NASA-CR-167783

FOUR FREQUENCY GROUND SCATTEROMETER

UH/CLC TECHNICAL REPORT

Prepared by

E.T. Dickerson

The University of Houston
at Clear Lake City
Houston, Texas 77058

OCTOBER 1982

Supported by

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lyndon B. Johnson Space Center

Contract NAS 9-[redacted] 16422

(NASA-CR-167783) FOUR FREQUENCY GROUND SCATTEROMETER (Houston Univ.) 84 p HC A05/MF A01 CSCL 20N

N83-16593

Unclas

G3/32 02592

FOUR FREQUENCY GROUND SCATTEROMETER

UH/CLC Technical Report

Prepared by

E. T. Dickerson

The University of Houston
at Clear Lake City
Houston, Texas 77058

OCTOBER 1982

Supported by

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lyndon B. Johnson Space Center

Contract NAS 9-[redacted] 16422

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENT

The author and editor wishes to acknowledge the vast contributions and support giver by the following list of individuals.

Richard Fenner	Program Director-NASA/EE
Jerry Pels	Computer support and Hardware analysis-NASA/CH
Ray Nuss	Computer support and Hardware analysis-NASA/EE
Jerry Williams	Hardware design-Lockheed/EMSCO
Tom Withrow	Hardware implementation-Lockheed/EMSCO
Steve Reid	Hardware deisgn and system analysis-Lockheed/EMSCO

1.0 INTRODUCTION

In order to predict accurately the performance of an air-borne or satellite-borne radar system it is necessary to have a known return power level as a reference. To obtain a reference such as this has been the goal of radar system engineers for a great number of years. An extensive effort has been made to define a process by which this reference level might be achieved. There are four groups sponsored by NASA working to achieve an accurate repeatable radar calibration technique. These four groups are: (1) NASA/JSC, (2) Texas A&M University, (3) The University of Kansas, and (4) NASA/JPL.

The purpose of this report is to describe the FM-CW Radar being used by NASA/JSC as a Microwave Scatterometer. This description is limited to a system description, system parameter corrections, and a presentation of two data sets.

This report will be divided into five major parts: (1) scatterometer system design, (2) scatterometer system calibration, (3) parameter calculation and correction for data acquisition, (4) ground scatterometer data acquisition at Jornada Experimental Range, and (5) Kansas radar cross-calibration test.

2.0 FOUR FREQUENCY GROUND SCATTEROMETER

2.1 SYSTEM DESCRIPTION

The ground scatterometer consists of four separate radars with operating frequencies of 1.6 GHz, 4.75 GHz, 9.5 GHz and 13.3 GHz. Each system is a swept FM radar using triangular modulation (see Figure 2.1). The modulation is provided by the sweeper which sweeps linearly from 0 to 10 volts and back at a frequency of 150 Hz. Each YIG oscillator is swept through a range of fc -500 MHz to f_c +500 MHz, where f_c is the center frequency except for the 1.6 GHz which is swept $\pm$ 160 MHz. The YIG oscillators serve as the transmitter oscillators as well as the LO's for the mixers. The signal out of the mixer is fed to the spectrum analyzer where it is sampled and digitized, and then to the calculator for processing and data storage.

2.2 FREQUENCY CONSIDERATIONS

The four ground scatterometer systems are swept FM systems with triangular modulation, the legs of the triangle being linear. The system is nominally swept from f_c -500 MHz to f_c +500 MHz, except for the 1.6 GHz as described above, f_c being the center frequency of the system or from f_1 to f_2 and back as shown in Figure 2-2 at a rate m.

The received frequency tracks the transmitted frequency but is delayed by the time (τ) which is a function of the range to the target. For a point target at range R,

$$\tau = \frac{2R}{C} \quad , \text{ c = velocity of light}$$

$$f_T = \begin{cases} f_1 + mt & , \text{ f increasing} \\ f_2 - mt & , \text{ f decreasing} \end{cases}$$

$$f_R = f_T\,(t-\tau) = f_T\,(t - \frac{2R}{C})$$

$$= \begin{cases} (f_1 + m\,(t - \frac{2R}{C}) & , \text{ f increasing} \\ (f_2 - m(t - \frac{2R}{C}\,) & , \text{ f decreasing} \end{cases}$$

ORIGINAL PAGE IS
OF POOR QUALITY

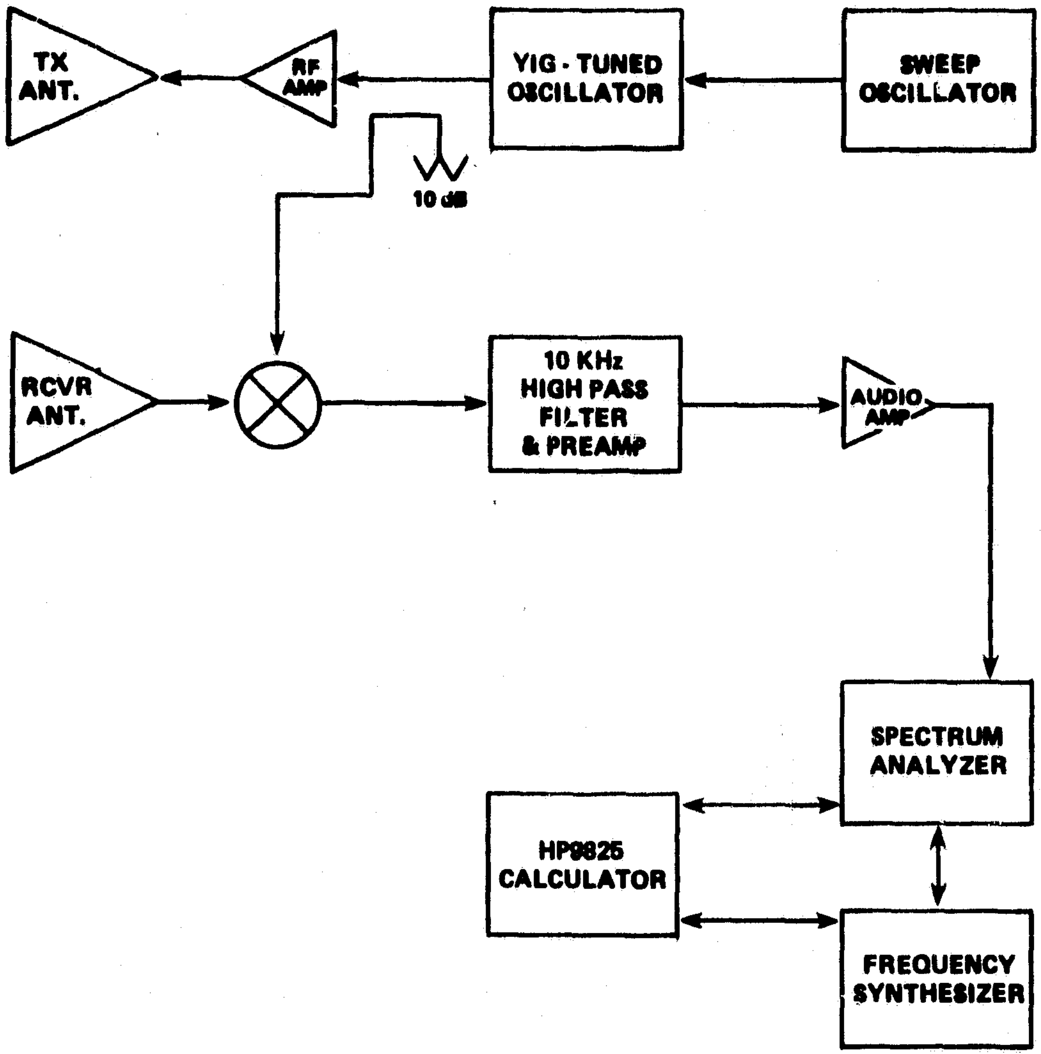


Figure 2-1 Scatterometer System Block Diagram

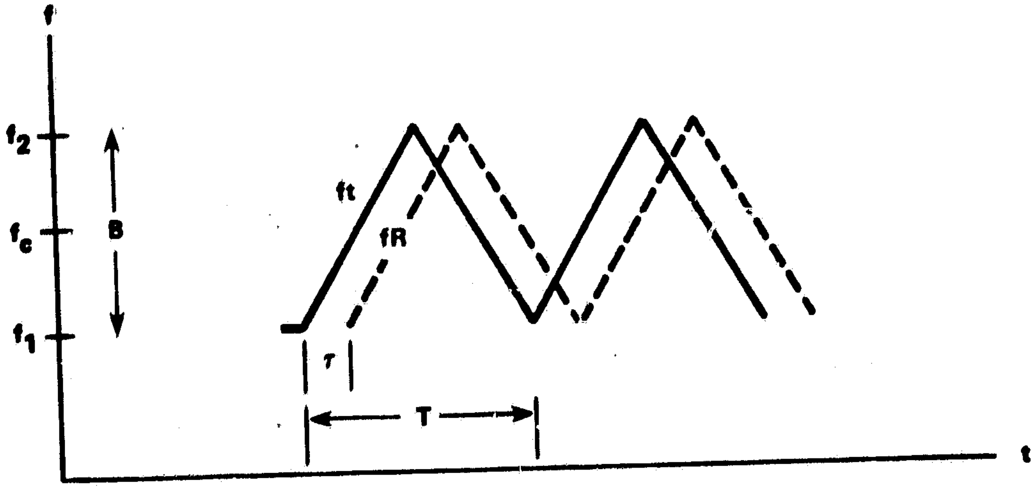


Figure 2-2 FM-CW Signal Description

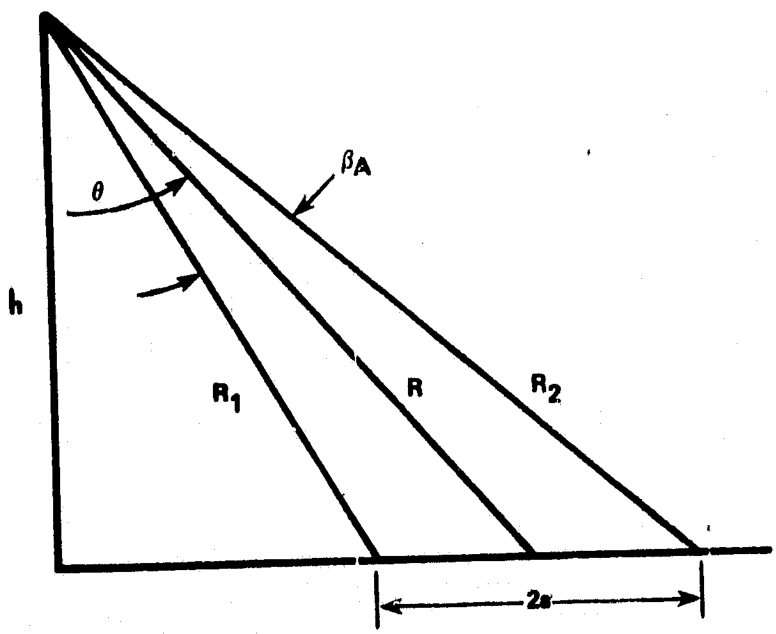


Figure 2-3 Scatterometer Geometry for Extended Target

Mixing an attenuated part of the transmitted frequency with the received frequency and using the difference, the IF, which is also the signal frequency, for point target range R is

$$f_s = F_{IF} = |f_T - f_R| = f_1 + mt - f_1 - m\left(t - \frac{2R}{C}\right).$$
$$fs = \frac{2mR}{C}.$$

The actual signal used in the application of the ground scatterometer is obtained from an extended target and the ranges from different parts of the target are different. Hence, the actual signal will be a band of frequencies whose value will be bounded by the ranges at the edge of the receiver antenna beamwidth. Hence,

$$\Delta fs = f_{R2} - f_{R1} = \frac{2mR_2}{C} - \frac{2mR_1}{C},$$

$$\Delta fs = \frac{2m}{C}(R_2 - R_1) = \frac{2m}{C}\Delta R.$$

Since the system is swept through the bandwidth B (nominally, 1 GHz) in time T, where T is given by $T = \frac{1}{2\ frep}$, the FM rate is

$$m - \frac{B}{T} = 2B\ frep.$$

Nominally, frep = 150 Hz.

Since $\Delta fs = \frac{2m}{C}\Delta R$, the slope of the frequency vs. range is $\frac{2m}{C} = \frac{2}{C}(2B\ frep) = \frac{4B\ frep}{C}$.

Using nominal values the slope should be

$$\frac{2m}{C} = \frac{4B\ rep}{C} = \frac{4\ (10^9)\ (150)}{3 \cdot x\ 10^8} = 2KHz/meter..$$

As we shall see later, the actual measured value of $\frac{2m}{c}$ is somewhat less than this, indicating that B is less than 1 GHz.

2.3 GEOMETRICAL CONSIDERATIONS

The non zero antenna beamwidth and the antenna position relative to the target results in different slant ranges to the target as shown in Figure 2-3. The slant ranges at the antenna half power points and points of maximum gain are given by the following equations:

$$R = h/\cos\Theta ,$$

$$R_1 = h/\cos(\Theta - \beta_A/2) ,$$

$$R_2 = h/\cos(\Theta + \beta_A/2) ,$$

where

h = vertical height above ground ,

β_A = 3 dβ along track antenna beamwidth,

Θ = look angle ,

R = slant range to center of footprint ,

R_1 = slant range to near edge of beamwidth , and

R_2 = slant range to far edge of beamwidth .

Using the Tri-Ex tower, the nominal value of h is 51.5 feet.

3.0 SCATTEROMETER SYSTEM CALIBRATION

3.1 DETERMINATION OF P_R

The signal return for the ground scatterometer system can be estimated in the usual manner by using the radar equation as follows:

$$P_R = \frac{P_T G_T G_R \lambda^2 \sigma}{(4\pi)^3 R^4}$$

where

P_R = return power at receiver antenna

P_T = power transmitted

G_T, G_R = transmitter and receiver antenna gains

λ = radar wavelength

σ = radar cross-section of target

R = range of target

The ground scatterometer is designed to measure sigma zero (σ^0), the radar cross section per unit area or scattering coefficient. If the target is homogeneous and small enough such that σ does not vary over the angle β_A, the average scattering coefficient for a target may be written as

$$\sigma^0 = \frac{\sigma}{A} \text{ , where A = Footprint area for an extended target.}$$

Substituting the σ^0 in the radar equation yields:

$$P_R = \frac{P_T G_T G_R \lambda^2 \sigma^0 A}{(4\pi)^3 R^4} .$$

ORIGINAL PAGE IS
OF POOR QUALITY

The calibration of the ground scatterometer could be performed by measuring P_T, G_T, and G_R and then determining the system response to measure P_R at the output of the system. Another method is to measure the cross-section of a known target and take the ratio of the power returned from a target to the power returned from the known calibration target. This method eliminates the need to measure the system gains and responses, and, in modified form, is the method used to calibrate the ground scatterometer.

From the radar equation above,

$$\sigma^0 = \left[\frac{(4\pi)^3}{P_T G_T G_R \lambda^2}\right] \quad \frac{P_R R^4}{A} = K \frac{P_R R^4}{A}$$

For a given stable system, the quantity in brackets, K, should remain a constant. The determination of R and A is done by direct measurement or calculation.

The determination of P_R is done using the spectrum analyzer. The output of the spectrum analyzer is a power spectral density, and the voltage output at a given frequency is related to the power input within a small bandwidth Δf centered at that frequency by the relation

$$V(f) = \sqrt{\frac{P(f)}{k\Delta f}}$$

where k is a constant of proportionality which includes the system response. The return power is estimated by

$$P_R = k \int_{\Delta fs} V^2(f)df$$

where Δfs is the signal bandwidth. A method for approximating the integral will be given in the next section.

The calibration of the ground scatterometer system reduces to the determination of K in the equation for σ^0. This can be accomplished by making measurements on a calibration target with a known cross-section, generally a sphere. A sphere has the advantages of having the same cross-section at all radar frequencies, easy alignment of target and radar, and no depolarization of the reflected signal. Table 3-1 gives various calibration targets and the method of determining their cross-section.

3.2 CALIBRATION CONSTANT DETERMINATION

3.2.1. RADAR EQUATION

$$P_R = \frac{P_T G_T G_R \lambda^2 \sigma}{(4\pi)^3 R^4} \qquad \text{Cal Target}$$

$$P_R = \frac{P_T G_T G_R \lambda^2 \sigma_o A}{(4\pi)^3 R^4} \qquad \text{Extended Target}$$

where:

P_R = Return power,

P_T = Power transmitted,

G_T, G_R = Transmit and receive antenna gains,

λ = Radar wavelength,

σ = Radar cross-section of target,

R = Range to target, and

A = Footprint area for extended target,

Assuming, for a given system, that P_T, G_T, and G_R are constant

$$\left[\frac{(4\pi)^3}{P_T G_T G_R \lambda^2}\right] = K = \frac{\sigma}{P_R R^4}.$$

For a given Cal Target, such as a sphere, the calculated value of σ is used and P_R and R are measured to determine K.

TABLE 3-1

Radar Cross-Section of Various Calibration Reflectors

Sphere

$$\sigma = \pi r^2 \quad , \frac{r}{\lambda} > 5$$

Luneberg Lens

$$\sigma = \frac{4\pi^3 r^4}{\lambda^2} \quad , 2\pi r > \lambda \text{ and } f < 10\text{GHz}$$

Flat Plate

$$\sigma = \frac{4\pi^3 r^4}{\lambda^2} \quad , \text{normal incidence}$$

Trihedral Corner Reflector

$$\sigma = \frac{4\pi(0.289\ell^2)^2}{\lambda^2}$$

3.2.2. DETERMINATION OF P_R

The output of the ground scat mixer is a voltage which is proportional to the square root of received power, i.e.,

$$V \cong \sqrt{P_R} \; .$$

The voltage output of the mixer is spread over the signal bandwidth of the system. This mixer output is fed to the spectrum analyzer which produces a power spectral density of the signal. For our measurements the output of the spectrum analyzer is set for DBV with a 1 KHz bandwidth. Hence, the power spectral density for each spectrum analyzer sample is,

$$P(\text{dBV}) = 20 \text{ LOG } V = 10 \text{ LOG } V^2,$$

where V is voltage output of mixer

$$V^2\,(f) = 10^{\,P(\text{DBV})/10}$$

The total power received in the signal bandwidth is given by

$$P_R = k\int_{\Delta fs} V^2(f)df,$$

where k is a constant of proportionality. In actual practice, the above integral is approximated by the summation as follows:

$$P_R = \sum_{\Delta fs} V_i^{\,2}\,\Delta f,$$

where (see Figure 3-1):

Δf = sample separation Hz,

V_i^2 = normalized power in bandwidth Δf, and

Δfs = signal bandwidth at IF.

ORIGINAL PAGE IS
OF POOR QUALITY

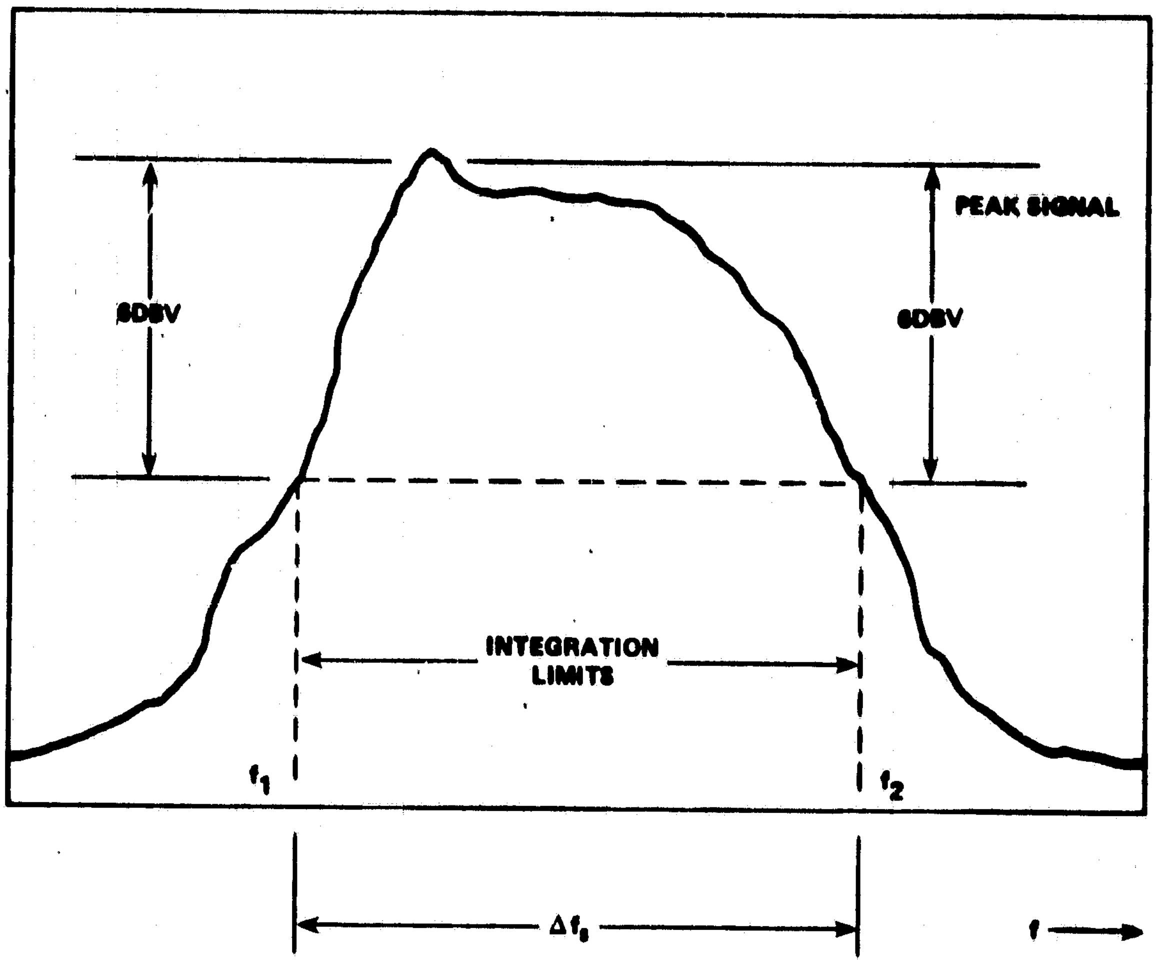


Figure 3-1 Power Spectrum of Radar Return from an Extended Target

4.0 PARAMETER CALCULATION AND CORRECTION FOR DATA ACQUISITION

4.1 GROUND SCAT BEAMWIDTH AND FOOTPRINT AREA CORRECTIONS

Since the beamwidths of the new configuration of the ground scatterometer have decreased while the transmit and receive antenna separations have increased and since the antennas are boresighted at a point 75' from the antennas, the overlap of the transmit/receive footprints is reduced as the range departs from 75', as shown in Figure 4-1. Previously, for calculating the footprint area, it was assumed that the transmit and receive footprints overlapped completely at all ranges and that the footprint area could be approximated by an ellipse whose major and minor axes were determined by projecting the along-track and cross-track beamwidths on the ground at the desired range.

