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RADAR RETURNS FROM GROUND CLUTTER IN VICINITY OF AIRPORTS

RESEARCH GRANT - NASA - LANGLEY
RESEARCH CENTER

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OBJECTIVE OF PROJECT

TO DEVELOP A DYNAMIC SIMULATION OF THE RECEIVED SIGNALS FROM NATURAL AND MAN-MADE GROUND FEATURES IN THE VICINITY OF AIRPORTS. THE SIMULATION IS RUN DURING LANDING AND TAKEOFF STAGES OF A FLIGHT. MODELLING OF CLUTTER BASED ON MOST UP - TO - DATE THEORIES AND RESULTS AVAILABLE

NOTEWORTHY FEATURES OF SIMULATION - I

(1) COHERENT SUMMATION OF COMPLEX VECTOR FIELDS OF SCATTERED WAVE, IMPLYING THAT:

   (A) RELATIVE PHASE BETWEEN SCATTERING CELLS IS ACCOUNTED FOR

   (B) POLARIZATION OF SCATTERED FIELDS IS ACCOUNTED FOR

(2) VELOCITIES OF RADAR AND SCATTERING CELLS ARE COMPUTED - DOPPLER SHIFT IS DETERMINED FOR RETURN FROM EACH SCATTERING CELL

NOTEWORTHY FEATURES OF SIMULATION - II

(3) MODELLING OF COMPLEX ANTENNA PATTERN

(A) IN TRANSMITTING MODE-GENERATE Θ AND Ø COMPONENTS OF COMPLEX RADIATED (ELECTRIC) FIELDS FROM X AND Y COMPONENTS OF COMPLEX APERTURE (ELECTRIC) FIELD

(B) IN RECEIVING MODE-GENERATE X AND Y COMPONENTS OF COMPLEX APERTURE (ELECTRIC) FIELD FROM Θ AND Ø COMPONENTS OF INCOMING COMPLEX (ELECTRIC) FIELD

(4) MODELLING OF TIME FUNCTIONS

(A) TRAJECTORIES OF RADAR AND MOVING CLUTTER SOURCES, UNDULATING SURFACES (E.G. WATER SURFACES), ANTENNA SCANNING PATTERN

(5) EM COMPUTATIONS PERFORMED IN FREQUENCY SPACE-CAN BE FT'D BACK TO TIME DOMAIN

NOTEWORTHY FEATURES OF SIMULATION - III

(5) MULTIPATH EFFECTS

TWO AND THREE-BOUNCE PROCESSES CONTRIBUTING TO RECEIVED RADAR SIGNAL ARE ACCOUNTED FOR

(6) BLOCKAGE AND SHADOWING

TOTAL AND PARTIAL BLOCKAGE OF CELLS BY OTHER CELLS IS ACCOUNTED FOR

FOR SINGLE BOUNCE CASE, OCCURS AT LOW GRAZING ANGLES.

AFFECTS MULTIPLE BOUNCE CASES AT ALL GRAZING ANGLES

(7) OUTPUTS AVAILABLE

(A) AVERAGE POWER IN RECEIVED SIGNAL

(B) CORRELATION FUNCTIONS AND SPECTRA

(C) AMPLITUDE PROBABILITY DISTRIBUTIONS

(D) EFFECTS OF RECEIVER FILTERING ON (A), (B) OR (C)

GROUND - CLUTTER DATABASES

A PREPARED FROM AIRPORT OBSTRUCTION CHARTS OBTAINED FROM NASA - LANGLEY

B AIRPORTS ARE: JFK, LA GUARDIA, LOGAN, WILLOW-RUN, MIAMI, DENVER, NEW ORLEANS, DALLAS, SAN DIEGO, TUCSON, BOEING(SEATTLE)

C <u>TYPICAL CLUTTER SOURCES</u>:

