03
.04
.05
.06
.07
.08
RMS SLOPE

Fig. 5

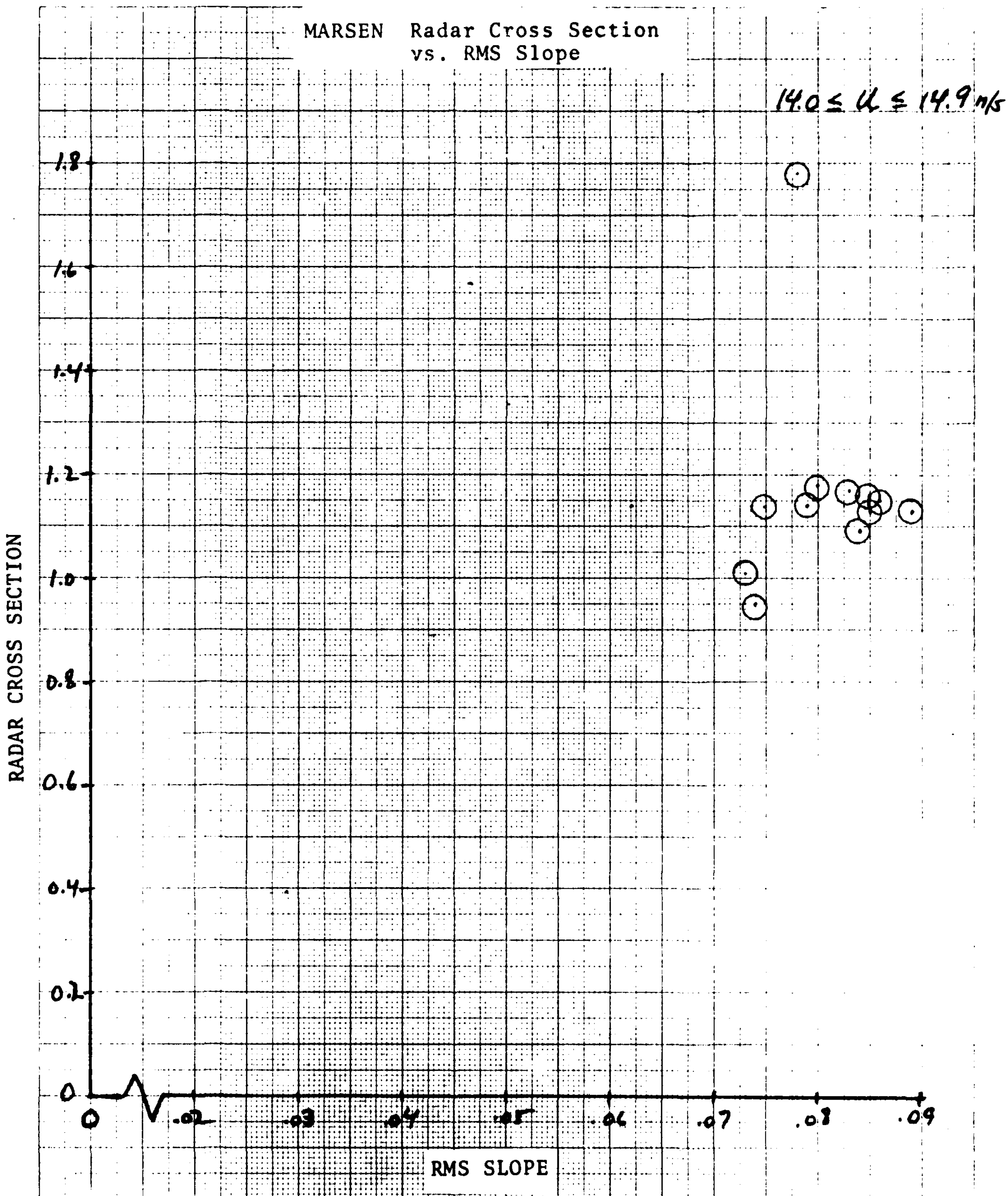
MARSEN Radar Cross Section
vs. RMS Slope
14.0 ≤ U ≤ 14.9 m/s
RADAR CROSS SECTION
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
.02
.03
.04
.05
.06
.07
.08
.09
RMS SLOPE