The reduced beamwidths and increased antenna separations of the reconfigured ground scatterometer system require that correction factors for the footprint areas and gains be applied. The separation, L, of the centers of the transmit and receive footprints is shown in Figure 4-2. The separation of the antennas is S.

For a given range, R, the footprint center separation is:

$$L = \frac{S}{75}\ \text{abs}\ (R-75),$$

where

L = footprint center separation,

$$S = \text{antenna separation} = \begin{cases} 1.78' \text{ for } 18' \text{ dishes and} \\ 4.53' \text{ for } 4' \text{ dishes} \end{cases}$$

R = range from antennas to footprint center.

This separation of the transmit and receive footprints complicates the two-way along-track and cross-track beamwidth calculations. The shaded area in Figure 4-3 and Figure 4-4 represents the overlap of the one-way transmit and receive patterns. Clearly, to calculate the two-way along-track beamwidth, the axis must lie along line AB.

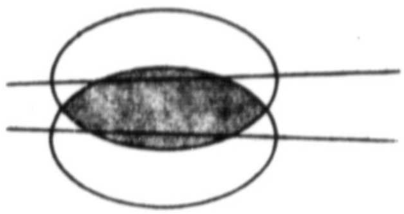


Figure 4-1 Antenna Pattern Overlap

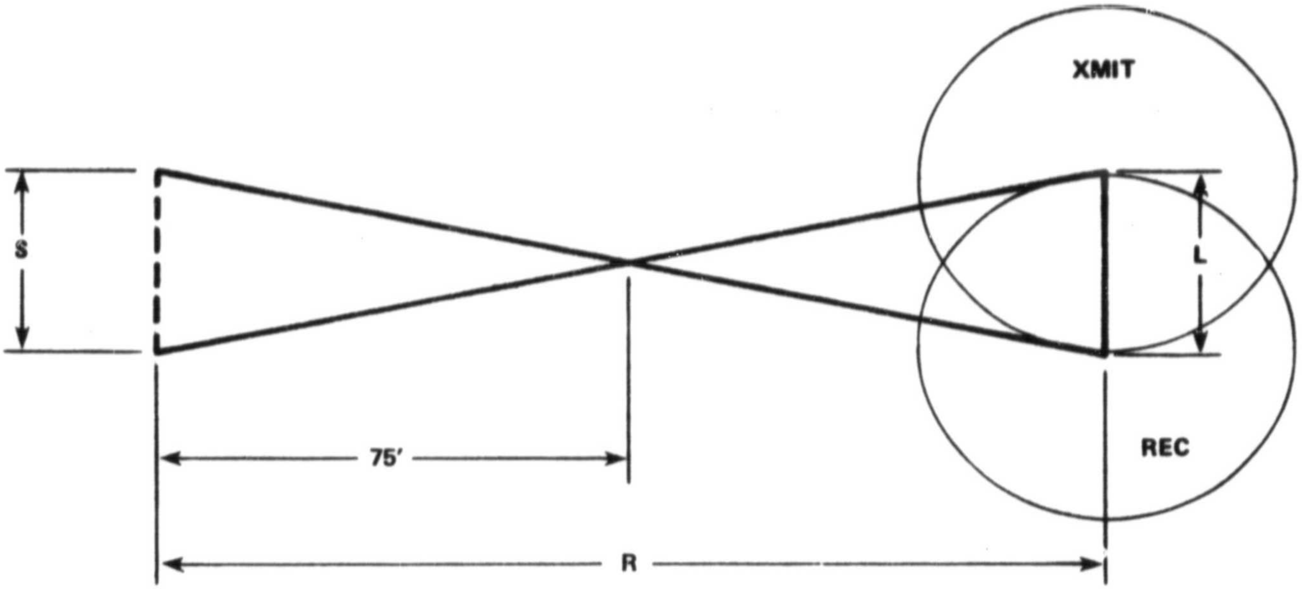


Figure 4-2 Receive and Transmit Antenna Boresight Separation as a Function of Range to the Target

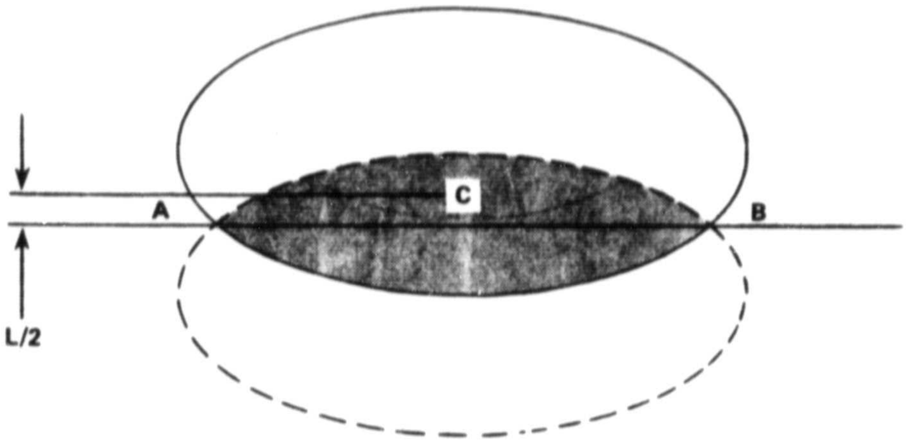


Figure 4-3 Along Track Two-way Antenna Beamwidth, AB

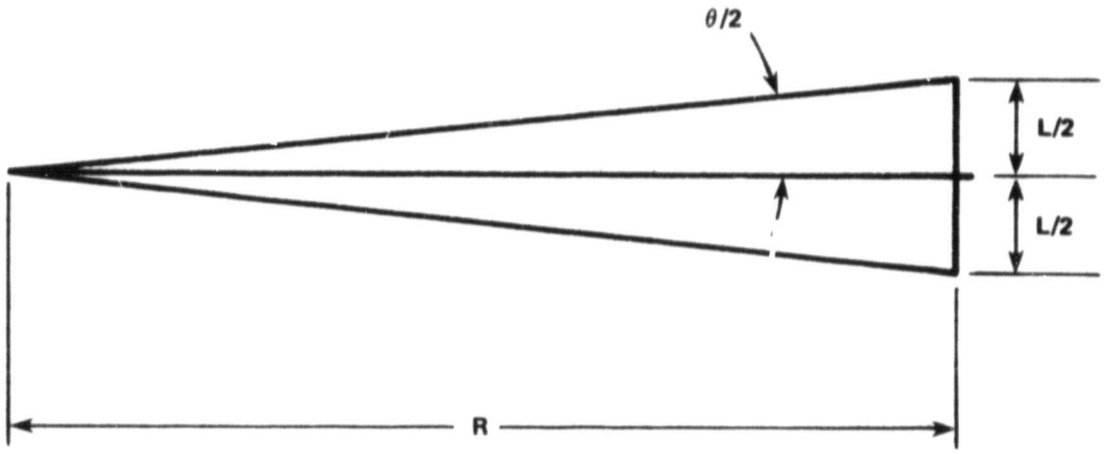


Figure 4-4 Angular Offset From Antenna Boresight

This axis is offset from the center of the pattern, C, by the amount L/2, where L is the footprint center separation, calculated above.

The angular offset, $\phi/2$, represented by the offset distance L/2 is given by:

$$\phi/2 = \tan^{-1}(L2R).$$

This angular offset will be used along with pattern information to calculate two-way beamwidths.

To facilitate the use of a computer to perform the beamwidth and footprint area calculations, a simple function is required to describe the pattern information. One such function that seems to work very well was proposed by Morris Drexler of the Physical Sciences Laboratory (PSL), New Mexico State University. It represents the gain versus angle dependency of the pattern in the functional form

$$G = \cos^{\eta}\theta, \text{ see Figure 4-5, and}$$

$$G(db) = 20\ \eta \log(\cos\theta),$$

where

$$\eta = A + B\theta = \frac{G(dB)}{20 \log(\cos\theta}.$$

$$\theta = \text{angle measured from peak gain, and}$$

$$g = \text{gain.}$$

Several points from the measured pattern are used to determine the regression equation for η versus θ and determine the constants A and B. Table 4-1 lists the values for A and B for each frequency, antenna, and polarization for both along-track and cross-track beamwidths. With these values stored in the computer, any of the antenna patterns can be reconstructed with a maximum error of 0.2 dB. To determine the two-way along-track beamwidths for any combination of polarizations, recall that the transmit and receive patterns are each offset from the along track axis by an angular distance $\phi/2$. Figure 4-6 shows that the peak gain of the along-track pattern offset from the peak of the cross-track pattern by $\phi/2$ is reduced by ΔG. Assume that the along-track pattern has the same shape for any angle in the cross-track pattern but reduced in gain depending upon $\phi/2$.

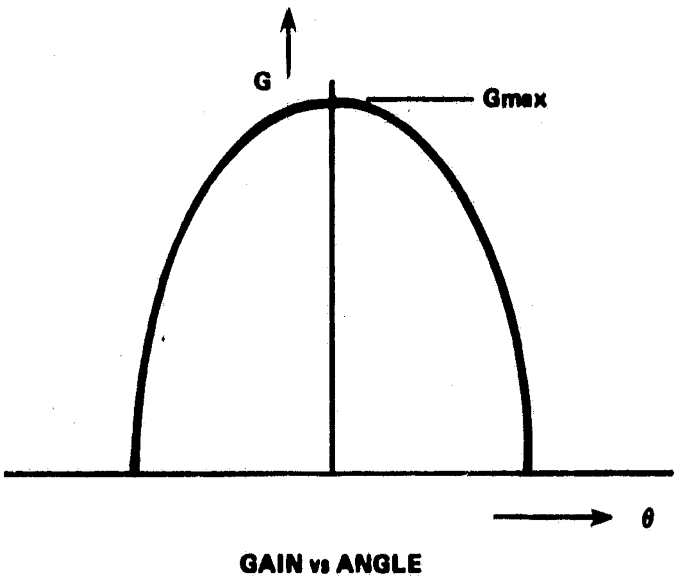


Figure 4-5 $COS^n\theta$ Pattern Approximation

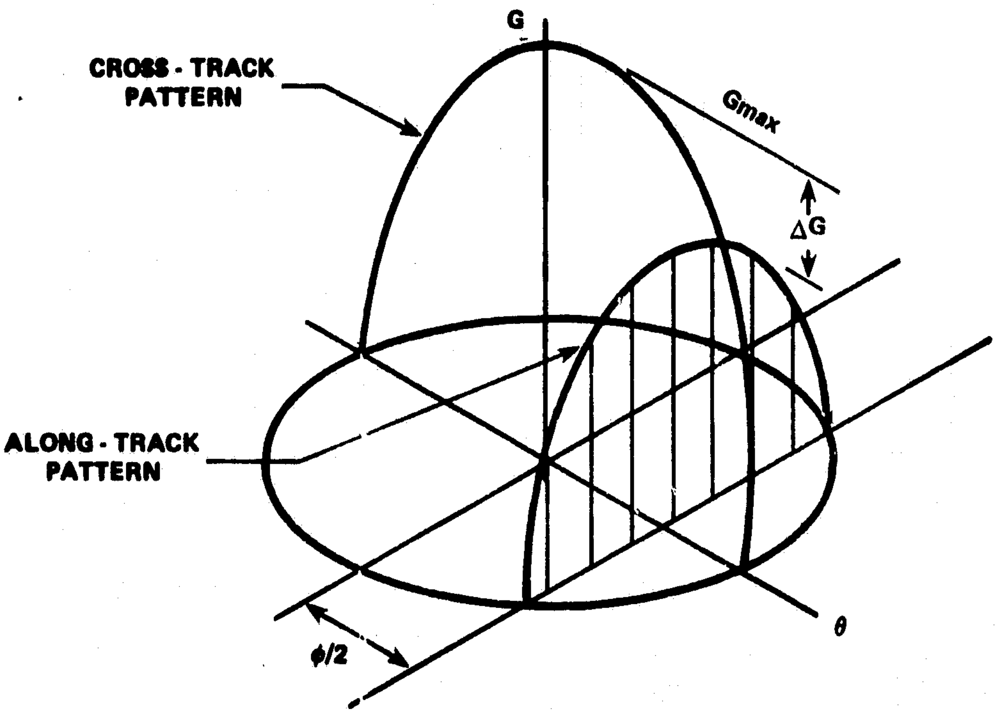


Figure 4-6 Along-Track and Cross-Track Antenna Pattern

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 4-1

REGRESSION EQUATION PARAMETERS

	Port		RECEIVE (Dish #1)		TRANSMIT (Dish #2)	
			Along-Track	Cross-Track	Along-Track	Cross-Track
1.6 GHz	H	A	114.52949	95.87447	110.70820	68.22823
		B	-0.46396	-2.35479	-0.18304	1.62652
	V	A	103.89736	117.01953	68.43885	108.03487
		B	-3.61144	-0.89083	1.26610	2.31202
4.75 GHz	H	A	847.69575	786.49935	648.14155	594.99888
		B	90.81535	-31.69313	229.91505	58.25549
	V	A	662.28381	777.53580	572.57125	892.40060
		B	43.53338	109.78388	76.92901	66.37332
9.5 GHz	H	A	367.23479	323.09613	276.06934	389.69973
		B	28.35611	13.42379	81.13510	-10.03755
	V	A	245.19170	447.25262	268.10552	378.09661
		B	56.67478	-24.95307	38.45177	8.82711
13.3 GHz	H	A	1175.92320	553.20650	707.41458	535.43653
		B	-248.05369	53.09570	-70.24071	-0.44003
	V	A	827.61286	433.82269	369.83395	305.16556
		B	-131.83885	228.48441	50.60591	143.63006

One can then obtain the two-way, 3dB, along-track pattern by summing the two patterns, reduced by the appropriate ΔG, point by point and finding where the sum is 3-dB down from Gmax, the cross-track peak gain, as shown in Figure 4-7.

The cross-track two-way beamwidths are somewhat easier to obtain. The cross-track patterns are first constructed from the data in Table 4-1, and are each offset from the peak by the angle $\phi/2$, see Figure 4-8. The two patterns are then summed point-by-point and the resultant two-way pattern is obtained. The points where the resultant gain is -3dB determine the two-way cross-track beamwidth.

Since the angle $\phi/2$ varies with range, and the two-way beamwidths vary with $\phi/2$, a large lookup table would be required in the data collection program to take into account the complete variation of beamwidth with range. A more compact method of storing the required data is to perform a regression of beamwidth on range and store the resulting curve-fit constants. This was performed for the ground scatterometer in its present configuration and the data is given in Table 4-2. In general, it was found that different regression equations were required for ranges less than 75 feet and ranges greater than 75 feet. Also, a polynomial of the second degree was required to best fit the data and is given as ;

$$BW = A_0 + A_1 R + A_2 R^2,$$

where ,

BW = two-way beamwidth in degrees, and

R = range in feet.

The constants given in Table 4-2 are stored in the Data Collection Program and used to calculate the footprint area. The range, R, is first determined from the ground scatterometer geometry using the corrected height of the antennas and the antenna look angle. This calculated range is used to determine the along-track and cross-track two-way beamwidths from Table 4-2 depending on the frequency, polarization, and whether $R \leq 75'$ of $R > 75'$. The footprint is an oblique

ORIGINAL PAGE IS
OF POOR QUALITY

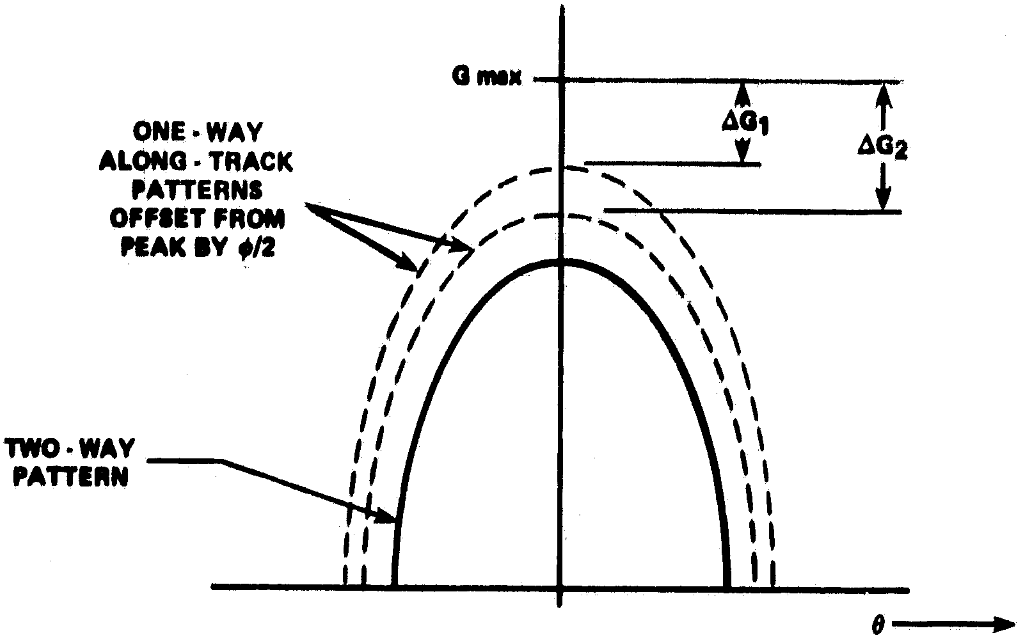


Figure 4-7 Two-way Along-Track Pattern

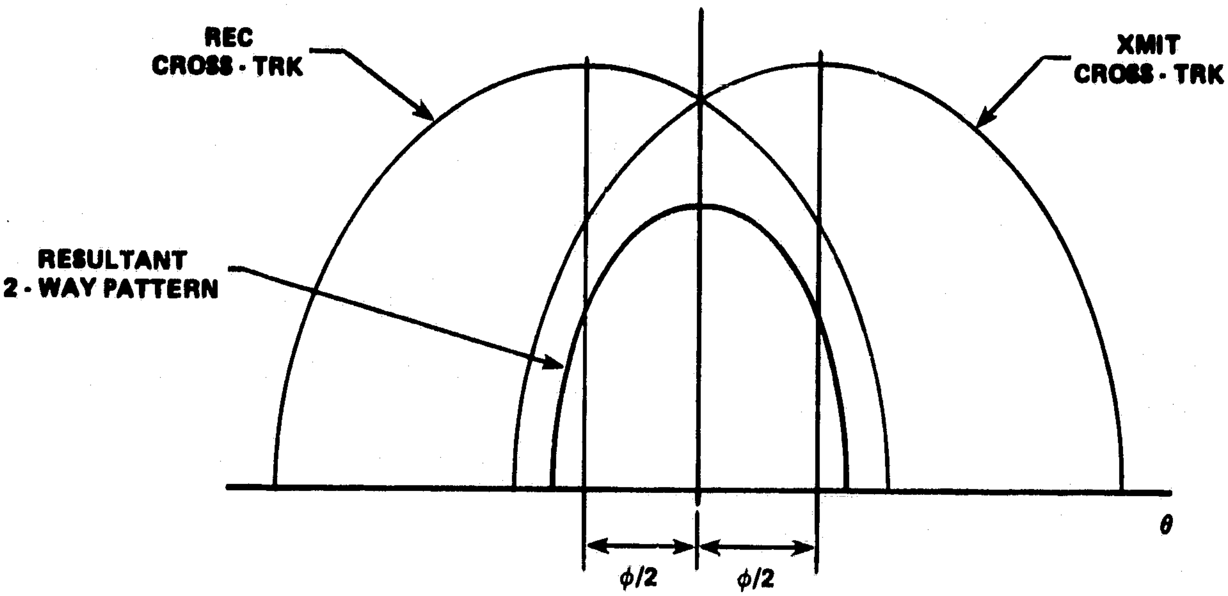


Figure 4-8 Two-way Cross-Track Pattern

TABLE 4-2

REGRESSION CURVE FIT CONSTANTS

			HH	VV	HV	VH
1.6 GHz Along-Trk	R≤75'	A_0	4.35429	4.11857	4.28714	4.25429
		A_1	0.05697	0.09456	0.06750	0.07700
		A_2	-0.00040	-0.00067	-0.00047	-0.00054
	R>75'	A_0	6.44416	7.40355	6.71827	7.22926
		A_1	0.00034	0.00359	0.00146	-0.00296
		A_2	-0.00001	-0.00004	-0.00002	0
1.6 GHz Cross-Trk	R≤75'	A_0	-1.97000	-2.81571	-2.46857	-2.50714
		A_1	0.21079	0.20159	0.21109	0.20273
		A_2	-0.00113	-0.00107	-0.00114	-0.00107
	R>75'	A_0	12.01074	10.98727	11.64727	11.40468
		A_1	-0.08064	-0.08472	-0.08472	-0.08522
		A_2	0.00027	0.00029	0.00029	0.00029
4.75 GHz Along-Trk	R≤75'	A_0	-4.12714	-8.36000	-5.00000	-6.65143
		A_1	0.17973	0.31229	0.20926	0.25703
		A_2	-0.00127	-0.00223	0.00149	-0.00183
	R>75'	A_0	1.90900	2.35913	2.14788	2.24719
		A_1	0.01062	0.01123	0.00924	0.00897
		A_2	-0.00009	-0.00011	-0.00008	-0.00009
4.75 GHz Cross-Trk	R≤75'	A_0	-6.54286	-6.76000	-6.17429	-7.10857
		A_1	0.20026	0.20086	0.18923	0.21109
		A_2	-0.00106	-0.00109	-0.00100	-0.00114
	R>75'	A_0	6.77420	6.59740	6.69004	6.82996
		A_1	-0.07536	-0.07891	-0.07691	-0.08136
		A_2	0.00024	0.00027	0.00026	0.00027
9.5 GHz Along-Trk	R≤75'	A_0	2.62000	3.19286	2.79000	3.03286
		A_1	0.02003	0.01133	0.01859	0.01133
		A_2	-0.00014	-0.00007	-0.00013	-0.00007
	R>75'	A_0	3.38260	3.71333	3.53333	3.55333
		A_1	-0.00069	-0.00093	-0.00093	-0.00093
		A_2	0	0	0	0
9.5 GHz Cross-Trk	R≤75'	A_0	0.19857	0.13714	-0.35857	0.34857
		A_1	0.07370	0.06891	0.08567	0.06777
		A_2	-0.00039	-0.00034	-0.00047	-0.00034
	R>75'	A_0	5.40675	4.91359	5.22087	5.26753
		A_1	-0.03355	-0.02732	-0.03243	-0.03190
		A_2	0.00012	0.00009	0.00011	0.00011
13.3 GHz Along-Trk	R≤75'	A_0	1.79000	2.23000	1.69714	1.99000
		A_1	0.01859	0.01859	0.02809	0.01859
		A_2	-0.00013	-0.00013	-0.00020	-0.00013
	R>75'	A_0	2.38675	2.96260	2.70078	2.68078
		A_1	0.00218	-0.00069	0.00032	0.00032
		A_2	-0.00002	0	-0.00001	-0.00001
13.3 GHz Cross-Trk	R≤75'	A_0	-0.27857	-0.07857	-0.50571	-0.12286
		A_1	0.06564	0.06164	0.07217	0.06491
		A_2	-0.00033	-0.00033	-0.00040	-0.00034
	R>75'	A_0	4.32433	4.11212	4.34866	4.46684
		A_1	-0.02716	-0.02524	-0.03051	-0.02950
		A_2	0.00009	0.00008	0.00011	0.00010

projection on the ground of the two-way antenna pattern and is assumed to be elliptical. The semi-major and semi-minor axes are calculated as follows (see Figure 4-9).

$$b = R \tan (CTBW/2)$$

$$R_n = H/\cos (\theta - ATBW/2)$$

$$R_F = H/\cos (\theta + ATBW/2)$$

$$a = \left[R_N^2 + R_F^2 - 2R_N R_F \cos(ATBW)\right]^{\frac{1}{2}}/2$$

where

R = range to center of footprint

θ = look angle

H = corrected height

$ATBW$ = along-track two-way beamwidth

$CTBW$ = cross-track two-way beamwidth

R_N = range to near edge of footprint

R_F = range to far edge of footprint

a = semi-major axis

b = semi-minor axis

The footprint area is therefore:

$$A = \pi ab.$$

To calculate the gain reduction caused by the incomplete overlapping of the one-way footprints at ranges other than 75', we use the procedure in Figure 4-3 and described in the text for that figure. This gain reduction can be described in a regression equation on the range R. It was found to be significant only for the 4.75 GHz system.