SEA WATER SURFACES (HARBORS, E.G. JFK, LA GUARDIA, LOGAN)
FRESH WATER SURFACES (LAKES OR RIVERS, E.G. WILLOW-RUN, DENVER)
PAVEMENT SURFACES (ROADS, RUNWAYS, ALL AIRPORTS)
HILLY TERRAIN (CLIFFS, E.G. BOEING)
SNOW COVERED TERRAIN (ALL AIRPORTS IN WINTER EXCEPT MIAMI, NEW ORLEANS, TUCSON, SAN DIEGO)
TOWERS, ANTENNAS, BUILDINGS (NEARLY ALL AIRPORTS)
SURROUNDING URBAN STRUCTURES (ALL AIRPORTS NEAR CITY, E.G. LOGAN, LA GUARDIA, JFK)

DEVELOPMENT OF ALGORITHMS FOR TERRAIN FEATURES

(1) MODELLING - WAVE APPROACH

- (A) RIGOROUS FORMULATION BASED ON MAXWELL EQUATIONS
- (B) ACCURATELY ACCOUNTS FOR POLARIZATION - BOTH CO-POL AND CROSS-POL RETURNS
- (C) DISADVANTAGES - SOLUTIONS DIFFICULT AND CPU-TIME INTENSIVE; APPROXIMATIONS REQUIRED (E.G. 1ST AND 2ND ORDER BORN)

(2) RADIATIVE TRANSFER THEORY

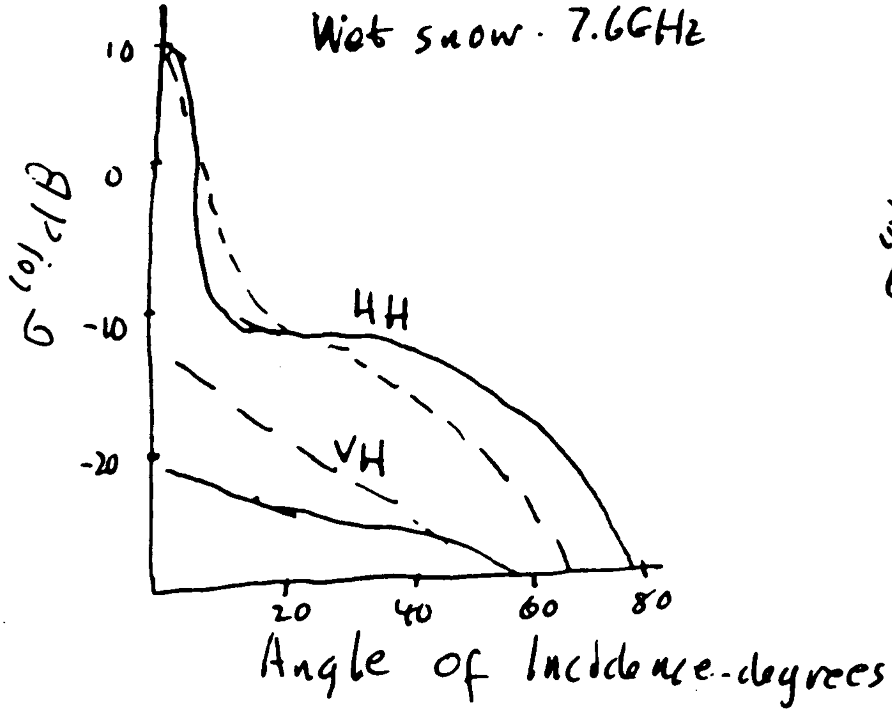
- (A) PURELY ENERGY - PHASE SUPPRESSED
- (B) EASILY ACCOUNTS FOR MULTIPLE SCATTERING
- (C) FASTER BUT LESS ACCURATE