Fig. 6

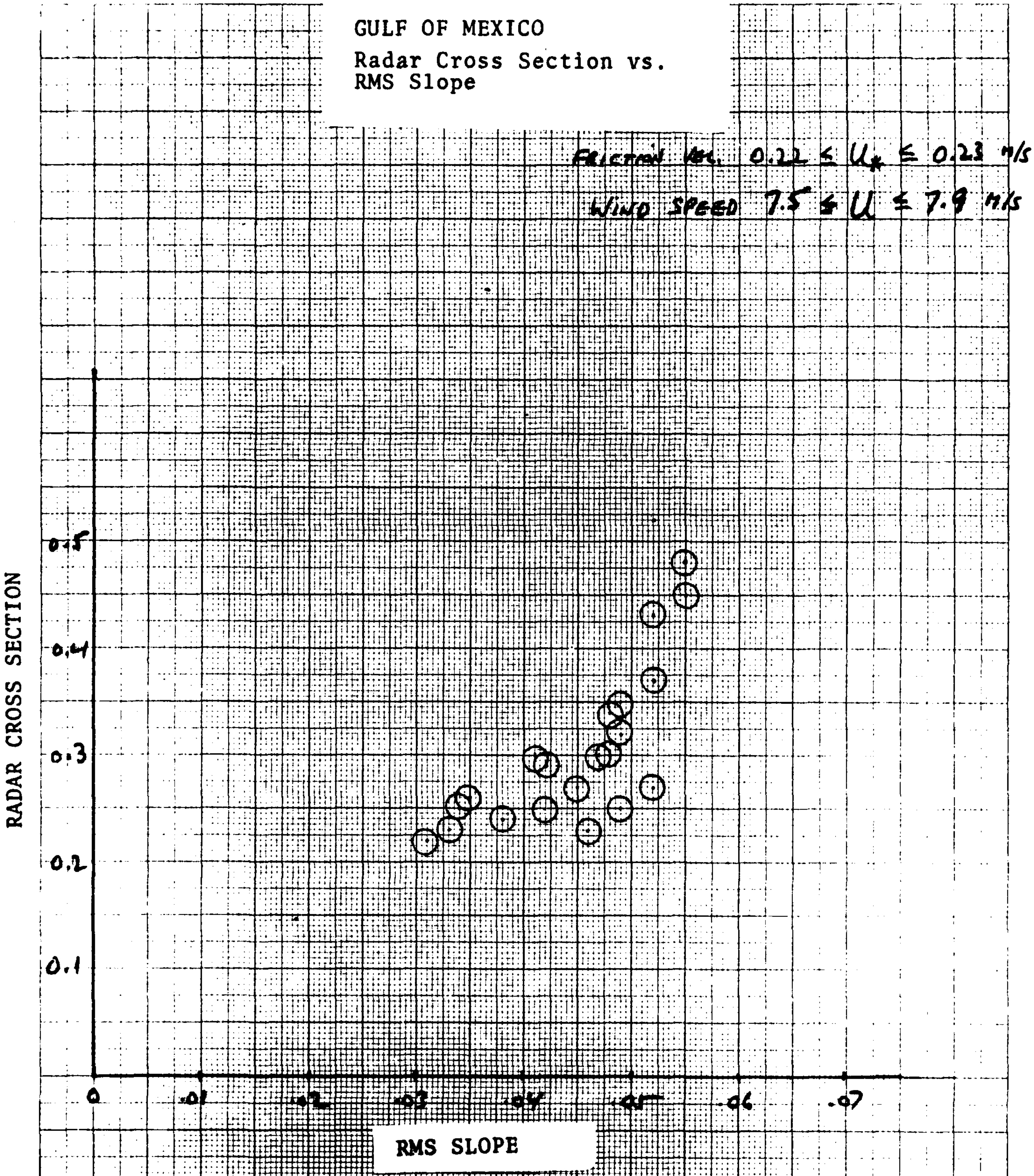
GULF OF MEXICO
Radar Cross Section vs.
RMS Slope
FRICTION VEL. 0.22 ≤ U* ≤ 0.23 m/s
WIND SPEED 7.5 ≤ U ≤ 7.9 m/s
RADAR CROSS SECTION
0.1
0.2
0.3
0.4
0.5
0
.01
.02
.03
.04
.05
.06
.07
RMS SLOPE

Fig. 7

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