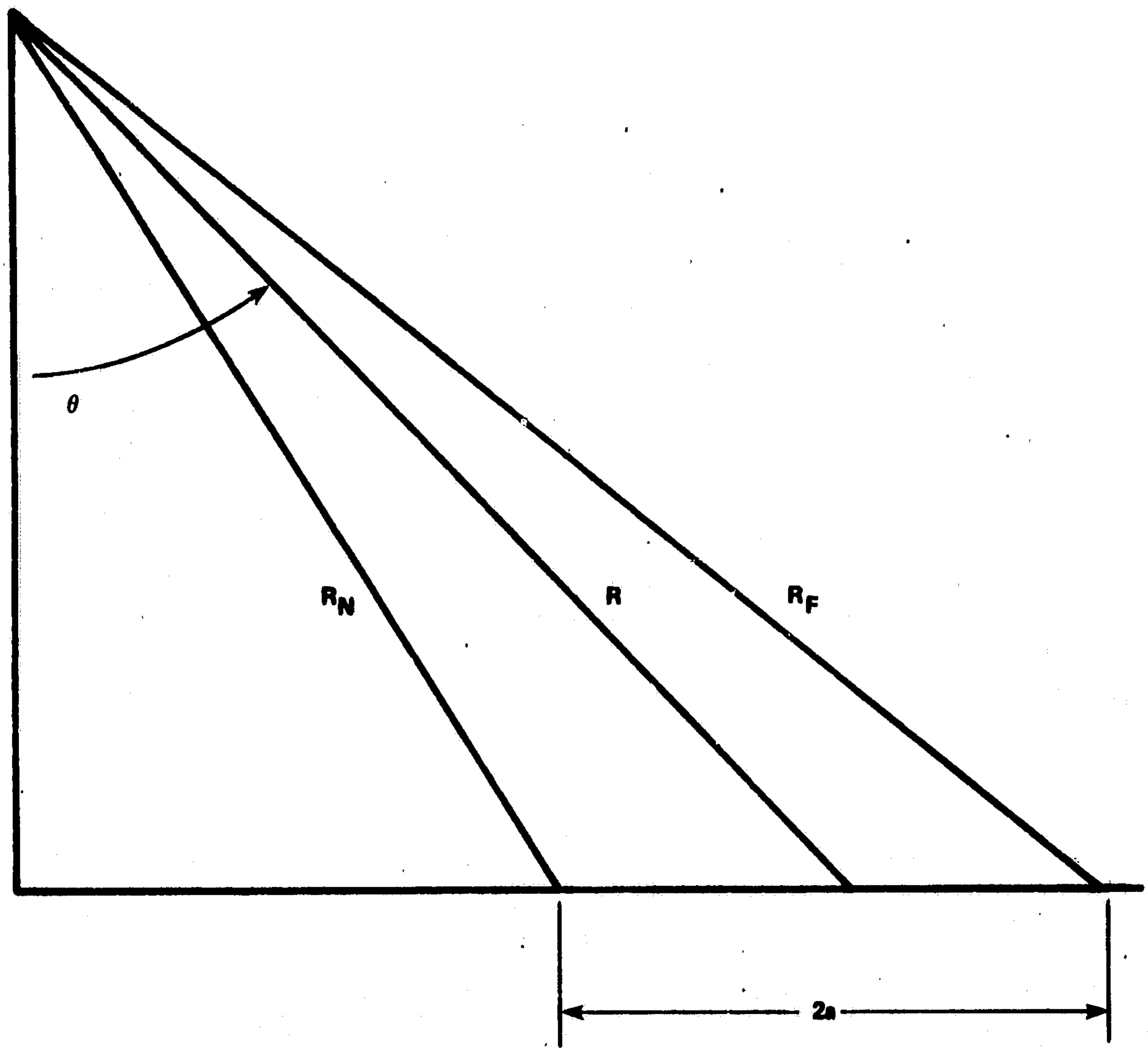


Figure 4-9 Antenna Footprint Geometry

4.75 GHz System

$$CF = -17.97 + 0.5065R - 3.566\times10^{-3}R^2, \quad R \leq 75'$$

$$CF = 0.1546 + 0.01131R - 1.673\times10^{-4}R^2, \quad R > 75'$$

where CF = correction factor in dB to be added to the calculated sigma zero (σ^o) in dB

These footprint area and gain corrections, while not exact, provide a better approximation of σo than was obtained in the past.

4.2 CORRECTION OF ANTENNA HEIGHT AND RANGE

During operation of the ground scatterometer, the measuring tape used to determine the height of the antennas above the ground is attached to the pivot shaft of the antenna positioner. The range is determined geometrically from the height and look angle. The range required for the sigma zero calculations is the electrical path from the antenna feed point to the target. Since the feed point of the antenna does not lie on the pivot shaft, the feed point height above the ground will vary with the look angle. The range to the target will also change with look angle. This change in range must be compensated for in the sigma zero calculation. The geometry and equations given on Figure 4-10 are sufficient to make this compensation when reducing the scatterometer data.

4.3 RANGE OFFSET AND FREQUENCY/RANGE SLOPE

As was discussed in the section on FREQUENCY CONSIDERATIONS, the IF frequency output of the ground scatterometer should vary linearly with range when measuring a point target. The range is measured from the feed point of the antennas, but the IF frequency depends on the entire electrical path including cables and other components. Therefore, when the range is zero, the frequency will not be zero, but some frequency higher than zero. Therefore,

$$f_{IF} = \frac{2m}{c} (R+RO),$$

H = HEIGHT TO ELEVATION ROTATOR PIVOT POINT (MEASURED)

H' = CORRECTED HEIGHT

θ = DATA COLLECTION LOOK ANGLE

L = DISTANCE FROM PIVOT POINT TO ANTENNA AXIS

d = DISTANCE FROM FRAME TO ANTENNA

f = ANTENNA FOCAL LENGTH

H' = $H + L \sin\theta + (f - d)\cos\theta$

18" DISH

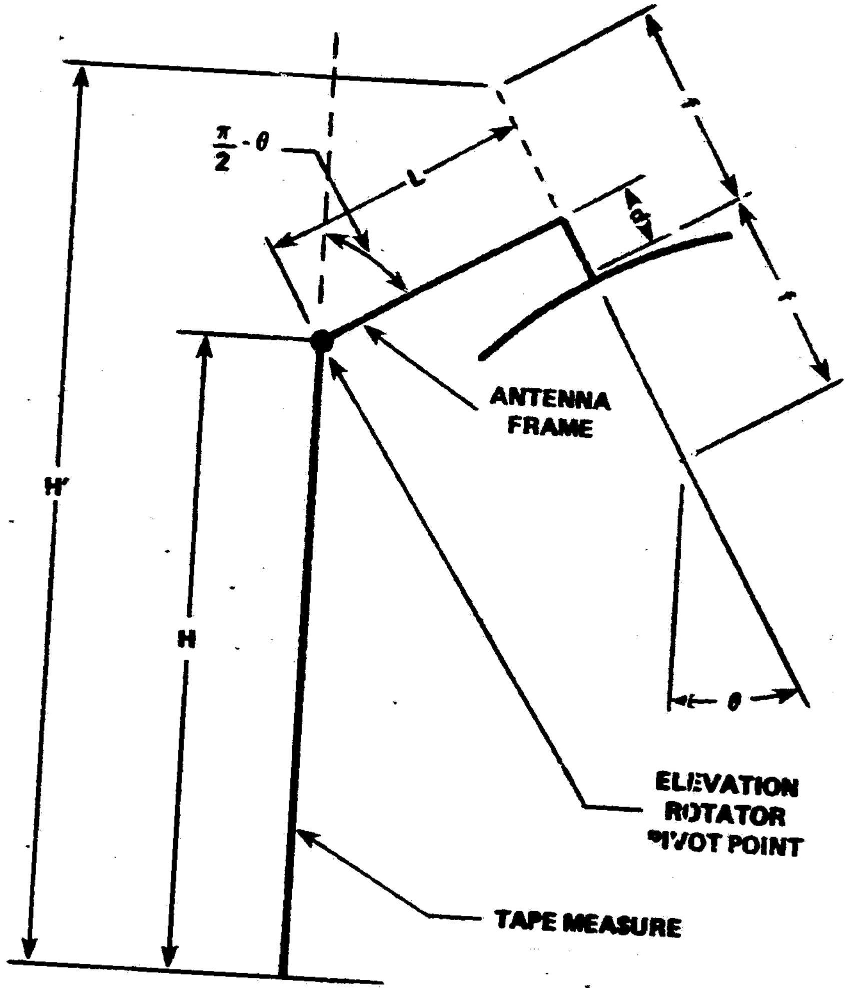
L = 58.5" = 4.88'
d = 7.5" = 0.63'
f = 6.25" = 0.52'

$H' = H + 4.88 \sin\theta - 0.11 \cos\theta$

4 FT. DISH

L = 26.7" = 2.23'
d = 2.5" = 0.21'
f = 17.5" = 1.46'

$H' = H + 2.23 \sin\theta + 1.25 \cos\theta$



ORIGINAL PAGE IS OF POOR QUALITY

GROUND SCATTEROMETER HEIGHT AND RANGE CORRECTIONS FOR DATA COLLECTION PROGRAM

Figure 4-10 Scatterometer Antenna Geometry where

R = range to target measured from antenna feed point,

RO = range offset due to cables, etc.,

$\frac{2m}{C}$ = slope of frequency/range plot, amd

m = FM rate ,

The slope and range offset could be calculated since all quantities involved can be measured. For instance, the FM rate in Hz/sec is given by

$$m = 2Bf_{rep},$$

where B is the FM bandwidth, nominally 1 GHZ, and F_{rep} is the sweep repetition frequency, nominally 150 Hz. In actuality, it is very difficult to measure B accurately using the spectrum analyzer. Similarly, it is difficult to measure R, since the propagation time for each type of cable and component must be known as a function of radar frequency.

A simple method is to measure the IF frequency for a point target at several ranges and use the data to fit a least squares curve. This curve has the form given by the following equation.

$$f = a_o + a_1 R,$$

where

$$a_o = \frac{(\Sigma f_i)\,(\Sigma Ri^2) - \Sigma Ri(\Sigma fiRi)}{N\Sigma R_i^2 - (\Sigma Ri)^2}, \text{ and}$$

$$a_1 = \frac{N\Sigma fiRi - (\Sigma Ri)\,(\Sigma fi)}{N\Sigma Ri^2 - (\Sigma Ri)^2} .$$

where f_1 is the frequency corresponding to R_1, f_2 corresponds to R_2, etc., and N is the number of (R_i, f_i) sets measured.

In terms of system parameters:

$$a_o = \frac{2m}{c} RO ,$$

$$a_1 = \frac{2m}{c} , \text{ and}$$

$$RO = ao/\frac{2m}{c} = \frac{ao}{a_1}$$

These measurements must be repeated for each system since they have different characteristics. The knowledge of these relationships permits us to roughly check the accuracy of the range during terrain measurements, lets us know how to set up the spectrum analyzer, and are used in the calculation of the number of independent samples for a single measurement.

4.4 FADING STATISTICS AND INDEPENDENT SAMPLES

Fading of a radar signal comes about because of phase interference phenomena in a coherent signal. The ground scatterometer generates a coherent signal and is therefore subject to fading. The effect manifests itself in that if two measurements are made on two different locations in a homogenous, randomly rough field, significant differences can be obtained. In fact, if each measurement contains only one independent sample, the variation in sigma zero between the two measurements can be 18dB! Fading statistics are similar to the statistics for narrow-band Gaussian noise and follow a Rayleigh distribution. To obtain a valid estimate of sigma zero, many independent samples must be taken and averaged. For two samples to be independent, it is necessary that the targets being measured differ sufficiently in aspect angle, radar frequency or location. It is possible to obtain more than one independent sample per measurement. The number of independent samples obtained in a given measurement is equal to the time/bandwidth product of the system for that measurement. The bandwidth required is the signal bandwidth, Δf_s. The time is the time required for the system to complete one sweep through the FM bandwidth given by:

$$T = \frac{1}{f_{rep}} .$$

Therefore, the number of independent samples, N_i, for a single measurement is given by:

$$Ni = (\Delta fs)\ T = \frac{\Delta fs}{2\ f_{rep}} .$$

Table 4-3 gives a rough estimate of the number of independent samples per measurement as a function of look angle for a given along-track antenna beamwidth, β_A with an antenna height of 50 feet. The 4.75 GHz system has the smallest β_A and hence the smallest RO at a given angle. Therefore, it has the smallest N_i at each angle. For all four systems, N_i increases with increasing look angle, increasing height, and increasing β.

TABLE 4-3

GROUND SCATTEROMETER
BEAMWIDTH VS. NUMBER OF
INDEPENDENT SAMPLES

LOOK ANGLE	BEAMWIDTH (DEG)									
(DEG)	1	2	3	4	5	6	7	8	9	10
2.5	.1	.2	.2	.3	.4	.5	.6	.7	.8	.9
5.0	.2	.3	.5	.6	.8	.9	1.1	1.3	1.4	1.6
7.5	.2	.5	.7	.9	1.2	1.4	1.7	1.9	2.1	2.4
10.0	.3	.6	1.0	1.3	1.6	1.9	2.2	2.6	2.9	3.2
15.0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
20.0	.7	1.4	2.1	2.8	3.4	4.1	4.8	5.5	6.2	6.9
30.0	1.2	2.4	3.5	4.7	5.9	7.1	8.3	9.5	10.7	11.9
40.0	1.9	3.9	5.8	7.8	9.7	11.7	13.7	15.7	17.6	19.7
50.0	3.3	6.6	9.9	13.2	16.5	19.8	23.2	26.6	30.0	33.5
60.0	6.1	12.3	18.5	24.7	30.9	37.2	43.6	50.1	56.5	63.3

NO. OF INDEPENDENT SAMPLES

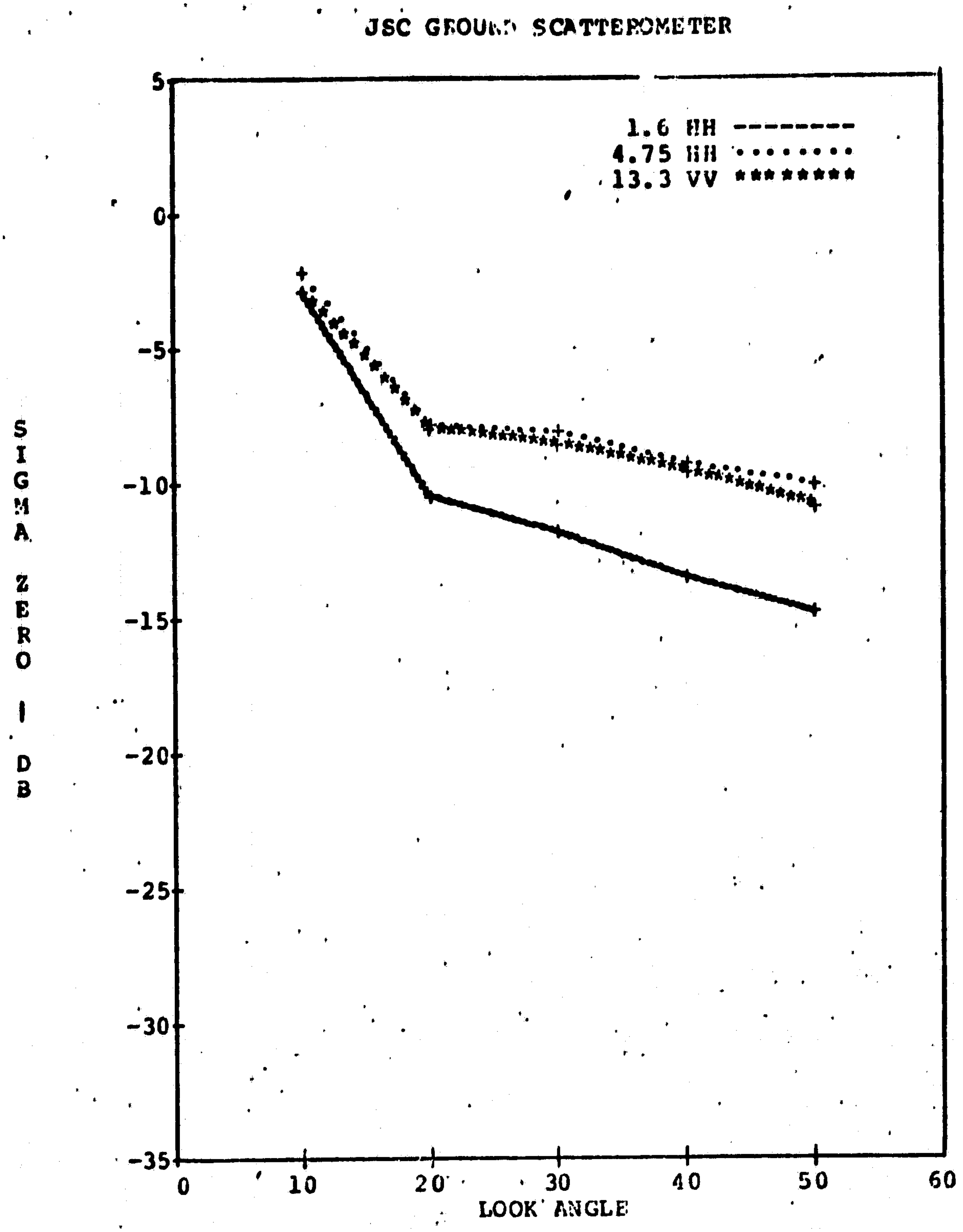
FM BANDWIDTH=1.0 GHZ
REP FREQUENCY=150 HZ
HEIGHT=50 FT

5.0 GROUND SCATTEROMETER DATA ACQUISITON AT JORNADA EXPERIMENTAL RANGE

The simulated roughness and agricultural sites used are located at the Jornada Experimental Range northeast of Las Cruces, New Mexico. These prepared fields are 2500 feet long and 500 feet wide. One field is divided into four random roughness sections separated by access roads. The two south fields have large-scale random roughness and the two north fields have small-scale random roughness. The other field is also divided into four sections, two each of different row spacings. The two north sections have closely spaced rows which will be used for the ground data acquisiton.