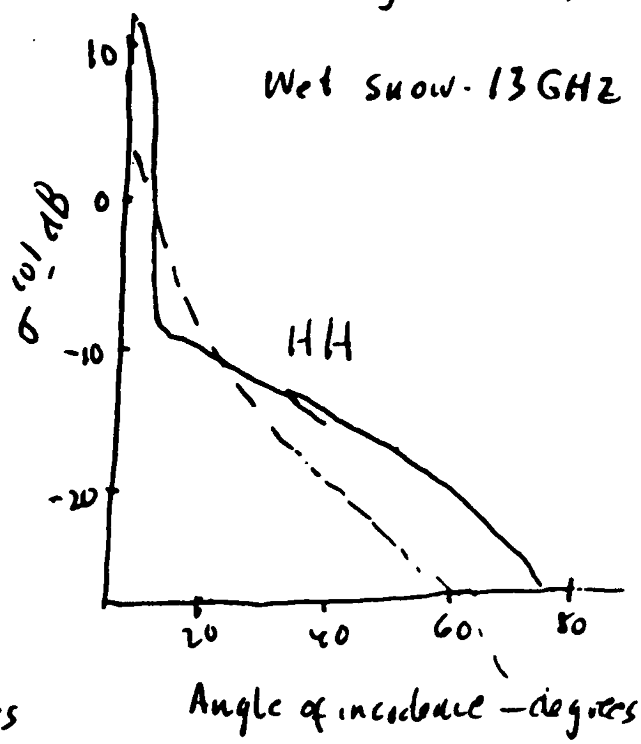
(3) DISCRETE SCATTERERS - SHORT OR LONG WAVE APPROXIMATIONS; EXACT SOLUTIONS FOR SIMPLE GEOMETRIES

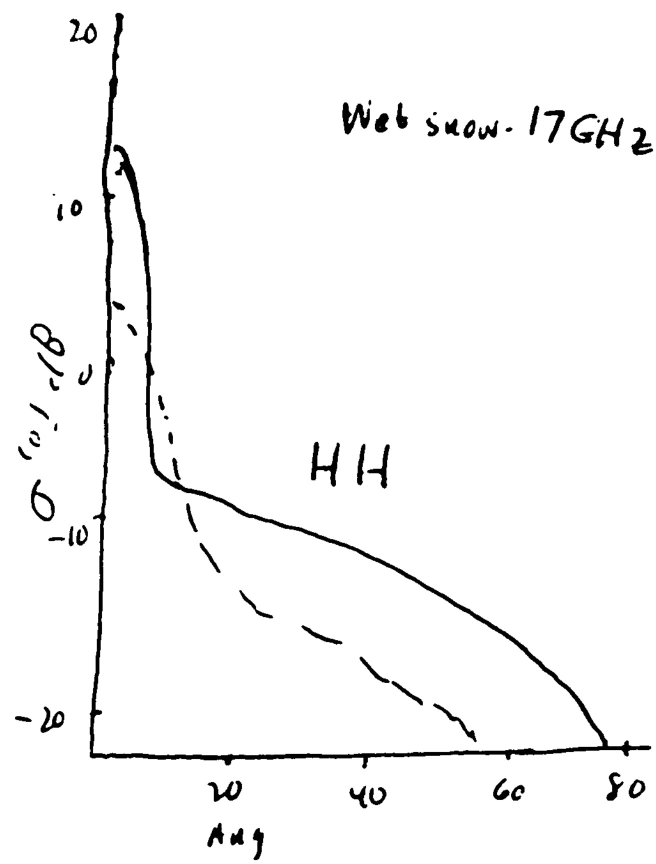
(4) SURFACE SCATTERING - TWO-SCALE MODEL WITH RANDOM SURFACE VARIATIONS

Wave theory results - cont'd

(U. Kansas Group - Stiles and Ulaby (1980))







In each case

—— Theory

- - - - Experiment

Typical wave theory results

(MIT μwave Remote Sensing Group - J. A. Kong et al). Backscatter cross sections - copol and crosspol

Grass - 35 GHz, 82° incidence

	σ_{HH}	$\sigma_{VH}=\sigma_{HV}$	σ_{VV}
Theory	−15.4	−23.6	−15.6
Exper.	−15.0	−23.2	−16.2

Trees 35 GHz, 82° incidence

	σ_{HH}	$\sigma_{VH}=\sigma_{HV}$	σ_{VV}
Theory	−13.1	−26.7	−13.1
Exper	−13.0	−25.2	−12.6