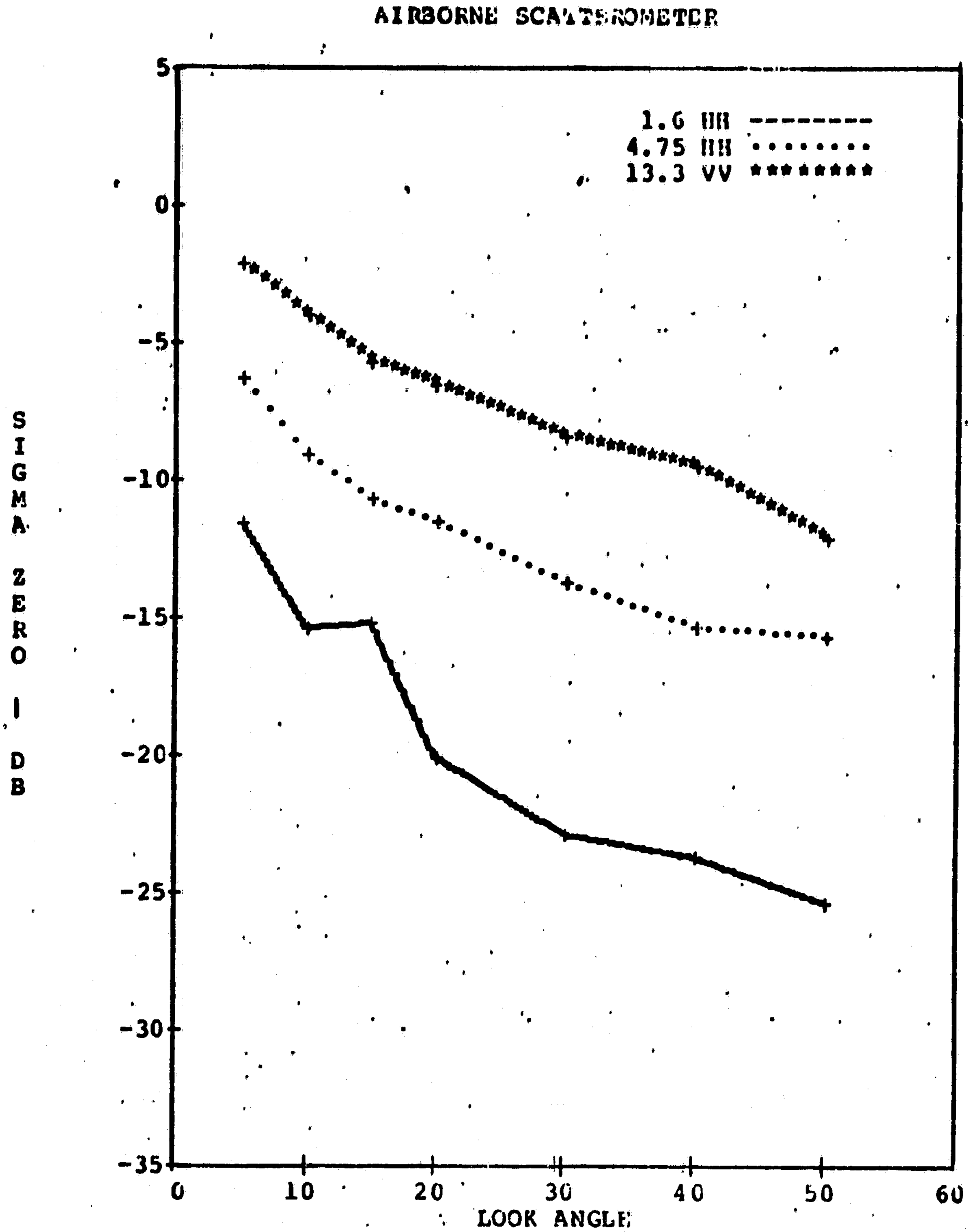
Data was acquired using the access road between the two north sections for small-scale roughness data and the access road between the two south sections for large-scale roughness data. Two physical locations, 50 feet each side of field centerline were used for each roughness scale. Sample data summaries are included for the different frequencies, look angles and antenna polarizations and are presented in Figures 5-1 and 5-2.

ORIGINAL PAGE IS
OF POOR QUALITY



Jornada Experimental Range
Sept. 19-22, 1981

Figure 5-1 Sigma Zero Data taken at Jornada Test Range



Jornada Experimental Range
Mission: 449 Line: 1 Run: 3
Sept. 18, 1981

Figure 5-2 Sigma Zero Data taken at Jornada Test Range

6.0 KANSAS RADAR CROSS-CALIBRATION TEST

During August 1982 a test was conducted by four Scatterometer teams in order to calibrate all four systems against several common targets. The fixed targets observed by the systems were as follows:

1) Four foot diameter aluminum sphere of known cross-section,
2) Corner reflector,
3) Two foot flat plate,
4) Eight inch Luneberg Lens,
5) Twelve inch Luneberg Lens, and
6) Seven foot Lazy Susan Gravel Target.

In addition to the above mentioned fixed targets several extended targets were observed. These targets are described below.

Target number one - This target was field corn with 18" row spacing and tassel height from seven to ten feet. This target presented some problems since there were radar returns from the ground as well as the crop canopy. The antenna height was adjusted in the computer data processor. The radar cross-sections, σo, for this target are given in Figures 6-1 to 6-3.

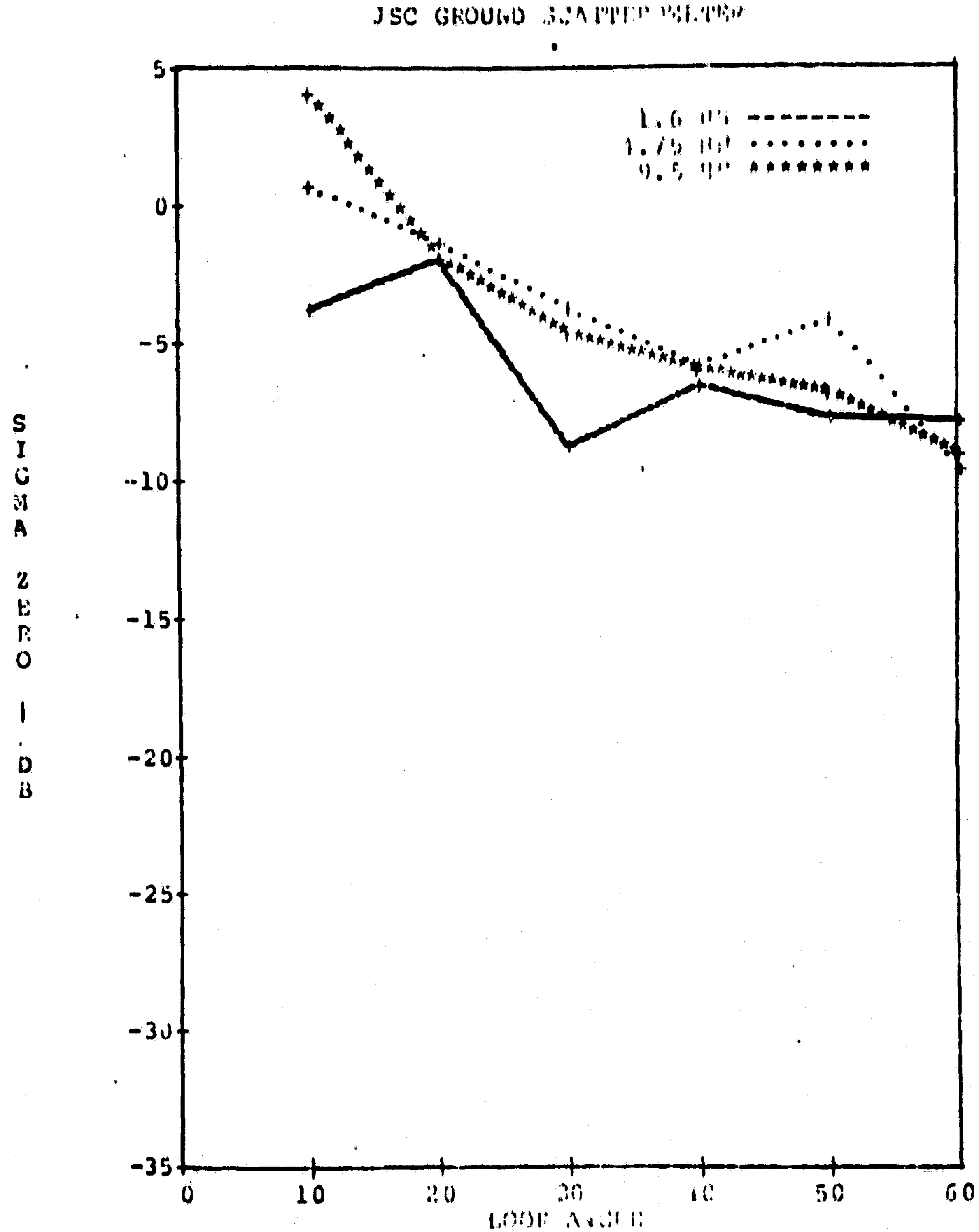
Target number two - This target was 50% mature Soy Beans with a crop canopy of about three feet. This target did not display the double return as observed in the corn observations. The radar cross-section measured for this target is summarized in Figures 6-4 to 6-6.

Target number three - This target was a randomly plowed field. For the purposes of comparison to the data taken in New Mexico, it should be noted that this field was covered with about 30% green vegetation. This vegetation cover will alter the radar return expected from a bare randomly plowed field. Figures 6-7 to 6-9 presents the summary of the results for this target.

Target number four - This target was a flat grass field. The grass height was between four and six inches. Just prior to taking radar observation at this field there was a one half inch rain. The narrow leaf grass was given about four hours to dry before starting data acquisition. Figures 6-10 to 6-12 gives the summary results of this field.

After the extended target data acquisition was completed the fixed calibration targets were observed to determine if there was any system drift. It is suggested that dielectric measurements be made to get a better indication of to near normal incidence radar return.

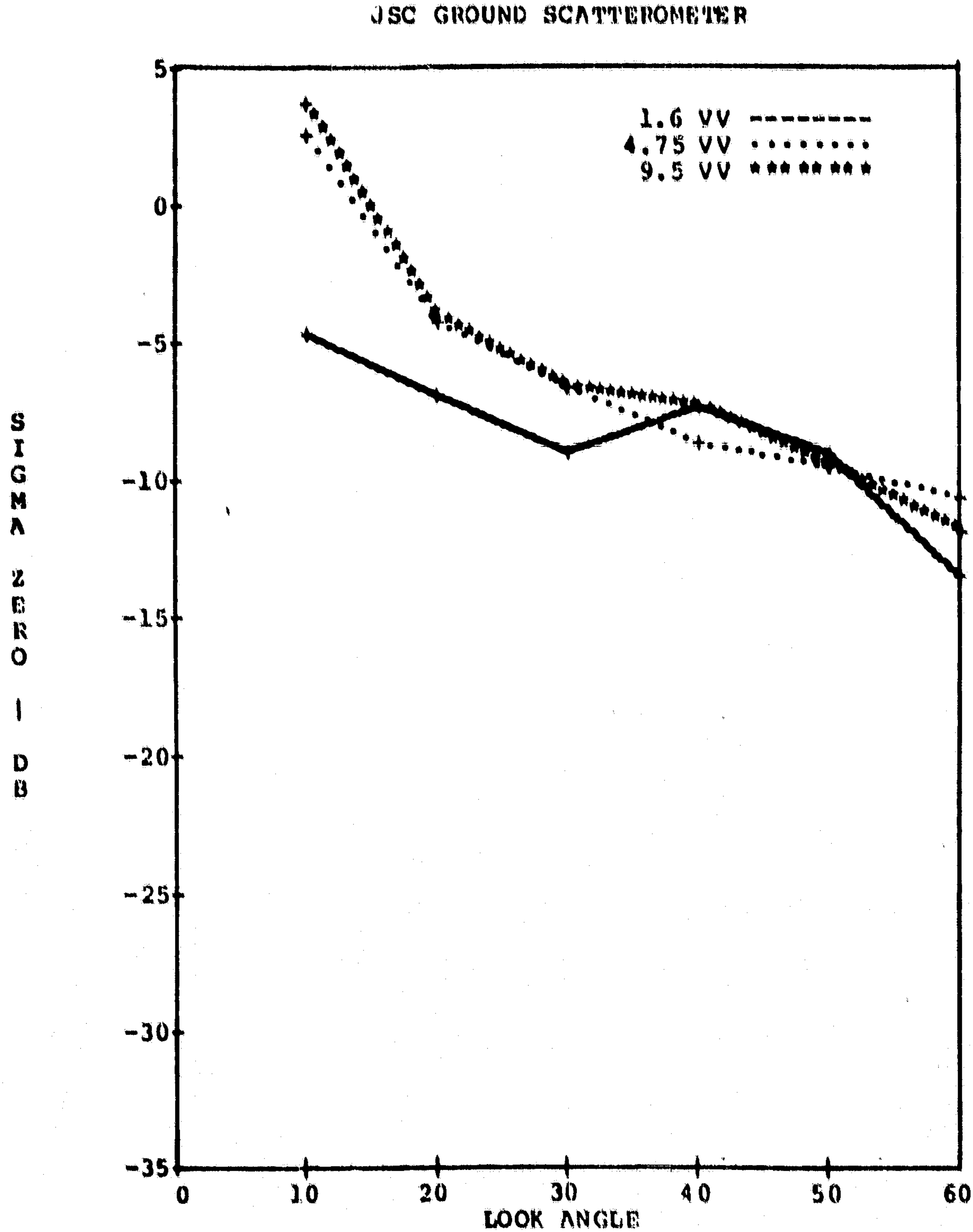
ORIGINAL PAGE IS
OF POOR QUALITY



Corn
8/19/82

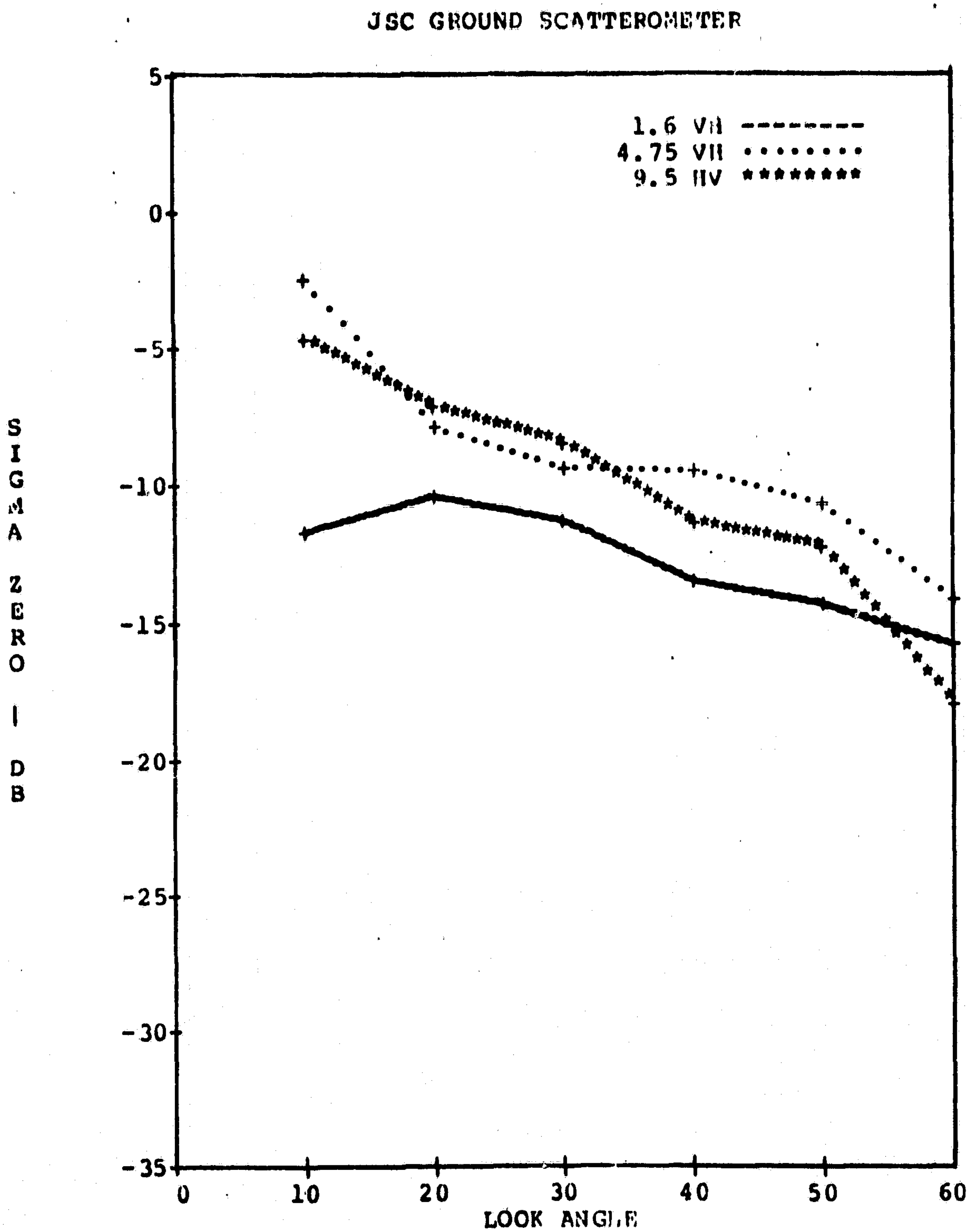
Figure 6-1 Sigma Zero Data for Corn HH Polarization

ORIGINAL PAGE IS
OF POOR QUALITY



Corn
8/19/82

Figure 6-2 Sigma Zero Data for Corn VV Polarization



Corn
8/19/82

Figure 6-3 Sigma Zero Data for Corn VH and HV Polarization

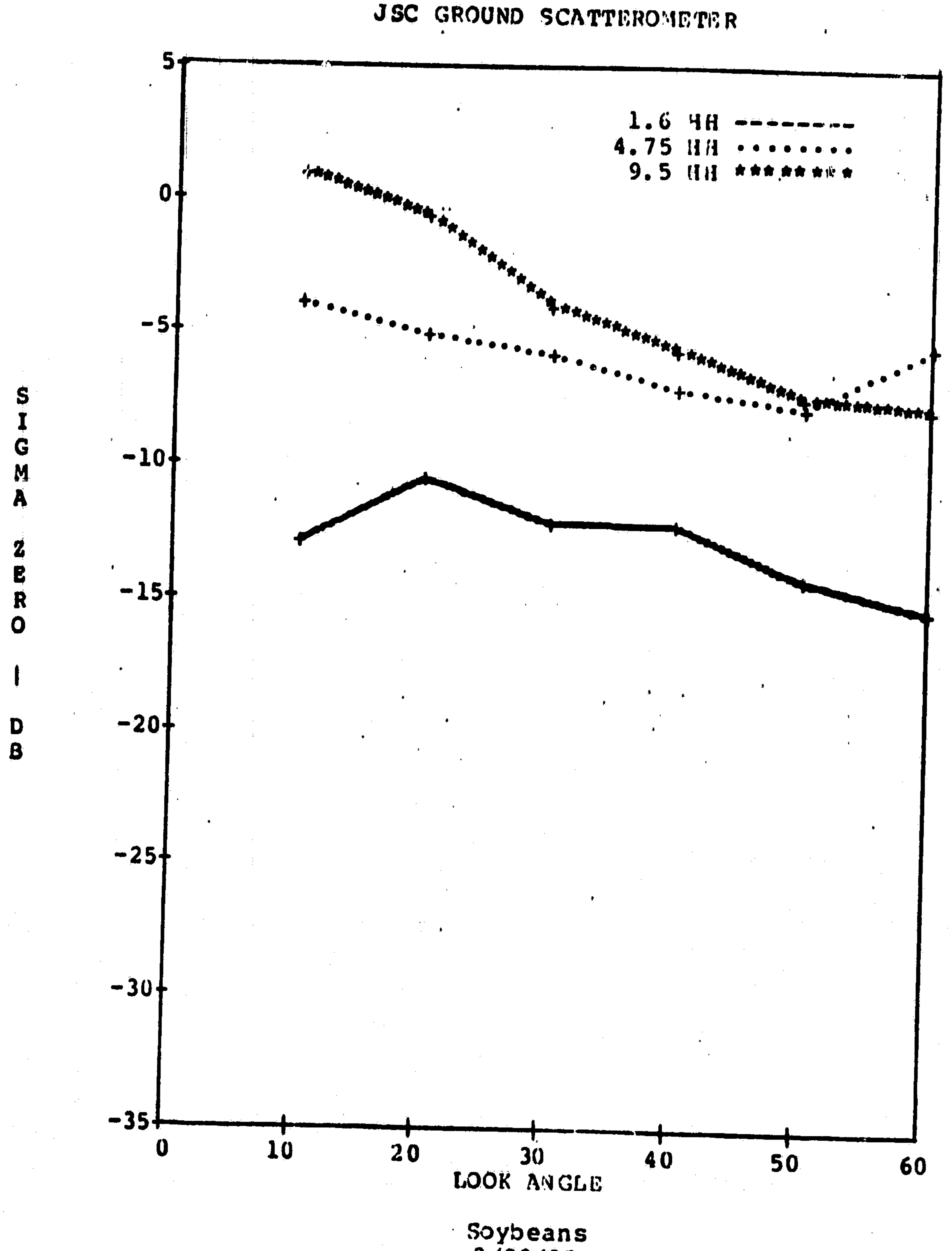


Figure 6-4 Sigma Zero Data for Soybeans HH Polarization

ORIGINAL PAGE IS
OF POOR QUALITY

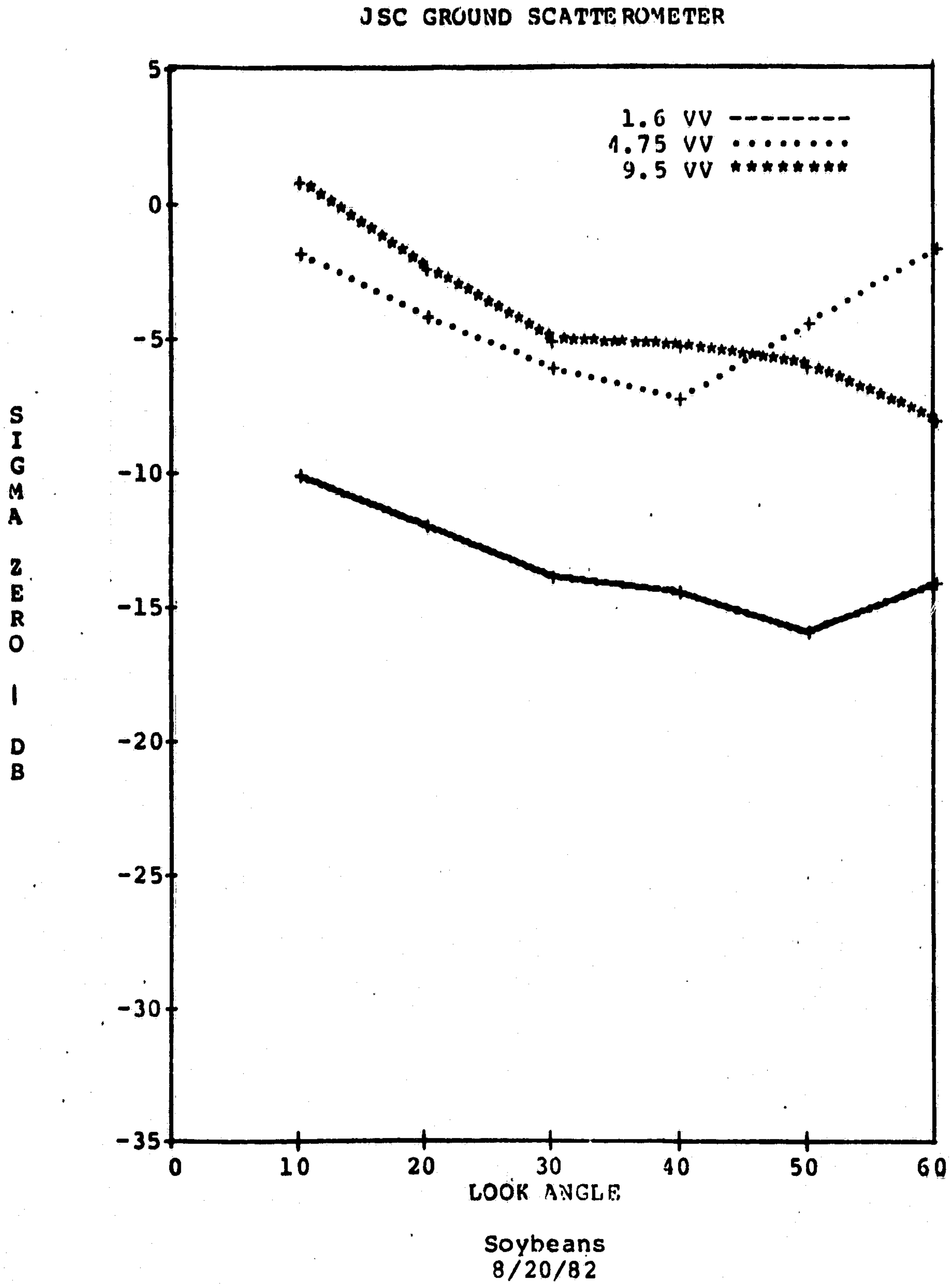
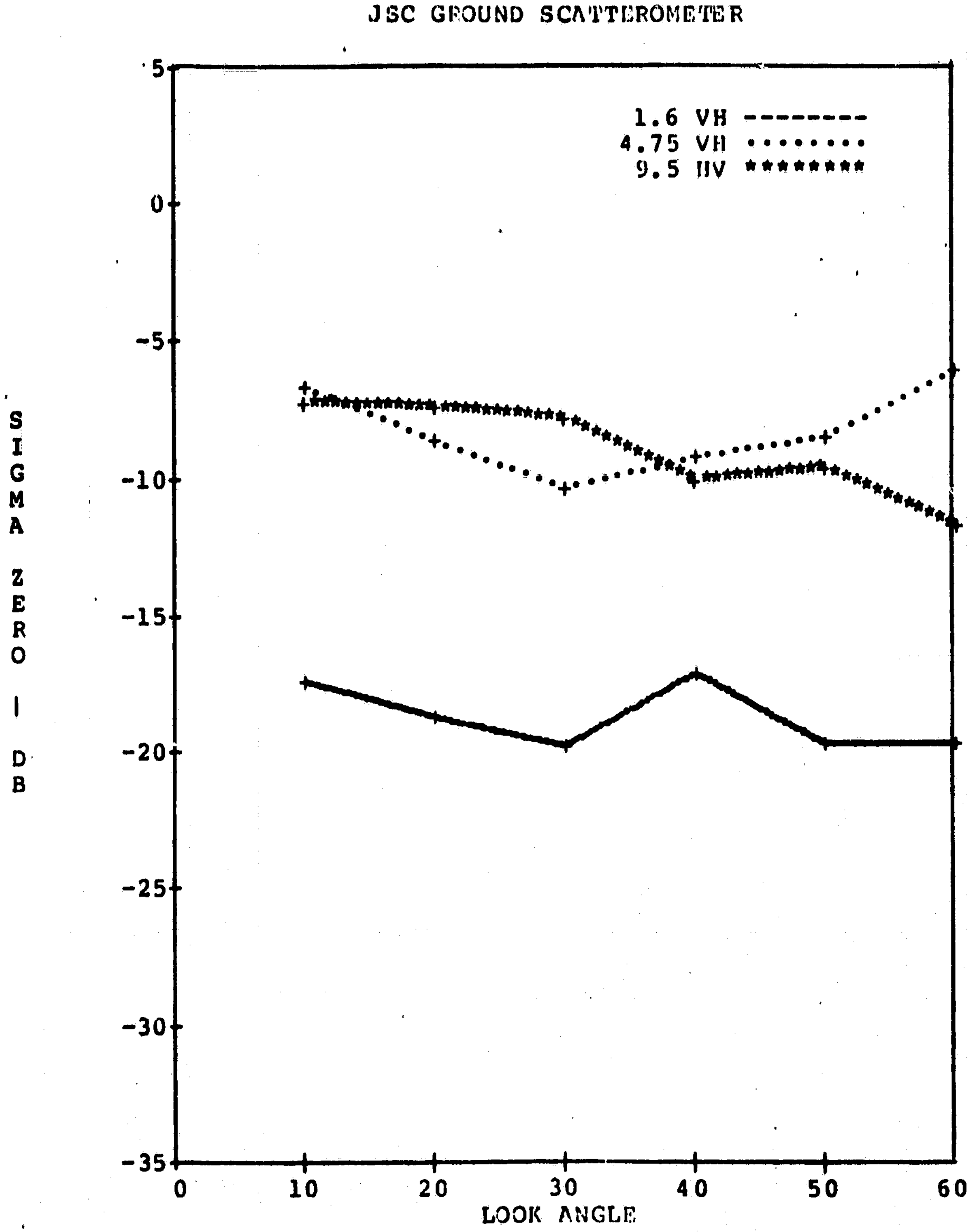


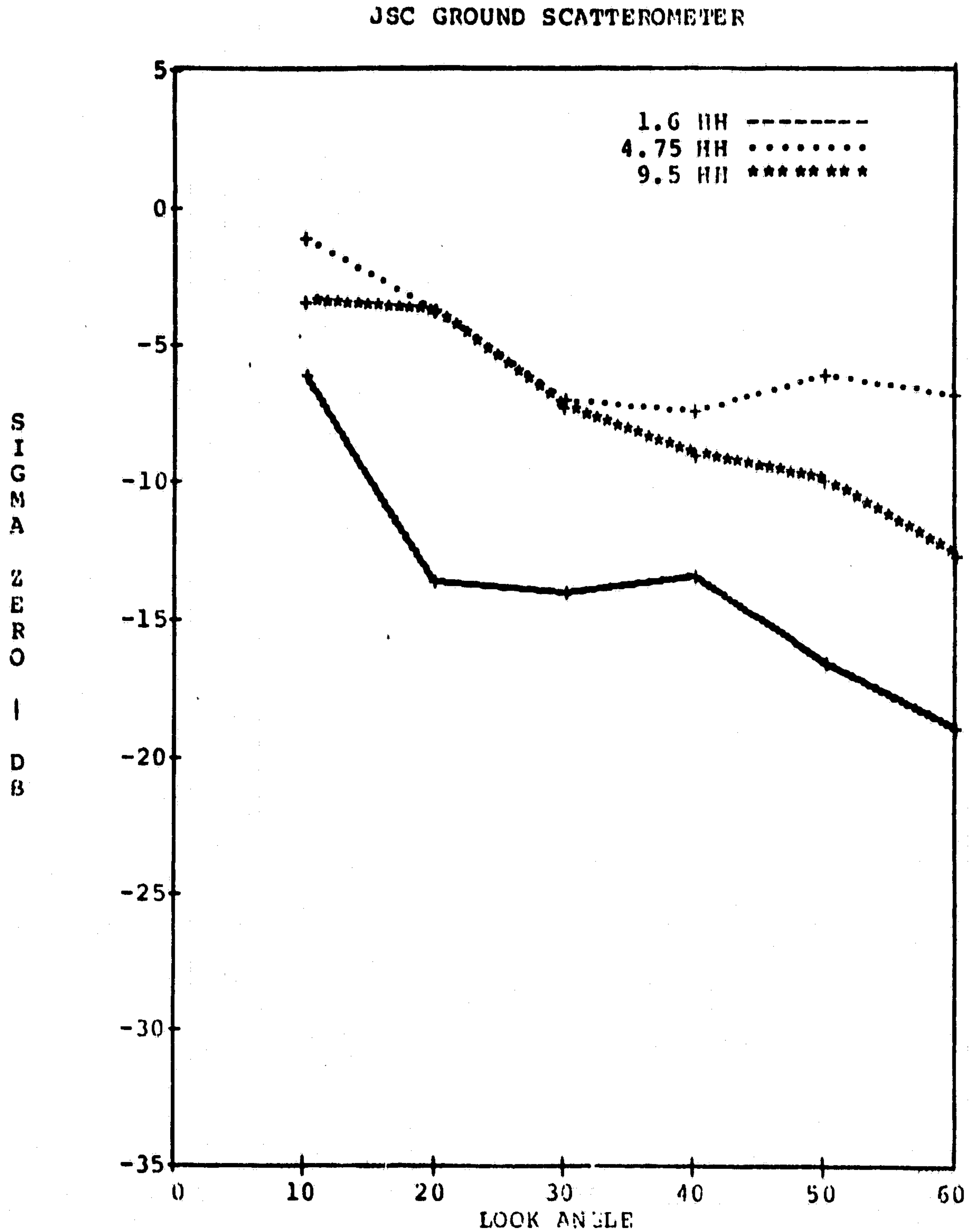
Figure 6-5 Sigma Zero Data for Soybeans VV Polarization



Soybeans
8/20/82

Figure 6-6 Sigma Zero Data for Soybeans VH and HV Polarization

ORIGINAL PAGE IS
OF POOR QUALITY



Rough/Bare Field
8/21/82

Figure 6-7 Sigma Zero Data for Rough Bare Field HH Polarization

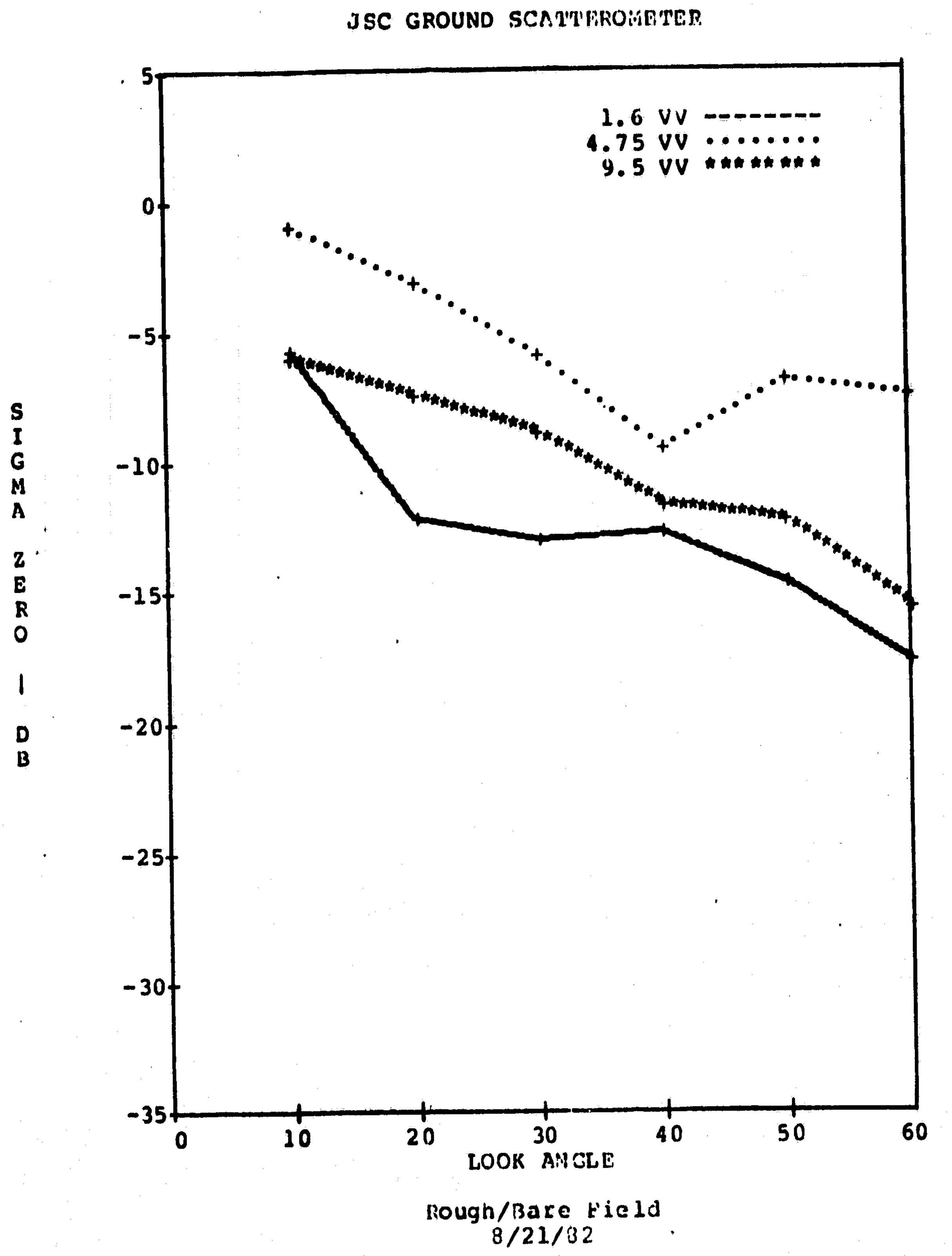


Figure 6-8 Sigma Zero Data for Rough Bare Field VV Polarization

ORIGINAL PAGE IS
OF POOR QUALITY

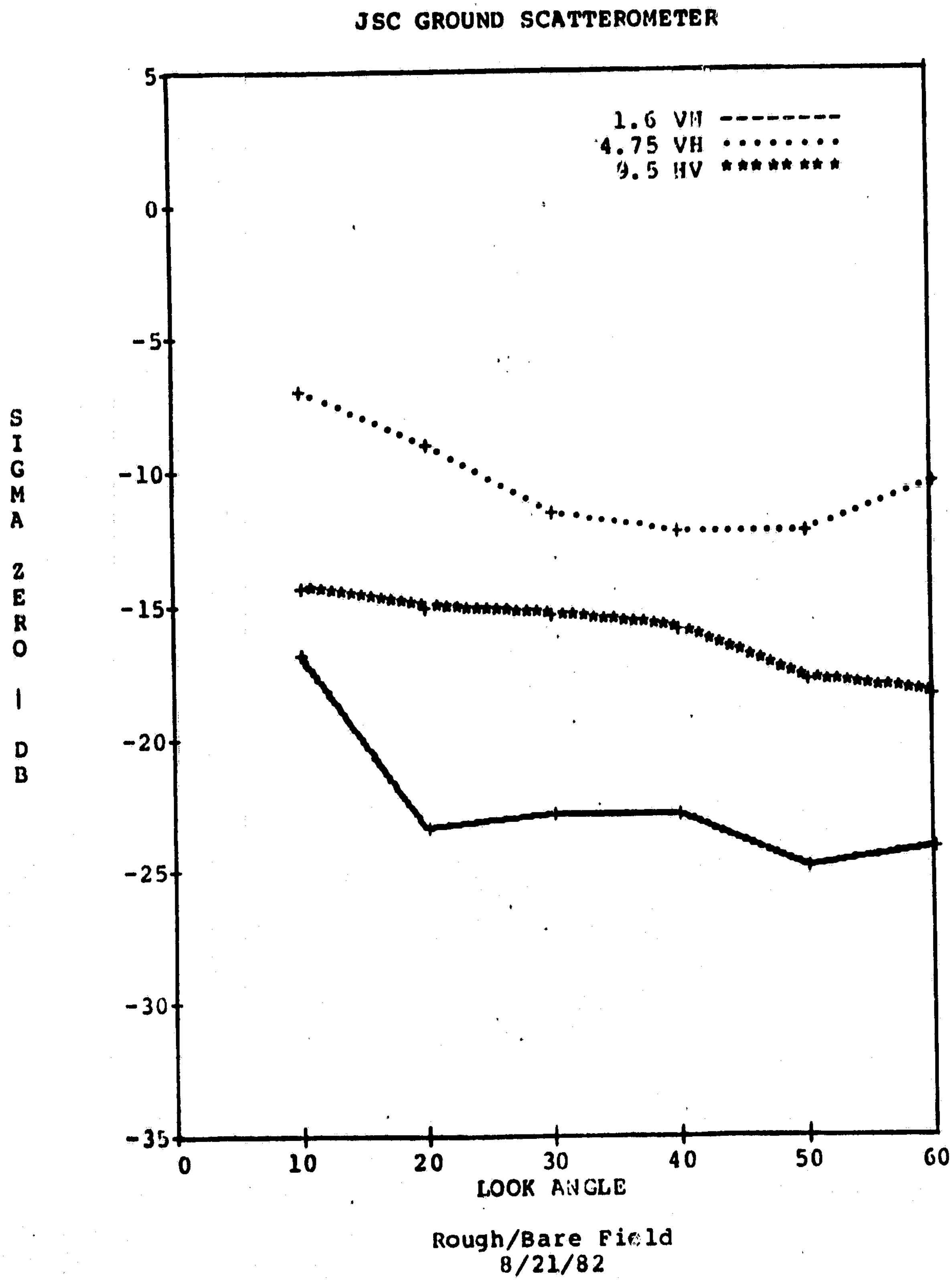
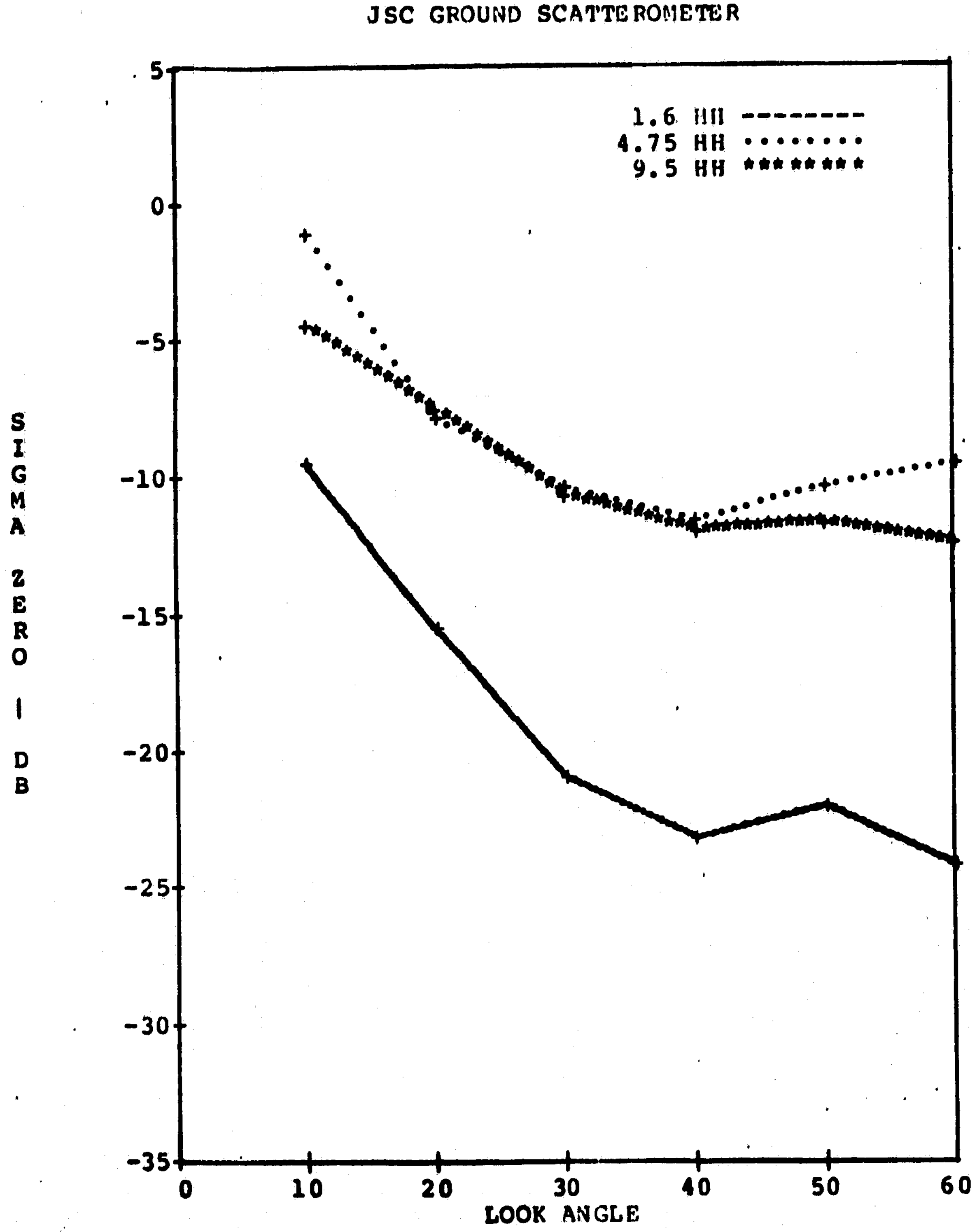