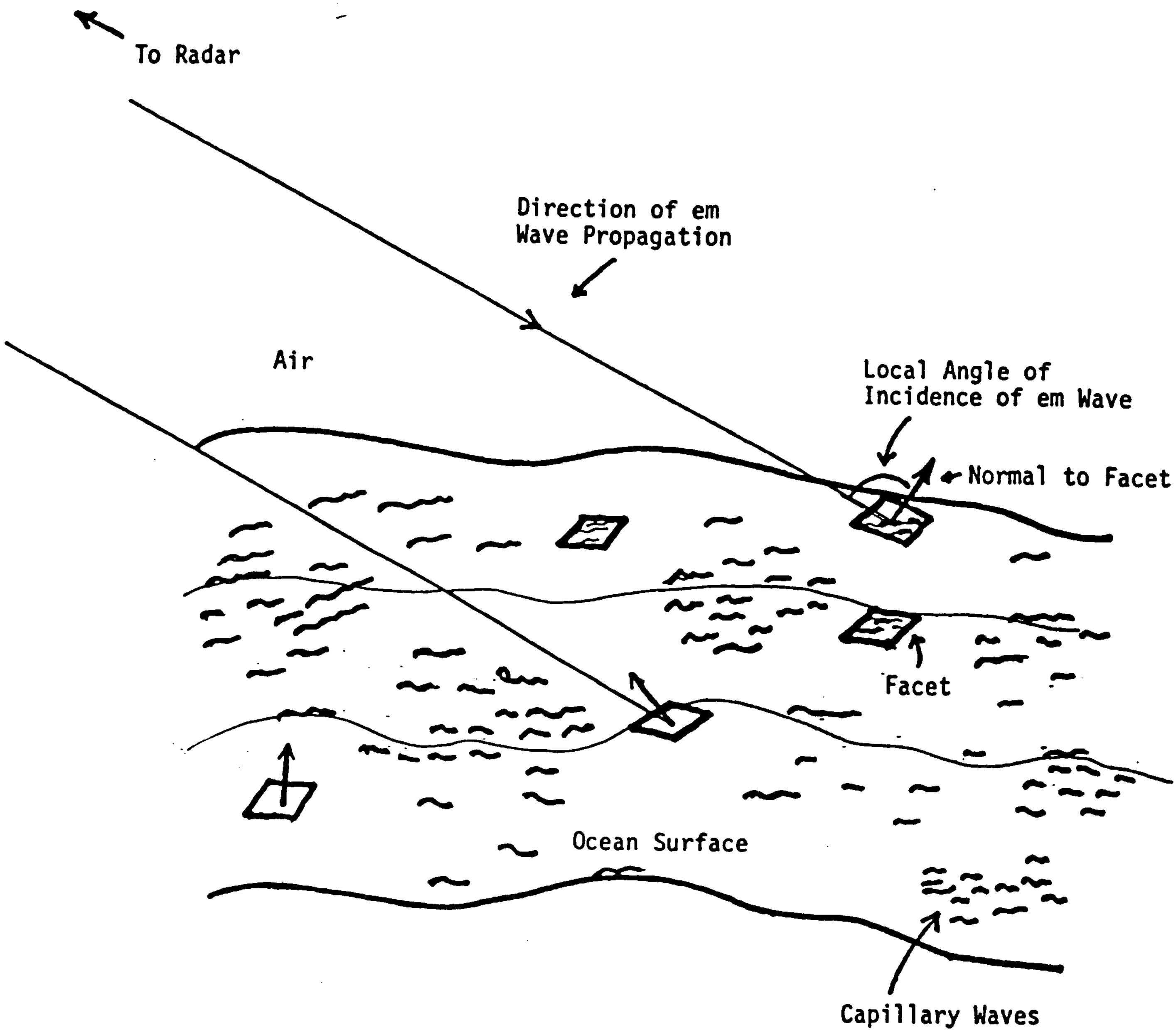


Fig. 2 Geometry of em wave scattering from ocean surface.