Figure 6-9 Sigma Zero Data for Rough Bare Field VH and HV Polarization

ORIGINAL PAGE IS
OF POOR QUALITY



Grass
8/22/82

Figure 6-10 Sigma Zero Data for Grass HH Polarization

ORIGINAL PAGE IS
OF POOR QUALITY

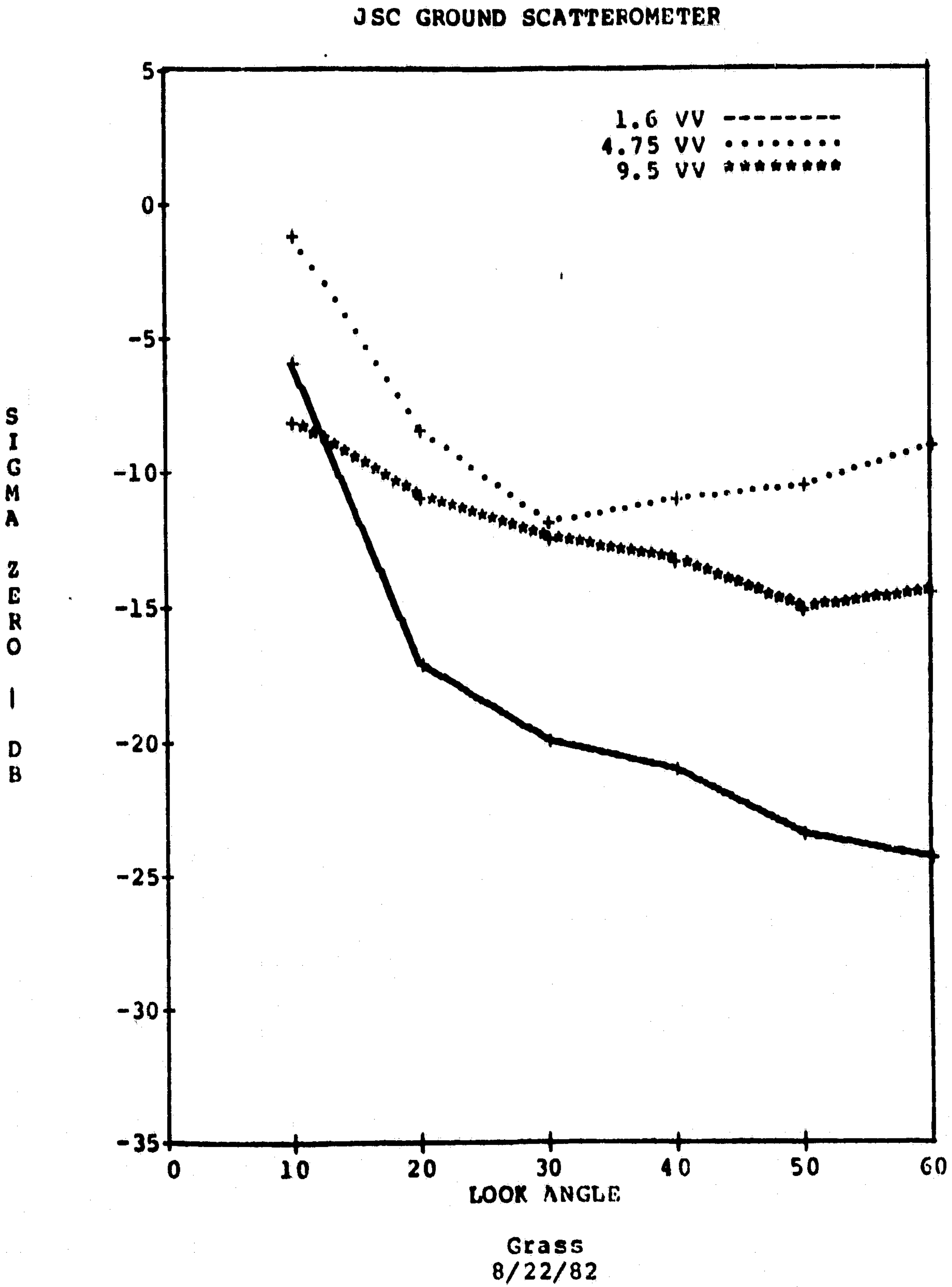
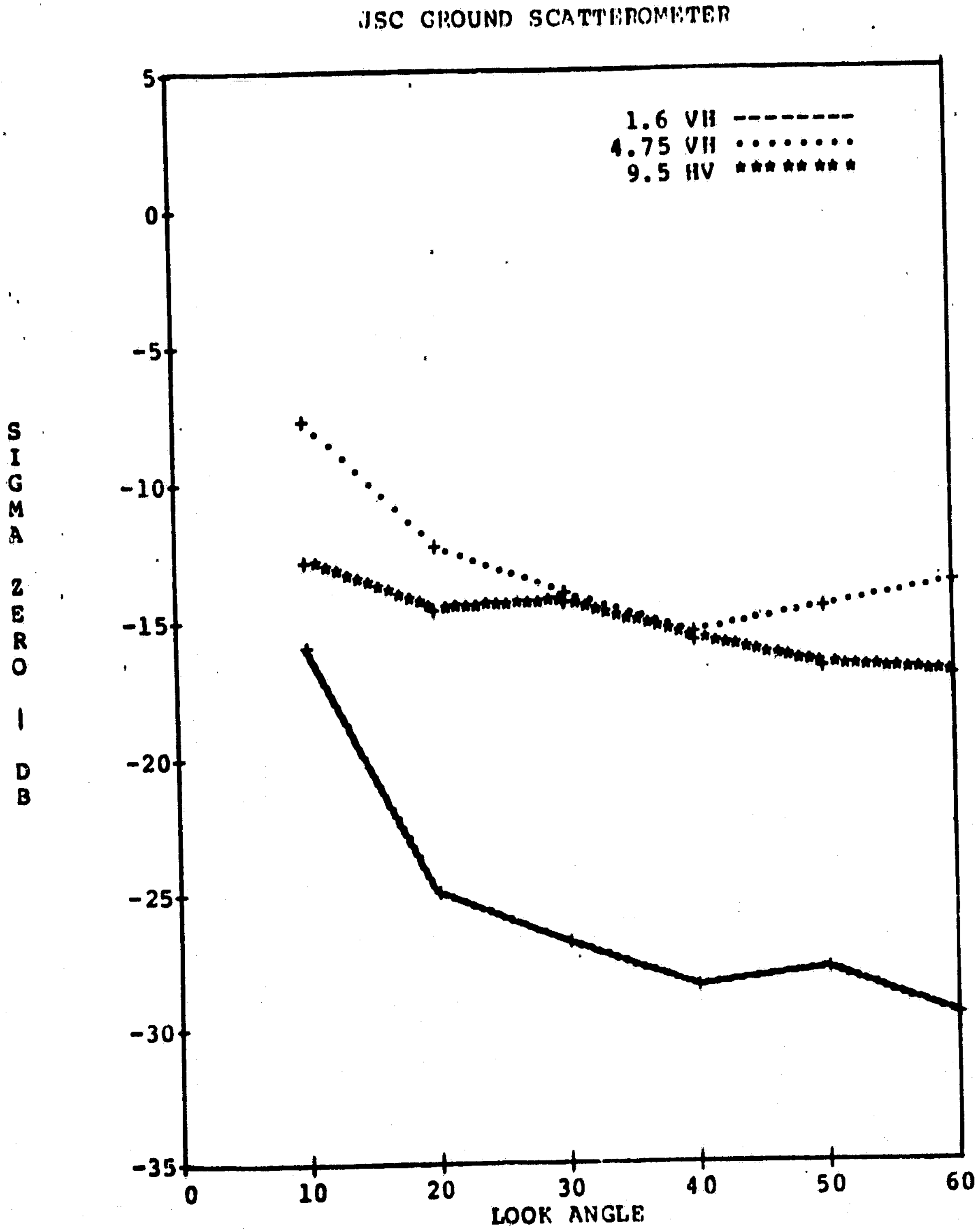


Figure 6-11 Sigma Zero Data for Grass VV Polarization

ORIGINAL PAGE IS
OF POOR QUALITY



Grass
8/22/82

Figure 6-12 Sigma Zero Data for Grass VH and HV Polarization

7.0 CONCLUSIONS

The implementation of the RADAR system described in this report has made considerable progress toward obtaining a repeatable end to end calibration. System operation is fairly straight forward, however; data acquisition time needs some improvement.

8.0 BIBLIOGRAPHY

1. Barton, D. K., Radar System Analysis, Prentice-Hall, Inc., New Jersey, 1964.

2. Berkowitz, R. S., Modern Radar, John Wiley and Sons, Inc., New York, 1965.

3. Brunfeldt, D. R., F. T. Ulaby and W. H. Stiles, "MAS 1-8 Scatterometer," RSL Technical Report 264-17, Remote Sensing Laboratory, University of Kansas Center for Research, Inc., Lawrence, Kansas, December, 1978.

4. Bush, T. F., and F. T. Ulaby, "8-18 Radar Spectrometer," RSL Technical Report 177-43, Remote Sensing Laboratory, University of Kansas Center for Research, Inc., Lawrence, Kansas, September, 1973.

5. Bush, T. F. and F. T. Ulaby, "Fading Characteristics of Radar Backscatter from Selected Agricultural Targets," IEEE Trans. on Geoscience Electronics, vol. GE-13, No. 4, pp. 149-157, October, 1975.

6. Dickerson, E. T., "Summary of the Apollo Lunar Reflectivity Program", Systems Group of TRW, Inc., Houston Operations, Project Technical Report 20029-H189-RO-00, TASK E-341, Contract NAS9-12330, June 1973.

7. Drexler, M. J. "Ground Scatterometer Antennas", Physical Science Laboratory, Contract NAS 9-95486, January 1979.

8. Rice, S. O., "Mathematical Analysis of Random Noise," Bell System Technical Journal, vol. 22, pp. 282-332, 1944; vol. 23, pp. 46-156, 1946.

9. Swerling, P., "Probability of Detection of Fluctuating Targets," IRE Trans., vol. IT-6, pp. 269-308, April, 1960.

10. Ulaby, F. T., W. H. Stiles, D. R. Brunfeldt, and M. E. Lubben, "MAS 8-18/35 Scatterometer," RSL Technical Report 360-5, Remote Sensing Laboratory, University of Kansas Center for Research, Inc., Lawrence, Kansas, February, 1979.

APPENDIX A

This appendix provides a listing of the computer programs developed on the HP 9825 to facilitate data collection and reduction.

```
0: "File 0: File Directory   7-9-82":
1: "                    ":
2: prt "File Directory","---- ---------";spc
3: prt "0:","File Directory";spc
4: prt "1:","Data Collection";spc
5: prt "2:","Calibration";spc
6: prt "3:","Plot Ground Scat","Sweep on Printer";spc
7: prt "4:","Range Offset-","Freq/Rng Slope";spc
8: prt "5:","Dump Data Files","   to Printer";spc
9: prt "6:","Dump Cal Files","   to Printer";spc
10: prt "7:","Data Table";spc
11: prt "8:","Statistics";spc
12: prt "9:","Plot Sigma 0 vs.","Angle on Printer";spc
13: spc 4;end
```

```
0: "File 1: Data Collection   8-5-82":
1: "                    ":
2: "Init":
3: prt "Data Collection","---- ----------";spc ;lcl 7;cfg 10
4: dim A[12],A$[12,8],L$[2],P$[4,2]
5: dev "SYN",704,"SPE ANA",717
6: "First"→A$[1];"Second"→A$[2];"Third"→A$[3]
7: "Fourth"→A$[4];"Fifth"→A$[5];"Sixth"→A$[6]
8: "Seventh"→A$[7];"Eighth"→A$[8];"Ninth"→A$[9]
9: "Tenth"→A$[10];"Eleventh"→A$[11];"Twelfth"→A$[12]
10: ent "Month?",r0,"Day?",r1,"Year?",r2
11: "                    ":
12: "Printer Setup":
13: ent "Print data on Line Printer?1=yes",X
14: if X#1;gto "Look Angle Setup"
15: ent "Insert paper;press CONTINUE",X
16: sfg 11;wtb 6,27,69;1→B
17: fmt 10x,z;wrt 6;wtb 6,27,77
18: wtb 6,27,87,int(8*120/64),int(8*120)
19: "                    ":
20: "Look Angle Setup":
21: ent "No. of look angles to be used?",N
22: for I=1 to N
23: dsp A$[I],"Look Angle?"
24: ent "",A[I]
25: next I
26: ent "Height in feet?",E;E→r3
27: "                    ":
28: "Tape":
29: ent "Insert Data Tape;press CONTINUE",X
30: ent "Data Tape Number?",r30
31: ent "No. of Files on Trk 0?",r31
32: ent "No. of Files on Trk 1?",r32
33: ent "Record Data on which trk? 0 or 1",r33;trk r33
34: if flg10;cfg 10;gto "Time"
35: "                    ":
36: "Freq":
37: ent "Scatterometer frequency in GHz?",F
38: fmt 1,f4.1," GHz System"
39: if F=4.75;fmt 1,f4.2," GHz System"
40: wrt 16.1,F;F→r4;prt "--------------"
41: "                    ":
42: "Polarization":
43: ent "No. of polarizations to be used?",P
44: for I=1 to P
45: dsp A$[I],"Pol? HH, VV, HV, or VH"
46: ent "",P$[I]
47: next I
48: "                        ":
49: "Site":
50: ent "Site number multiplied by 100?",S;S→r10
51: "                    ":
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
52: "Print initial conditions":
53: fmt "Date: ",f2.0,"-",f2.0,"-",f2.0;wrt 16,r0,r1,r2
54: fmt "Height(ft): ",f4.1;wrt 16,E
55: fmt "Site No: ",f7.2;wrt 16,S/100;spc
56: "                    ":
57: "Range Offset & Freq/Rng Slope":
58: "     The values for these parameters are determined":
59: "     for each frequency from File 4: Range Offset-":
60: "     Freq/Rng Slope Program":
61: ent "Sweep Repetition Rate?",r25;1+D
62: if F=1.6;19.6+r8;1.08*r25+r9
63: if F=4.75;15.1+r8;3.627*r25+r9
64: if F=9.5;13.4+r8;3.764*r25+r9
65: if F=13.3;16.2+r8;3.451*r25+r9
66: "                    ":
67: "pol":
68: if D>P;gto "Freq"
69: dsp "Set polarization to",P$[D],";CONTINUE"
70: ent "",X;1+J
71: fmt "Polarization: ",c2;wrt 16,P$[D];spc
72: "                ":
73: "Time":
74: if J>N;D+1+D;gto "pol"
75: ent "Time(hr.min)?",T;T+r11
76: int(T)+X;100*(T-X)+Y
77: "                    ":
78: "Angle":
79: A[J]+A;A+r12
80: fmt "Look Angle: ",f4.0;wrt 16,A
81: fmt "Time(h:m):",f3.0,":",fz2.0;wrt 16,X,Y
82: "                    ":
83: "Height Correction and Range Determination":
84: if F=1.6 or F=4.75;E+2.23*sin(A)+1.25*cos(A)+r13+H
85: if F=9.5 or F=13.3;E+4.88*sin(A)-.11*cos(A)+r13+H
86: fxd 1;prt "Height(corr)=",H
87: H/cos(A)+R+r14;fmt "Range(ft): ",f5.1;wrt 16,R
88: fmt "Set elevation to ",f2.0," deg;CONTINUE";wrt 0,A;stp
89: "                    ":
90: "HP 3330B Frequency Synthesizer and 3571A Spectrum Analyzer Setup":
91: "     Frequency Synthesizer":
92: "          Center Frequency:  Variable":
93: "          Frequency Step:    10 Hz":
94: "          Time/Step:         10ms":
95: "     Spectrum Analyzer":
96: "          Display Ref:  dBV":
97: "          Display Smoothing:  On":
98: "          Bandwidth:  1000 Hz":
99: "          Input Range:  +10 dBV":
100: "          Input Impedance:  1 megohm":
101: "          Measurement Control Mode:  External":
102: "Setup":
103: rem 7;fmt "R1S1C5V7Z241";wrt "SPE ANA"
104: "                    ":
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
105: "Center Frequency Search":
106: r9(R+r8)→C→Y
107: C-5050→C;-70→M;50→X;gsb "search"
108: Y-1010→C;10→X;gsb "search"
109: Y→C→r15;gto "prtfreq"
110: "search":
111: for I=1 to 200
112: C+X→C
113: fmt "L",f.1,"=";wrt "SYN",C;wait 5
114: wrt "SPE ANA","T";fmt f.2;red "SPE ANA",Z
115: if Z>M;Z→M;C→Y
116: next I
117: ret
118: "prtfreq":fxd 0;prt "Center Freq:",C
119: "                ":
120: "Summation of Data between -6 dBV Points":
121: gsb "data"
122: Z→M;"  "→L$;0→r27→r28
123: C-10→C
124: gsb "data"
125: if Z<M-6;gto "Low Freq"
126: if C<Y-5000;gto +2
127: gto -4
128: prt "Low 6-dBV limit","     not reached";1→r27
129: "Low Freq":
130: fmt "Low Freq: ",f6.0;wrt 16,C;C→r16
131: gsb "data"
132: tn^(Z/10)→V;tn^(Z/20)→U
133: "sum":
134: C+10→C
135: gsb "data"
136: V+tn^(Z/10)→V;U+tn^(Z/20)→U
137: if C<Y;gto +2
138: if Z<M-6;gto "High Freq"
139: if C>Y+5000;gto +2
140: gto "sum"
141: prt "High 6-dBV limit","     not reached";1→r28
142: "High Freq":
143: fmt "High Freq: ",f5.0;wrt 16,C;C→r17
144: r17-r16→r18;fmt "Signal Bw: ",f5.0;wrt 16,r18;gto "prtdata"
145: "data":
146: fmt "L",f.1,"=";wrt "SYN",C;wait 10
147: wrt "SPE ANA","T";fmt f.2;red "SPE ANA",Z
148: ret
149: "                ":
150: "prtdata":
151: fmt b,"V",b,"=",e12.3;wrt 16,126,29,V
152: U→r19;V→r20;beep;wait 500;beep
153: fmt "L",f.1,"=M100=Y";wrt "SYN",Y;lcl 7
154: "                ":
```

```
155: "Footprint Area":
156: gsb "Beamwidth"
157: fxd 1;prt "Along-trk BW:",r6,"Cross-trk BW:",r7
158: R*tan(r7/2)→X
159: H/cos(A-r6/2)→S
160: H/cos(A+r6/2)→T;T-S→W
161: √(S*S+T*T-2*S*T*cos(r6))/2→Y
162: π*X*Y→A;A→r21
163: fmt "Footprint(ft",b,")=",/,f16.2;wrt 16,29,A
164: "                    ":
165: "Calibration Data":
166: "                           1.6 GHz    4.75 GHz    9.5 GHz     13.3 GHz":
167: "                           -------    --------    --------    --------":
168: "     Sum of V^2     HH     29.925       6.91        .2386        .588  ":
169: "                    VV     26.85        3.737       .623         .4481":
170: "     Range(ft)             79.3        79.3        77.9         77.9   ":
171: "     Delta Freq            10.0        10.0        10.0         10.0   ":
172: "     Sigma(sphere)         12.57       12.57       12.57        12.57  ":
173: "                    ":
174: "     K=[Sigma(sphere)]/[(Sum of V^2)(Delta Freq)(Range)^4]  ":
175: if F#1.6;gto +4
176: if P$[D]="HH";1e-9→K
177: if P$[D]="VV";1.134e-9→K
178: if P$[D]="HV" or P$[D]="VH";1.092e-9→K
179: if F#4.75;gto +4
180: if P$[D]="HH";4.6e-9→K
181: if P$[D]="VV";8.506e-9→K
182: if P$[D]="HV" or P$[D]="VH";6.553e-9→K
183: if F#9.5;gto +4
184: if P$[D]="HH";1.431e-7→K
185: if P$[D]="VV";5.479e-8→K
186: if P$[D]="HV" or P$[D]="VH";9.895e-8→K
187: if F#13.3;gto +4
188: if P$[D]="HH";5.805e-8→K
189: if P$[D]="VV";7.617e-8→K
190: if P$[D]="HV" or P$[D]="VH";6.711e-8→K
191: K→r22
192: "                    ":
193: "Sigma Zero Calculation":
194: "      Sigma Zero=K*[(Sum of V^2)(Delta Freq)(Range)^4]/(Area)  ":
195: K*V*10*R^4/A→S
196: if F#4.75;gto +3
197: if R<=75;S*tn^((-17.97+.5065*R-3.566e-3*R^2)/10)→S
198: if R>75;S*tn^((.1546+.01131*R-1.673e-4*R^2)/10)→S
199: S→r23;10log(S)→r24
200: prt "*****************";spc
201: fxd 2;prt "Sigma Zero(dB)=",r24,"*****************";spc
202: fxd 1;prt "Sweep Rep Rate=",r25
203: W*r9/(2*r25)→r26
204: prt "No of Ind Smpls=",r26;spc
205: "                    ":
```

```
206: "Record Data on Tape":
207: ent "Record Data on Tape? 1=yes 0=no",X;if X=0;-1+A;gto "lp"
208: idf A,X,Y,X,X
209: if Y#0;fdf A+1;gto -1
210: rcf A,r28;fxd 0;prt "Tape No=",r30,"Track No=",X,"File No=",A
211: if X=0;gto "trk 0"
212: if X=1;gto "trk 1"
213: "trk 0":if A#r31-1;gto "lp"
214: if flg11;gsb "Line Printer"
215: if flg11;beep;wait 500;beep;wait 500;beep
216: if flg11;ent "Change paper(track switch);CONT",Z;1+B
217: rew;trk 1;1+r33;gto "inc"
218: "trk 1":if A#r32-1;gto "lp"
219: if flg11;gsb "Line Printer"
220: beep;wait 500;beep;wait 500;beep
221: ent "Change Data Tape & Paper",X
222: spc 3;J+1+J;sfg 10;gto "Tape"
223: "lp":if flg11;gsb "Line Printer"
224: "inc":spc 3;J+1+J;gto "Time"
225: "                    ":
226: "Beamwidth":
227: "      r6=Along-track Beamwidth":
228: "      r7=Cross-track Beamwidth":
229: "1.6 GHz":
230: if F#1.6;gto "4.75 GHz"
231: "1.6 HH":if P$[D]#"HH";gto +5
232: if R<=75;4.35429+.05697*R-.0004*R^2+r6
233: if R<=75;-1.97+.21079*R-.00113*R^2+r7;1+r5;ret
234: 6.44416+.00034*R-.00001*R^2+r6
235: 12.01074-.08064*R+.00027*R^2+r7;1+r5;ret
236: "1.6 VV":if P$[D]#"VV";gto +5
237: if R<=75;4.11657+.09456*R-.00067*R^2+r6
238: if R<=75;-2.81571+.20159*R-.00107*R^2+r7;2+r5;ret
239: 7.40355+.00359*R-.00004*R^2+r6
240: 10.98727-.08472*R+.00029*R^2+r7;2+r5;ret
241: "1.6 HV":if P$[D]#"HV";gto +5
242: if R<=75;4.28714+.0675*R-.00047*R^2+r6
243: if R<=75;-2.46857+.21109*R-.00114*R^2+r7;3+r5;ret
244: 6.71827+.00146*R-.00002*R^2+r6
245: 11.64727-.08472*R+.00029*R^2+r7;3+r5;ret
246: "1.6 VH":if R<=75;4.25429+.077*R-.00054*R^2+r6
247: if R<=75;-2.50714+.20273*R-.00107*R^2+r7;4+r5;ret
248: 7.22926-.00296*R+r6
249: 11.40468-.08522*R+.00029*R^2+r7;4+r5;ret
250: "4.75 GHz":
251: if F#4.75;gto "9.5 GHz"
252: "4.75 HH":if P$[D]#"HH";gto +5
253: if R<=75;-4.12714+.17973*R-.00127*R^2+r6
254: if R<=75;-6.54286+.20026*R-.00106*R^2+r7;1+r5;ret
255: 1.909+.01062*R-.00009*R^2+r6
256: 6.7742-.07536*R+.00024*R^2+r7;1+r5;ret
```

```
257: "4.75 VV":if P$[D]#"VV";gto +5
258: if R<=75;-8.36+.31229*R-.00223*R^2+r6
259: if R<=75;-6.76+.20086*R-.00109*R^2+r7;2+r5;ret
260: 2.35913+.01123*R-.00011*R^2+r6
261: 6.5974-.07891*R+.00027*R^2+r7;2+r5;ret
262: "4.75 HV":if P$[D]#"HV";gto +5
263: if R<=75;-5+.20926*R-.00149*R^2+r6
264: if R<=75;-6.17429+.18923*R-.001*R^2+r7;3+r5;ret
265: 2.14788+.00924*R-.00008*R^2+r6
266: 6.69004-.07691*R+.00026*R^2+r7;3+r5;ret
267: "4.75 VH":if R<=75;-6.65143+.25703*R-.00183*R^2+r6
268: if R<=75;-7.10857+.21109*R-.00114*R^2+r7;4+r5;ret
269: 2.24719+.00897*R-.00009*R^2+r6
270: 6.82996-.08136*R+.00027*R^2+r7;4+r5;ret
271: "9.5 GHz":
272: if F#9.5;gto "13.3 GHz"
273: "9.5 HH":if P$[D]#"HH";gto +5
274: if R<=75;2.62+.02003*R-.00014*R^2+r6
275: if R<=75;.19857+.0737*R-.00039*R^2+r7;1+r5;ret
276: 3.3826-.00069*R+r6
277: 5.40675-.03355*R+.00012*R^2+r7;1+r5;ret
278: "9.5 VV":if P$[D]#"VV";gto +5
279: if R<=75;3.19286+.01133*R-.00007*R^2+r6
280: if R<=75;.13714+.06891*R-.00034*R^2+r7;2+r5;ret
281: 3.71333-.00093*R+r6
282: 4.91359-.02732*R+.00009*R^2+r7;2+r5;ret
283: "9.5 HV":if P$[D]#"HV";gto +5
284: if R<=75;2.79+.01859*R-.00013*R^2+r6
285: if R<=75;-.35857+.08567*R-.00047*R^2+r7;3+r5;ret
286: 3.53333-.00093*R+r6
287: 5.22087-.03243*R+.00011*R^2+r7;3+r5;ret
288: "9.5 VH":if R<=75;3.03286+.01133*R-.00007*R^2+r6
289: if R<=75;.34857+.06777*R-.00034*R^2+r7;4+r5;ret
290: 3.55333-.00093*R+r6
291: 5.26753-.0319*R+.00011*R^2+r7;4+r5;ret
292: "13.3 GHz":
293: if F#13.3;gto "Incorrect"
294: "13.3 HH":if P$[D]#"HH";gto +5
295: if R<=75;1.79+.01859*R-.00013*R^2+r6
296: if R<=75;-.27857+.06564*R-.00033*R^2+r7;1+r5;ret
297: 2.38675+.00218*R-.00002*R^2+r6
298: 4.32433-.02716*R+.00009*R^2+r7;1+r5;ret
299: "13.3 VV":if P$[D]#"VV";gto +5
300: if R<=75;2.23+.01859*R-.00013*R^2+r6
301: if R<=75;-.07857+.06164*R-.00033*R^2+r7;2+r5;ret
302: 2.9626-.00069*R+r6
303: 4.11212-.02524*R+.00008*R^2+r7;2+r5;ret
304: "13.3 HV":if P$[D]#"HV";gto +5
305: if R<=75;1.69714+.02809*R-.0002*R^2+r6
306: if R<=75;-.50571+.07217*R-.0004*R^2+r7;3+r5;ret
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
307: 2.70078+.00032*R-.00001*R^2+r6
308: 4.34866-.03051*R+.00011*R^2+r7;3+r5;ret
309: "13.3 VH":if R<=75;1.99+.01859*R-.00013*R^2+r6
310: if R<=75;-.12286+.06491*R-.00034*R^2+r7;4+r5;ret
311: 2.68078+.00032*R-.00001*R^2+r6
312: 4.46684-.0295*R+.0001*R^2+r7;4+r5;ret
313: "Incorrect":dsp "Incorrect Frequency;press CONT";stp ;gto "Freq"
314: "             ":
315: "Line Printer":
316: if B=1;fmt 24x,"Tape No: ",f3.0;wrt 6,r27
317: if B=1;fmt 23x,"Track No: ",f3.0,2/;wrt 6,r30
318: if A<0;fmt "File No: N/A",7x,z;wrt 6;gto +2
319: fmt "File No:",f4.0,7x,z;wrt 6,A
320: fmt "Look Angle:",f5.1,5x,z;wrt 6,r12
321: fmt "IF Freq:",f6.0;wrt 6,r15
322: fmt "Date: ",f2.0,"-",f2.0,"-",f2.0,5x,z;wrt 6,r0,r1,r2
323: int(r11)+X;100*(r11-X)+Y
324: fmt "Time:",f3.0,":",fz2.0,10x,z;wrt 6,X,Y
325: fmt "Delta Freq: 10";wrt 6
326: fmt "Scat Freq:",z;wrt 6
327: if r4=4.75;fmt f5.2,4x,z;wrt 6,r4;gto +2
328: fmt f5.1,4x,z;wrt 6,r4
329: fmt "Height(corr):",f5.1,3x,"Ftprnt Area:",f6.1;wrt 6,r13,r21
330: fmt "Polarization: ",z;wrt 6
331: if r5=1;fmt "HH",3x,z;wrt 6
332: if r5=2;fmt "VV",3x,z;wrt 6
333: if r5=3;fmt "HV",3x,z;wrt 6
334: if r5=4;fmt "VH",3x,z;wrt 6
335: if r27=1;"L"+L$[1]
336: if r28=1;"U"+L$[1]
337: if r27=1 and r28=1;"LU"+L$
338: fmt "Range:",f6.1,9x,"Sgma Zero(dB):",f6.1,z;wrt 6,r14,r24
339: fmt 1x,c2;wrt 6,L$
340: fmt "Site No:",f5.2,6x,z;wrt 6,r10/100
341: fmt "Sig Bndwth:",f3.1,2x,"Ind Smpls:",f6.1,/;wrt 6,r18,r26
342: B+1+B
343: if B>9;beep;wait 500;beep;wait 500;beep
344: if B>9;1+B;ent "Change paper;press CONTINUE",X
345: ret
```

```
0: "File 2: Calibration and RCS Comparison   7-9-82":
1: "                    ":
2: dim P$[2]
3: dev "SYN",704,"SPE ANA",717
4: prt "  Calibration","  -----------";spc ;lcl 7
5: ent "Month?",r0,"Day?",r1,"Year?",r2
6: "                    ":
7: "Tape":
8: ent "Insert Data Tape; press CONTINUE",X
9: ent "Data Tape Number?",r20
10: ent "Record Data on which trk? 0 or 1",r21;trk r21
11: "                    ":
12: "Freq":ent "Scat Freq(GHz)?",F;F+r3
13: if F=1.6;prt " 1.6 GHz System"
14: if F=4.75;prt "4.75 GHz System"
15: if F=9.5;prt "9.5 GHz System"
16: if F=13.3;prt "13.3 GHz System"
17: ent "Polarization? HH or VV",P$;1+r4;if P$="VV";2+r4
18: fmt c2," Polarization";wrt 16,P$
19: "                    ":
20: "Range Offset & Freq/Rng Slope":
21: "      The values for these parameters are determined":
22: "      for each frequency from File 3: Range Offset-":
23: "      Freq/Rng Slope Program":
24: ent "Sweep Repetition Rate?",r22;fxd 1;prt "Sweep Rep Rate:",r22
25: if F=1.6;26.5+r5;1.025*r22+r6
26: if F=4.75;19.1+r5;3.518*r22+r6
27: if F=9.5;12.1+r5;3.607*r22+r6
28: if F=13.3;7.9+r5;3.595*r22+r6
29: "                    ":
30: "Target":
31: ent "Cal Target?",T;T+r7;spc ;fxd 2;prt "Target:"
32: if T=1;prt " 1 ft diam Plate";.5+r8
33: if T=2;prt " 2 ft diam Plate";1+r8
34: if T=3;prt " 3 ft diam Plate";1.5+r8
35: if T=4;prt "4 ft diam Sphere";1.5+r8
36: if T=5;prt "     2 ft Corner","       Reflector";1.547+r8
37: "                    ":
38: "Date and Time":
39: spc ;fmt "Date: ",f2.0,"-",f2.0,"-",f2.0;wrt 16,r0,r1,r2
40: ent "Time(hr.min)?",r9;fxd 2;prt "Time(hr.min):",r9
41: "                    ":
42: "Range and Frequency":
43: spc ;fxd 1;ent "Range(ft)?",R;prt "Range(ft):",R
44: if T=4;R-2+R
45: R+r10
46: r6(R+r5)+C
47: ent "Ready for data? press CONTINUE",X
48: "                    ":
```

```
49: "HP 3330B Frequency Synthesizer and 3571A Spectrum Analyzer Setup":
50: "      Frequency Synthesizer":
51: "           Center Frequency:  Variable":
52: "           Frequency Step:     10 Hz":
53: "           Time/Step:          10 ms":
54: "      Spectrum Analyzer":
55: "           Display Ref:  dBV":
56: "           Display Smoothing:  On":
57: "           Bandwidth:   1000 Hz":
58: "           Input Range:  +10 dBV":
59: "           Input Impedance:  1 megohm":
60: "           Measurement Control Mode:  External":
61: "Setup":
62: rem 7;fmt "P1S1B5V7Z2M1";wrt "SPE ANA"
63: "                    ":
64: "Center Frequency Search":
65: C-5050→C;-70→M;50→X;gsb "search"
66: Y-1010→C;10→X;gsb "search"
67: Y→C→r11;gto "prtfreq"
68: "search":
69: for I=1 to 200
70: C+X→C
71: fmt "L",f.1,"=";wrt "SYN",C;wait 5
72: wrt "SPE ANA","T";fmt f.2;red "SPE ANA",Z
73: if Z>M;Z→M;C→Y
74: next I
75: ret
76: "prtfreq":fxd 0;prt "Center Freq:",C
77: "                    ":
78: "Summation of Data between -6 dBV Points":
79: gsb "data"
80: Z→M;0→r18→r19
81: C-10→C
82: gsb "data"
83: if Z<M-6;gto "Low Freq"
84: if C<Y-5000;gto +2
85: gto -4
86: prt "Low 6-dBV limit not reached";1→r18
87: "Low Freq":
88: prt "Low Freq:",C;C→r12
89: gsb "data"
90: tn^(Z/10)→V;tn^(Z/20)→U
91: "sum":
92: C+10→C
93: gsb "data"
94: V+tn^(Z/10)→V;U+tn^(Z/20)→U
95: if C<Y;gto +2
96: if Z<M-6;gto "High Freq"
97: if C>Y+5000;gto +2
98: gto "sum"
99: prt "High 6-dBV limit not reached";1→r19
```

```
100: "High Freq":
101: prt "High Freq:",C;C+r13
102: r13-r12+r14;prt "Signal BW:",r14;spc ;gto "prtdata"
103: "data":
104: fmt "L",f.1,"=";wrt "SYN",C;wait 10
105: wrt "SPE ANA","P";fmt f.2;red "SPE ANA",S
106: ret
107: "                    ":
108: "prtdata":
109: U+r15;V+r16
110: prt "****************"
111: fmt b,"V",b,"=",e12.3;wrt 16,126,29,V
112: fmt "L",f.1,"=M100=Y";wrt "SYN",Y;lcl 7
113: "                    ":
114: "Target Sigma":
115: if T=1;8.0135*F^2+S
116: if T=2;128.2*F^2+S
117: if T=3;649.03*F^2+S
118: if T=4;12.57+S
119: if T=5;17.359*F^2+S
120: S+r17
121: "                    ":
122: prt "Delta Freq=10 Hz"
123: fxd 1;prt "Cal Range(ft)=",R
124: prt "Sigma(Target)="
125: fmt f12.2," ft",b;wrt 16,S,29
126: prt "****************";spc
127: "                    ":
128: "Record Data on Tape":
129: ent "Record Data on Tape? 1=yes 0=no",X;if X=0;gto "compare"
130: idf A,X,Y
131: if Y#0;fdf A+1;gto -1
132: rcf A,r19;fxd 0;prt "Tape No=",r20,"File No=";A
133: "                    ":
134: "compare":
135: ent "Compare actual to calc RCS?1=yes",X;if X#1;gto "mordata"
136: prt "Target RCS(calc)"
137: fmt 6x,"=",f6.2," dB";wrt 16,10log(S)
138: if F#1.6;gto +3
139: if P$="HH";1e-9+K
140: if P$="VV";1.184e-9+K
141: if F#4.75;gto +3
142: if P$="HH";4.6e-9+K
143: if P$="VV";8.506e-9+K
144: if F#9.5;gto +3
145: if P$="HH";1.431e-7+K
146: if P$="VV";5.479e-8+K
147: if F#13.3;gto +3
148: if P$="HH";5.805e-8+K
149: if P$="VV";7.617e-8+K
150: K*V*10*R^4+X;10log(X)+Y
151: prt "Target RCS(meas)"
152: fmt 6x,"=",f6.2," dB";wrt 16,Y
153: fxd 2;prt "Delta RCS=",Y-10log(S);spc 3
154: "                    ":
155: "mordata":
156: ent "Take more cal data? 1=yes 0=no",X;if X=1;spc 3;gto "Freq"
157: spc 3;end
```

```
0: "File 3: Plot Ground Scat Sweep on HP 9871A Printer   7-31-81":
1: "             ":
2: dev "SYN",704,"SPE ANA",717;lcl 7
3: dim D[100],L[100],L$[20],F$[14],S$[25],P$[11],T$[25]
4: gto "start"
5: "loc":
6: wtb 6,27,65,int(120X/64),int(120X),int(96Y/64),int(96Y)
7: ret
8: "cl Ar":
9: for I=1 to 25