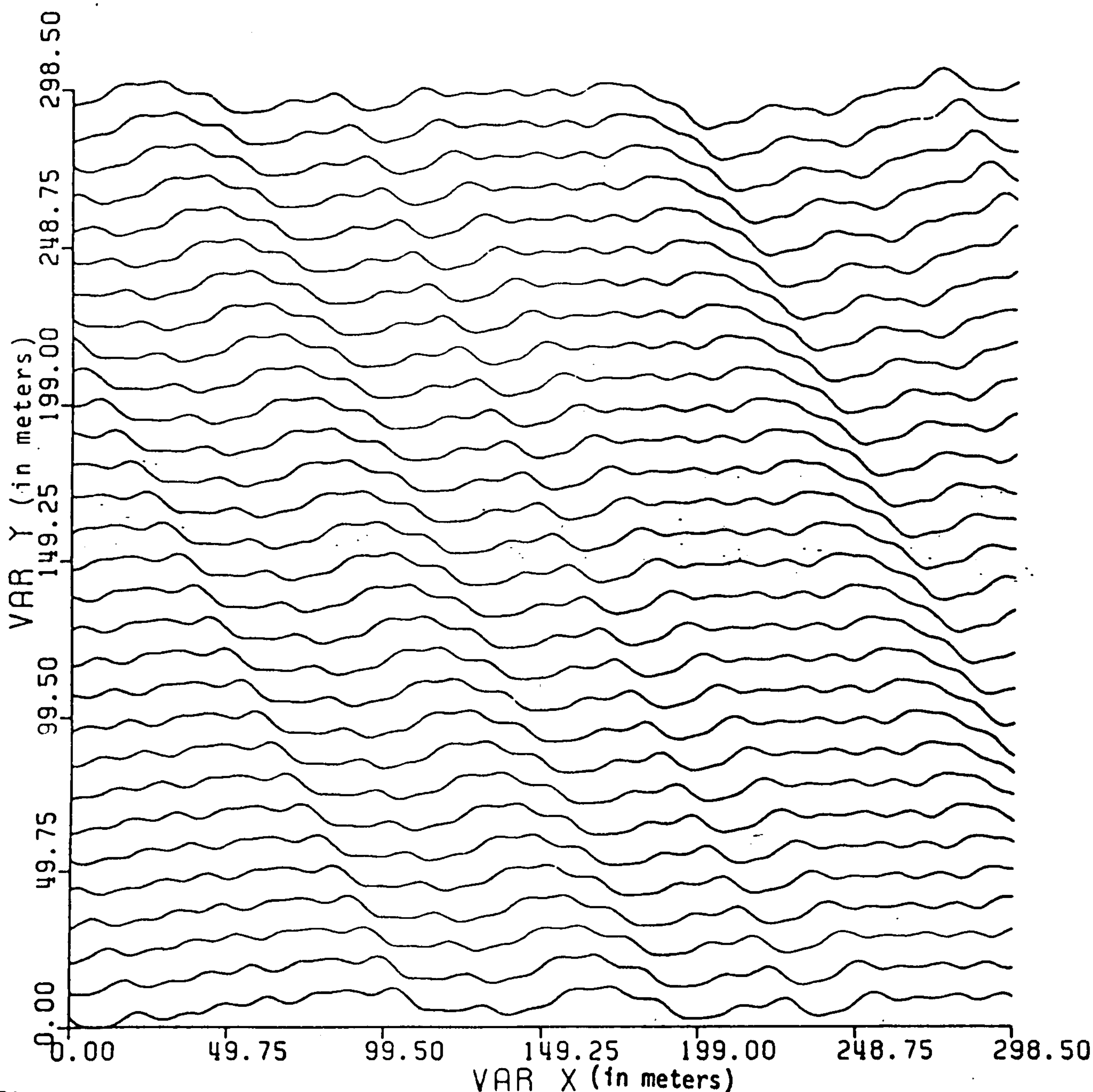


Fig. 4 A typical gravity wave height profile generated by the computer for a wind speed of 20 knots directed at a 45° angle with respect to the x-axis. The x and y axes in the plot represent two orthagonal directions on the mean ocean surface. A different scale is used for the height of the gravity waves.

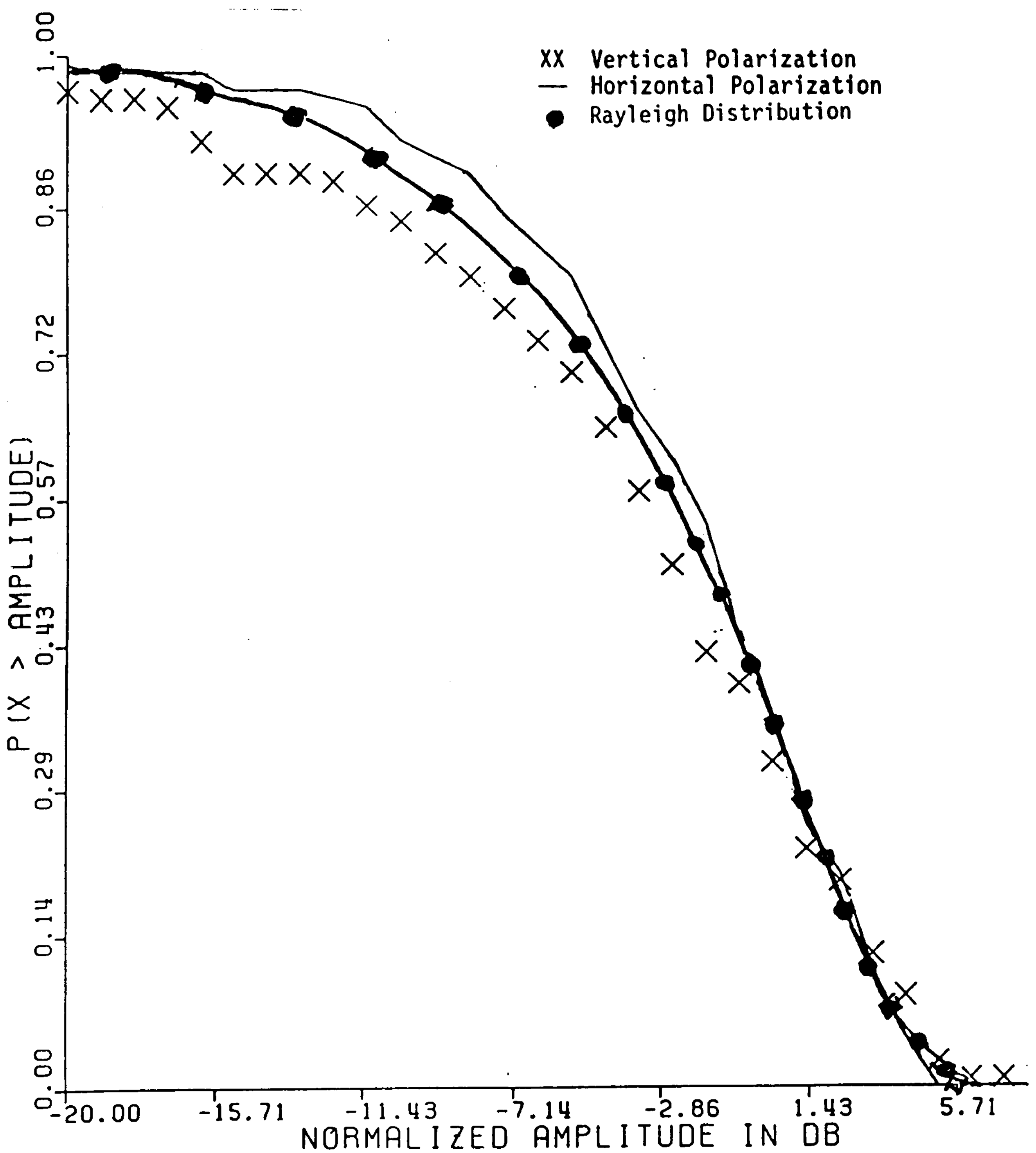


Fig. 6 & 7 The probability distribution of the backscattered signal envelope, (the angle of incidence of em wave is 70°; wind speed is 5 knots and is directed along the x-axis). The ordinate gives the probability that the backscattered signal envelope will exceed the abscissa.

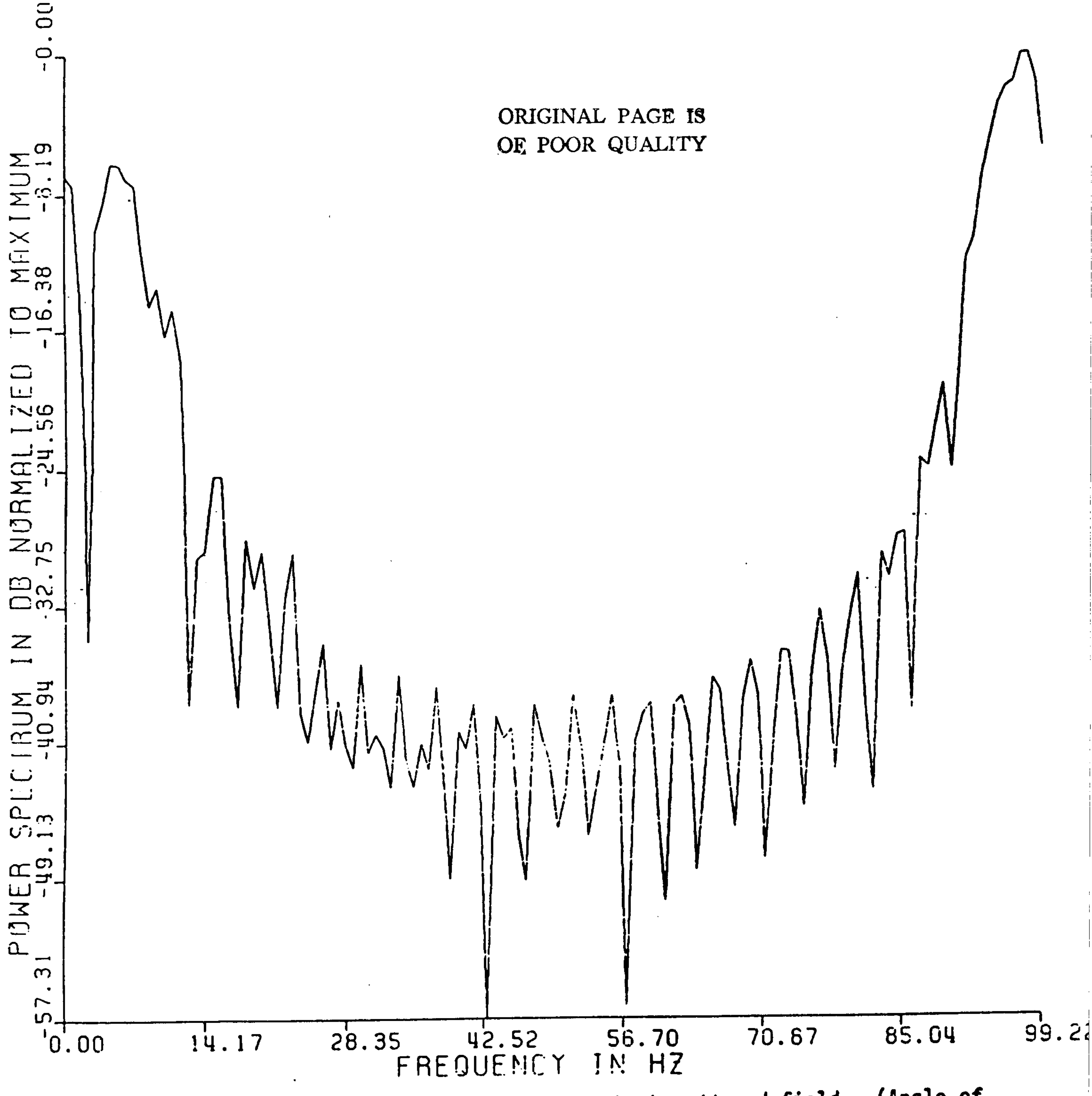


Fig. 5 A typical doppler spectrum of the backscattered field. (Angle of incidence of microwave (x-band) is 70°; wind speed = 20 knots, wind direction is 45° from the x axis; the incident and scattered fields are vertically polarized.)