10: if I>len(L$);if I<=20;" "→L$[I,I]
11: if I>len(F$);if I<=14;" "→F$[I,I]
12: if I>len(S$);if I<=25;" "→S$[I,I]
13: if I>len(P$);if I<=11;" "→P$[I,I]
14: if I>len(T$);if I<=25;" "→T$[I,I]
15: next I
16: ret
17: "info":
18: ent "Scat Frequency?",F$,"Polarization?",P$
19: ent "Site?",S$,"Date?",T$
20: gsb "cl Ar"
21: ret
22: "prtinfo":
23: if flg1=1;gsb "loc"
24: fmt "Scat Freq: ",c14,"Site: ",c25;wrt 6,F$,S$;wtb 6,27,10
25: if flg1=1;gsb "loc"
26: fmt 9"_",16x,4"_";wrt 6
27: if flg1=1;Y-.2→Y;gsb "loc"
28: fmt "Polarization: ",c11,"Date: ",c25;wrt 6,P$,T$;wtb 6,27,10
29: if flg1=1;gsb "loc"
30: fmt 12"_",13x,4"_";wrt 6
31: ret
32: "start":ent "Minimum frequency in Hz?",L;cfg 1;cfg 3
33: ent "Maximum frequency in Hz?",H
34: rem 7
35: (H-L)/100→S
36: fmt "R1S1B5V7Z0M1";wrt "SPE ANA"
37: fmt "L",f.2,"=M",f.1,"=R";wrt "SYN",L,S
38: fmt f.2;red "SPE ANA",X;X→D[1];10^(X/20)→L[1]
39: for I=2 to 100
40: fmt "*";wrt "SYN"
41: fmt f.2;red "SPE ANA",X;X→D[I];10^(X/20)→L[I]
42: next I
43: (L+H)/2→F
44: fmt "L",f.2,"=Y";wrt "SYN",F
45: lcl 7;ent "Print Data? 1=yes 0=no",X;if X=0;gto "Plot"
46: ent "1)Linear or 2)dBV?",X;if X=1;sfg 3
47: dsp "Ready to Print?";stp
48: wtb 6,27,69;fmt 5x,z;wrt 6
49: wtb 6,27,77;gsb "info"
50: gsb "prtinfo"
```

```
51: sfg 1
52: fmt /," Freq",6x,"Ampl.",14x," Freq",6x,"Ampl.";wrt 6
53: fmt 2" (Hz)        (dBV)                 ",/
54: if flg3=1;fmt 2" (Hz)      (Volts)              ",/
55: wrt 6
56: L→F;L+50S→G
57: for I=1 to 50
58: I+50→J
59: D[I]→X;D[J]→Y;if flg3=1;L[I]→X;L[J]→Y
60: fmt 1,f5.0,6x,f5.1,14x,f5.0,6x,f5.1
61: if flg3=1;fmt 1,f5.0,6x,f5.3,14x,f5.0,6x,f5.3
62: wrt 6.1,F,X,G,Y
63: F+S→F;G+S→G
64: next I
65: cfg 3
66: "Plot":ent "Plot Data? 1=yes 0=no",X;if X=0;gto "end"
67: ent "1)Linear or 2)dBV?",X;if X=1;sfg 3
68: dsp "Ready to Plot?";stp
69: wtb 6,27,69;wtb 6,27,84;wtb 6,27,77
70: wtb 6,27,87,int(7*120/64),int(7*120)
71: wtb 6,27,76,int(7*96/64),int(7*96)
72: wtb 6,27,70,int(8*96/64),int(8*96)
73: wtb 6,27,79,int(1*120/64),int(1*120),int(1*96/64),int(1*96)
74: 0→X;0→Y
75: gsb "loc"
76: wtb 6,"-"
77: if (X+.1→X)<5.1;gto -2
78: 0→X;0→Y
79: gsb "loc"
80: wtb 6,"|"
81: if (Y+.1→Y)<5.1;gto -2
82: if flg3=1;"AMPLITUDE | Volts"→L$;17→N;gto +2
83: "AMPLITUDE | dBV"→L$;15→N
84: 3.83→Y;-.9→X
85: for I=1 to N
86: gsb "loc"
87: fmt c1;wrt 6,L$[I,I]
88: Y-.16→Y
89: next I
90: if flg1=0;gsb "info"
91: sfg 1;0→X;-.6→Y
92: gsb "prtinfo"
93: if flg3=1;gto "linear"
94: "dBV":-.3→X
95: for I=-70 to 10 by 10
96: 5/80*(I+70)→Y
97: gsb "loc"
98: fmt f3.0,"-";wrt 6,I
99: next I
100: gto "freq"
```

```
101: "linear":
102: max(L[*])+M
103: if M<=3.2;3.2+W;.4+B
104: if M<=2.4;2.4+W;.3+B
105: if M<=1.6;1.6+W;.2+B
106: if M<=.8;.8+W;.1+B
107: if M<=.32;.32+W;.04+B
108: if M<=.24;.24+W;.03+B
109: if M<=.16;.16+W;.02+B
110: if M<=.08;.08+W;.01+B
111: if M<=.032;.032+W;.004+B
112: if M<=.016;.016+W;.002+B
113: -.5+X
114: for I=0 to 8
115: 5/W*I*B+Y
116: gsb "loc"
117: fmt f5.1,"-"
118: if M<=.32;fmt f5.2,"-"
119: if M<=.032;fmt f5.3,"-"
120: wrt 6,I*B
121: next I
122: "freq":if H<=1000;"Hz"+L$;gsb "cl Ar"
123: if H>1000;"kHz"+L$;gsb "cl Ar"
124: 1.8+X;-.4+Y;gsb "loc"
125: fmt "FREQUENCY - ",c20;wrt 6,L$
126: if H-L<=1000;100+K;gto "pltdat"
127: if H-L<=5000;500+K;gto "pltdat"
128: if H-L<=10000;1000+K;gto "pltdat"
129: if H-L<=50000;5000+K;gto "pltdat"
130: if H-L<=100000;10000+K;gto "pltdat"
131: dsp "Desired plot outside prog design";stp
132: "pltdat":
133: for I=0 to 10 by 2
134: .5I+X;0+Y;gsb "loc"
135: fmt "|";wrt 6
136: -.2+Y
137: L+K*I+P;if H>1000;P/1000+P
138: if int(P)#P;fmt 2,f5.1;X-.3+X;gto +2
139: fmt 2,f4.0;X-.2+X
140: gsb "loc"
141: wrt 6.2,P
142: next I
143: 0+X;5/80*(D[1]+70)+Y;if flg3=1;5/W*L[1]+Y
144: gsb "loc"
145: for I=1 to 100
146: .5*(I-1)*S/K+X
147: 5/80*(D[I]+70)+Y;if flg3=1;5/W*L[I]+Y
148: wtb 6,27,97,int(120X/64),int(120X),int(96Y/64),int(96Y)
149: next I
150: "end":ent "More Plots? 1=yes 0=no",X;if X=1;gto "start"
151: wtb 6,27,69;end
```

```
0: "File 4:  Range Offset - Frequency/Range Slope   8-5-82":
1: "                  ":
2: "Init":
3: dim D[4,6],F[4]
4: prt "Range Offset-"," Freq/Rng Slope"
5: prt "----------------";spc ;lcl 7
6: dev "SYN",704,"SPE ANA",717
7: "                  ":
8: "Freq":
9: ent "Sqat Freq(GHz)? If no more, CONT",F;if flg13;gto "Calc"
10: fxd 1;if F=4.75;fxd 2
11: prt "Scat Freq(GHz):",F;fxd 1
12: ent "Range(ft)?",R;fmt "Range(ft):",f6.1;wrt 16,R
13: ent "Frequency Repetition Rate?",L;prt "Freq Rep Rate:",L
14: ent "Ready to take data? CONTINUE",X
15: if F=1.6;19.6→r0;164.9→r1;1→I;√(R^2+.22)+1.25→R;1.6→F[1]
16: if F=4.75;15.1→r0;550.7→r1;2→I;√(R^2+.22)+1.25→R;4.75→F[2]
17: if F=9.5;13.4→r0;573.6→r1;3→I;√(R^2-23.02)-.11→R;9.5→F[3]
18: if F=13.3;16.2→r0;527→r1;4→I;√(R^2-23.02)-.11→R;13.3→F[4]
19: "                  ":
20: "Data":
21: gsb "prtrng"
22: gsb "search"
23: D[I,1]+1→D[I,1];D[I,2]+R→D[I,2];D[I,3]+R^2→D[I,3]
24: D[I,4]+C→D[I,4];D[I,5]+R*C→D[I,5];D[I,6]+L→D[I,6]
25: gto "Freq"
26: "                  ":
27: "Calc":
28: for I=1 to 4
29: D[I,1]*D[I,3]-D[I,2]^2→X;if X=0;gto +5
30: (D[I,3]*D[I,4]-D[I,2]*D[I,5])/X→Y
31: (D[I,1]*D[I,5]-D[I,2]*D[I,4])/X→S;Y/S→O
32: D[I,6]/D[I,1]→L
33: gsb "prtdata"
34: next I
35: prt "****************";end
36: "                  ":
37: "prtrng":fxd 1;prt "Range(corr):",R;ret
38: "                  ":
39: "prtdata":
40: prt "****************";fxd 1;if F=4.75;fxd 2
41: prt "Scat Freq(GHz):",F[I]
42: fxd 1;prt "Range Offset=",O,"Freq/Rng Slope=",S
43: prt "Avg Freq","     Rep Rate=",L;spc 2
44: ret
45: "                  ":
46: "search":
47: rem 7;fmt "R1S1B5V7Z2M1";wrt "SPE ANA"
48: r1(R+r0)→C
49: C-5050→C;-70→M;50→X;gsb "scan"
50: Y-1010→C;10→X;gsb "scan"
51: Y→C;gsb "prtfreq"
52: ret
53: "                  ":
```

```
54: "scan":
55: for J=1 to 200
56: C+X→C
57: fmt "L",f.1,"=";wrt "SYN",C;wait 10
58: wrt "SPE ANA","T";fmt f.2;red "SPE ANA",Z
59: if Z>M;Z→M;C→Y
60: next J
61: ret
62: "               ":
63: "prtifeq":
64: fxd 0;prt "IF Freq:",C;spc 2
65: fmt "L",f.1,"=M100=Y";wrt "SYN",C;lcl 7
66: ret
```

```
0: "File 5: Dump Data Files to HP9871A Printer    10-8-81":
1: "                    ":
2: dim X[50];cll 13
3: wtb 6,27,59
4: fmt 10x,z;wrt 6;wtb 6,27,77;wtb 6,27,84
5: wtb 6,27,70,int(8*120/64),int(8*120)
6: wtb 6,27,87,int(8*120/64),int(8*120)
7: ent "Tape No?",T,"Track No?",R;trk R
8: ent "First File No?",A
9: ent "Last File No?",B
10: ent "Exclude any files? 1=yes",X;if X#1;gto "Init"
11: for I=1 to 50
12: ent "File No. to be excluded?",X;if flg13=1;gto "Init"
13: X→X[I]
14: next I
15: "                    ":
16: "Init":
17: fmt 24x,"Tape No: ",f3.0;wrt 6,T;1→C
18: fmt 23x,"Track No:",f3.0,2/;wrt 6,R
19: "Cont":
20: if A>B;gto "end"
21: for I=1 to 50
22: if A#0;if A=X[I];A+1→A;gto "Cont"
23: next I
24: ldf A,r0
25: fmt "File No:",f4.0,7x,"Look Angle:",f5.1,5x,z;wrt 6,A,r12
26: fmt "IF Freq:",f6.0;wrt 6,r15
27: fmt "Date: ",f2.0,"-",f2.0,"-",f2.0,5x,z;wrt 6,r0,r1,r2
28: if r11>100;r11/100→r11
29: int(r11)→X;100*(r11-X)→Y
30: fmt "Time:",f3.0,":",z;wrt 6,X
31: if 10>Y;fmt "0",f1.0,10x,z;wrt 6,Y;gto +2
32: fmt f2.0,10x,z;wrt 6,Y
33: fmt "Delta Freq: 10";wrt 6
34: fmt "Scat Freq:",z;wrt 6
35: if r4=4.75;fmt f5.2,4x,z;wrt 6,r4;gto +2
36: fmt f5.1,4x,z;wrt 6,r4
37: fmt "Height(corr):",f5.1,3x,"Ftprnt Area:",f6.1;wrt 6,r13,r21
38: fmt "Polarization: ",z;wrt 6
39: if r5=1;fmt "HH",3x,z;wrt 6
40: if r5=2;fmt "VV",3x,z;wrt 6
41: if r5=3;fmt "HV",3x,z;wrt 6
42: if r5=4;fmt "VH",3x,z;wrt 6
43: fmt "Range:",f6.1,9x,"Sgma Zero(dB):",f6.1;wrt 6,r14,r24
44: r10/100→r10;fmt "Site No:",f5.2,6x,z;wrt 6,r10
45: fmt "Sig Bndwth:",f6.1,2x,"Ind Smpls:",f6.1,/;wrt 6,r18,r26
46: A+1→A;C+1→C
47: if C>9;ent "Change Paper - press CONTINUE",X;gto "Init"
48: gto "Cont"
49: "end":end
```

```
0: "File 6: Dump Cal Files to HP9871A Printer    8-24-81":
1: "                    ":
2: dim X[50];ctg 13
3: wtb 6,27,69
4: fmt 10x,z;wrt 6;wtb 6,27,77;wtb 6,27,84
5: wtb 6,27,70,int(8*120/64),int(8*120)
6: wtb 6,27,87,int(8*120/64),int(8*120)
7: ent "Tape No?",T
8: ent "First File No?",A
9: ent "Last File No?",B
10: ent "Exclude any files? 1=yes",X;if X#1;gto "Init"
11: for I=1 to 50
12: ent "File No. to be excluded?",X;if flg13=1;gto "Init"
13: X→X[I]
14: next I
15: "                    ":
16: "Init":
17: fmt 24x,"Tape No: ",f3.0,2/;wrt 6,T;1→C
18: "Cont":
19: if A>B;gto "end"
20: for I=1 to 50
21: if A#0;if A=X[I];A+1→A;gto "Cont"
22: next I
23: ldf A,r0
24: fmt "File No: ",f4.0,7x,z;wrt 6,A
25: fmt "Date: ",f2.0,"-",f2.0,"-",f2.0,6x,z;wrt 6,r0,r1,r2
26: if r9>100;r9/100→r9
27: int(r9)→X;100*(r9-X)→Y
28: fmt "Time:",f3.0,":",z;wrt 6,X
29: if 10>Y;fmt "0",f1.0;wrt 6,Y;gto +2
30: fmt f2.0;wrt 6,Y
31: fmt 5x,"Scat Freq:",z;wrt 6
32: if r3=4.75;fmt f5.2,20x,z;wrt 6,r3;gto +2
33: fmt f5.1,20x,z;wrt 6,r3
34: fmt "Sum of V^2: ",e9.3;wrt 6,r16
35: fmt 5x,"Polarization: ",z;wrt 6
36: if r4=1;fmt "HH",19x,z;wrt 6
37: if r4=2;fmt "VV",19x,z;wrt 6
38: fmt "Delta Freq: 10 Hz";wrt 6
39: fmt 5x,"Cal Target: ",z;wrt 6
40: if r7=1;fmt "1-ft Plate",13x,z;wrt 6
41: if r7=2;fmt "2-ft Plate",13x,z;wrt 6
42: if r7=3;fmt "3-ft Plate",13x,z;wrt 6
43: if r7=4;fmt "4-ft Sphere",12x,z;wrt 6
44: if r7=5;fmt "Corner Reflector",7x,z;wrt 6
45: fmt "Range: ",f5.1;wrt 6,r10
46: fmt 5x,"Center Freq: ",f6.0,16x,"Target Sigma: ",f8.2;wrt 6,r11,rl
47: fmt 5x,"Sig Bandwidth: ",f5.0,/;wrt 6,r14
48: A+1→A;C+1→C
49: if C>8;ent "Change Paper - press CONTINUE",X;gto "Init"
50: gto "Cont"
51: "end":end
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
0: "File 7: Data Table   10-14-81":
1: "                    ":
2: "Heading":
3: prt "Insert Paper","Horizontally";spc
4: ent "See printer. Ready to print?",X
5: dim A[7],X[100],A$[7,7],D$[20],P$[2],S$[20]
6: for I=1 to 100
7: 5000+X[I]
8: next I
9: wtb 6,27,69
10: fmt 5x,z;wrt 6;wtb 6,27,77,27,84
11: wtb 6,27,70,10,672
12: wtb 6,27,87,18,1200
13: ent "This month?",M,"Day?",D,"Year?",Y
14: ent "Scatterometer Frequency(GHz)?",F,"Polarization?",P$
15: if P$="HH";1+P
16: if P$="VV";2+P
17: if P$="HV";3+P
18: if P$="VH";4+P
19: ent "Date data taken?",D$,"Site Name?",S$
20: ent "Data tape number?",T,"Track Number?",Q;trk Q
21: for I=1 to 20
22: if 1>len(S$);" "+S$[I,I]
23: if I>len(D$);" "+D$[I,I]
24: next I
25: "                    ":
26: "Angle":
27: "First"+A$[1];"Second"+A$[2];"Third"+A$[3]
28: "Fourth"+A$[4];"Fifth"+A$[5];"Sixth"+A$[6];"Seventh"+A$[7]
29: ent "No of look angles(<=7)?",N
30: for I=1 to N
31: dsp A$[I],"Look Angle?"
32: ent "",A[I]
33: next I
34: dim D[0:3N,1:10]
35: "                 ":
36: "Data":
37: ent "Start File No?",L;L+A
38: ent "Stop File No?",H
39: ent "Exclude files? 1=yes 0=no",X;if X=0;gto "Load Data"
40: prt "Excluded files:"
41: for I=1 to 100
42: ent "File number to be excluded?",X;if flg13;cfg 13;gto "Load Data"
43: X+X[I];fxd 0;prt X
44: next I
45: "                    ":
46: "Load Data":
47: for I=0 to 3N
48: for J=1 to 10
49: 0+D[I,J]
50: next J
51: next I
```

```
52: 1→C
53: "ldt":
54: if A>H;gto "Prtdata"
55: for J=1 to 100
56: if A=X[J];A+1→A
57: next J
58: ldf A,r0,r26
59: A+1→A
60: if r4#F;gto "ldt"
61: if r5#P;gto "ldt"
62: 100→I
63: for J=1 to 7
64: if A[J]=r12;J→I
65: next J
66: if I=100;gto "ldt"
67: if D[0,1]=0;r10/100→D[0,1]
68: if r10/100#D[0,C];C+1→C
69: if C<=10;r10/100→D[0,C]
70: if C>10;A-1→A;gto "Prtdata"
71: 3(I-1)+1→R
72: A-1→D[R,C]
73: r24→D[R+1,C]
74: r26→D[R+2,C]
75: gto "ldt"
76: "                ":
77: "Prtdata":
78: fmt 75x,f2.0,"-",f2.0,"-",f2.0,/;wrt 6,M,D,Y
79: fmt 35x,"JSC GROUND SCATTEROMETER";wrt 6
80: wtb 6,27,10;fmt 35x,24"_";wrt 6
81: fmt 42x,"FIELD DATA";wrt 6
82: wtb 6,27,10;fmt 42x,10"_",/;wrt 6
83: fmt 17x,"System: ",z;wrt 6
84: fmt f4.1,z;if F=4.75;fmt f4.2,z
85: wrt 6,F
86: fmt " GHz",29x,"Date: ",c20;wrt 6,D$
87: wtb 6,27,10;fmt 17x,6"_",39x,4"_";wrt 6
88: fmt 17x,"Polarization: ",c2,29x,"Tape No: ",f2.0;wrt 6,P$,T
89: wtb 6,27,10;fmt 17x,12"_",33x,7"_";wrt 6
90: fmt 17x,"Site: ",c20,19x,"Track No: ",f1.0;wrt 6,S$,Q
91: wtb 6,27,10;fmt 17x,4"_",41x,8"_",/;wrt 6
92: fmt 45x,"Sites";wrt 6
93: wtb 6,27,10;fmt 45x,5"_",/;wrt 6
94: fmt 6x,z;wrt 6
95: for C=1 to 10
96: if D[0,C]=0;fmt 8x,z;wrt 6;gto +2
97: fmt 4x,f4.2,z;wrt 6,D[0,C]
98: if C=10;wtb 6,10,13
99: next C
100: fmt "Angle";wrt 6
```

```
101: for I=1 to N
102: fmt 5x,z;wrt 6
103: 3(I-1)+1→R
104: for C=1 to 10
105: if D[R,C]=0;if D[R+1,C]=0;if D[R+2,C]=0;fmt 8x,z;wrt 6;gto +2
106: fmt 5x,f3.0,z;wrt 6,D[R,C]
107: if C=10;wtb 6,10,13
108: next C
109: fmt 2x,f2.0,2x,z;wrt 6,A[I]
110: for C=1 to 10
111: if D[R,C]=0;if D[R+1,C]=0;if D[R+2,C]=0;fmt 8x,z;wrt 6;gto +2
112: fmt 3x,f5.1,z;wrt 6,D[R+1,C]
113: if C=10;wtb 6,10,13
114: next C
115: fmt 6x,z;wrt 6
116: for C=1 to 10
117: if D[R,C]=0;if D[R+1,C]=0;if D[R+2,C]=0;fmt 8x,z;wrt 6;gto +2
118: fmt 4x,f4.1,z;wrt 6,D[R+2,C]
119: if C=10;wtb 6,10,13,10
120: next C
121: next I
122: if A>H;gto "end"
123: ent "Change Paper  CONTINUE",X;gto "Load Data"
124: "end":dsp "Finished";end
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
0: "File 8: Statistics   10-16-81":
1: "                    ":
2: "Init":
3: dim S[100],X[100],A$[7,7],D$[20],E$[8],N$[30],S$[20],Y$[2]
4: "First"→A$[1];"Second"→A$[2];"Third"→A$[3]
5: "Fourth"→A$[4];"Fifth"→A$[5];"Sixth"→A$[6];"Seventh"→A$[7]
6: ent "Today's date? (XX-XX-XX)",E$
7: ent "No. of scat frequencies?",M;dim F[M],P$[4,2]
8: for I=1 to M
9: dsp A$[I],"Scat Frequency(GHz)?"
10: ent "",F[I];fxd 1;if F[I]=4.75;fxd 2
11: prt F[I]
12: ent "Polarization?",P$[I];fmt 14x,c2;wrt 16,P$[I];spc
13: next I
14: ent "Site name?",N$
15: ent "Date data taken?",D$
16: for I=1 to 100
17: 5000→X[I]
18: next I
19: for I=1 to 30
20: if I>len(D$);if I<=20;" "→D$[I,I]
21: if I>len(N$);" "→N$[I,I]
22: next I
23: ent "How many look angles?",N;dim A[N],O[M,N,4],R[M,N,6]
24: prt "Look Angles:     "
25: for I=1 to N
26: dsp A$[I],"Look Angle?"
27: ent "",A[I];fxd 0;prt A[I]
28: next I
29: ent "Key on sites? 1=yes 0=no",X;if X=0;sfg 9;gto +6
30: spc ;prt "Sites:          "
31: for I=1 to 100
32: ent "Site number multiplied by 100?",S[I];if flg13;cfg 13;gto "Prev"
33: fxd 2;prt S[I]/100
34: next I
35: "Prev":ent "Previous data? 1=yes 0=no",X;if X=1;gsb "prevdata"
36: "                    ":
37: "Tape":
38: ent "Tape number?",X;fxd 0;spc 2;prt "Tape no: ",X
39: ent "Track number?",Q;trk Q;prt " Track:",Q
40: ent "Start File No?",L;L→A
41: fxd 0;prt " Start File:",L
42: ent "Stop File No?",H
43: prt "  Stop File:",H;spc
44: ent "Exclude any files? 1=yes 0=no",X;if X=0;gto "Ldf"
45: prt "Excluded Files: "
46: for I=1 to 100
47: ent "File number to be excluded?",X[I];if flg13;cfg 13;gto "Ldf"
48: fxd 0;prt X[I]
49: next I
50: "                    ":
51: "Ldf":
52: if A>H;gsb "moredata"
53: for I=1 to 100
54: if A=X[I];A+1→A
55: next I
56: ldf A,r0,r26
57: "                    ":
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
58: "Check criteria":
59: cfg 10
60: for I=1 to M
61: if r5=1;"HH"→Y$
62: if r5=2;"VV"→Y$
63: if r5=3;"HV"→Y$
64: if r5=4;"VH"→Y$
65: if r4=F[I];if Y$=P$[I];sfg 10;I→J
66: next I
67: if flg10=0;A+1→A;gto "Ldf"
68: cfg 10
69: for I=1 to N
70: if r12=A[I];sfg 10;I→K
71: next I
72: if flg10=0;A+1→A;gto "Ldf"
73: cfg 10
74: if flg9;gto +5
75: for I=1 to 100
76: if r10=S[I];sfg 10
77: next I
78: if flg10=0;A+1→A;gto "Ldf"
79: "                ":
80: "Data Matrix":
81: D[J,K,1]+1→D[J,K,1]
82: D[J,K,2]+r26→D[J,K,2]
83: D[J,K,3]+r26*r23→D[J,K,3]
84: D[J,K,4]+r26*r23^2→D[J,K,4]
85: A+1→A;gto "Ldf"
86: "                ":
87: "Calc":
88: for I=1 to M
89: for J=1 to N
90: D[I,J,1]→C
91: D[I,J,2]→B
92: D[I,J,3]→X
93: D[I,J,4]→Y
94: X/B→W
95: √((B/(C-1))(Y/B-W^2))→Z
96: gsb "student T"
97: W-T*Z/√(B-1)→U
98: W+T*Z/√(B-1)→V
99: 10log(W)→R[I,J,1]
100: 10log(Z)→R[I,J,2]
101: B→R[I,J,3]
102: C→R[I,J,4]
103: 5000→R[I,J,5];if U>0;10log(U)→R[I,J,5]
104: 10log(V)→R[I,J,6]
105: next J
106: next I
107: "                ":
```

```
108: "Prtdata":
109: wtb 6,27,69;fmt 5x,z;wrt 6;wtb 6,27,77
110: for I=1 to M
111: fxd 1;if F[I]=4.75;fxd 2
112: dsp "Print",F[I],"Data?"
113: ent "",X;if X=0;gto "inc"
114: ent "Ready to print?",X
115: fmt 52x,c8,/;wrt 6,E$
116: fmt 18x,"JSC GROUND SCATTEROMETER";wrt 6
117: wtb 6,27,10;fmt 18x,24"_";wrt 6
118: fmt 22x,"STATISTICAL DATA";wrt 6
119: wtb 6,27,10;fmt 22x,16"_",/;wrt 6
120: if F[I]=4.75;fmt "SYSTEM:",f5.2,z;wrt 6,F[I];gto +2
121: fmt "SYSTEM:",f5.1,z;wrt 6,F[I]
122: fmt " GHz",15x,"SITE: ",c30;wrt 6,N$
123: wtb 6,27,10;fmt 6"_",25x,4"_";wrt 6
124: fmt "POLARIZATION: ",c2,15x,"DATE: ",c20;wrt 6,P$[I],D$
125: wtb 6,27,10;fmt 12"_",19x,4"_",2/;wrt 6
126: fmt "Angle",3x,"Mean",3x,"Standard",5x,"Number of",z;wrt 6
127: fmt 5x,"Number",4x,"90% Confidence";wrt 6
128: fmt "(Deg)",3x,"(dB)",3x,"Dev (dB)",3x,"Ind. Samples",z;wrt 6
129: fmt 3x,"of Sites",4x,"Interval (dB)";wrt 6
130: wtb 6,27,10;fmt 5"_",3x,4"_",3x,8"_",3x,z;wrt 6
131: fmt 12"_",3x,8"_",3x,13"_",2/;wrt 6
132: for J=1 to N
133: if R[I,J,5]=5000;fmt 57x,"*****";wrt 6;gto +2
134: fmt 57x,f5.1;wrt 6,R[I,J,5]
135: fmt f3.0,4x,f5.1,4x,f5.1,6x,z;wrt 6,A[J],R[I,J,1],R[I,J,2]
136: fmt f7.1,9x,f4.0;wrt 6,R[I,J,3],R[I,J,4]
137: fmt 57x,f5.1,3/;wrt 6,R[I,J,6]
138: next J
139: "inc":next I
140: end
141: "                  ":
142: "prevdata":
143: spc ;prt "Previous Data:","                Angle","       Sigma 0(dB)"
144: prt "       Std Dev(dB)","No of Ind Smpls","       No of Sites";spc
145: for I=1 to M
146: fxd 1;if F[I]=4.75;fxd 2
147: prt "Freq:",F[I]
148: prt "Pol:",P$[I];spc
149: for J=1 to N
150: fxd 0;prt A[J]
151: dsp "Sigma 0(dB) for",A[J],"deg?"
152: ent "",X;fxd 1;prt X
153: fxd 0;dsp "Std dev for",A[J],"deg?"
154: ent "",Y;fxd 1;prt Y
155: fxd 0;dsp "No of Ind Smpls for",A[J],"deg?"
156: ent "",B;fxd 1;prt B
157: fxd 0;dsp "No of Sites for",A[J],"deg?"
158: ent "",C;fxd 0;prt C;spc
159: tn^(X/10)→X;tn^(Y/10)→Y
```

```
160: (C-1)*Y^2+B*X^2→Y;B*X→X
161: C→D[I,J,1]
162: B→D[I,J,2]
163: X→D[I,J,3]
164: Y→D[I,J,4]
165: next J
166: spc 2
167: next I
168: ret
169: "                ":
170: "mordata":
171: ent "More data? 1=yes 0=no",X
172: if X=0;gto "Calc"
173: for I=1 to 100
174: 5000→X[I]
175: next I
176: gto "Tape"
177: ret
178: "                ":
179: "student T":
180: 1.645→T;int(B)→X
181: if X<=120;1.66→T
182: if X<=61;1.67→T
183: if X<=41;1.68→T
184: if X<=31;1.7→T
185: if X<=27;1.71→T
186: if X<=23;1.72→T
187: if X<=20;1.73→T
188: if X<=18;1.74→T
189: if X<=17;1.75→T
190: if X<=15;1.76→T
191: if X<=14;1.77→T
192: if X<=13;1.78→T
193: if X<=12;1.8→T
194: if X<=11;1.81→T
195: if X<=10;1.83→T
196: if X<=9;1.86→T
197: if X<=8;1.9→T
198: if X<=7;1.94→T
199: if X<=6;2.02→T
200: if X<=5;2.13→T
201: if X<=4;2.35→T
202: if X<=3;2.92→T
203: if X<=2;6.31→T
204: ret
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
0: "File 9:  Plot Sigma Zero vs. Angle on Printer   1-5-82":
1: "                    ":
2: dim F[4],X[2],Y[2],A$[7,7],D$[20],P$[4,2],S$[30],X$[16]
3: "First"→A$[1];"Second"→A$[2];"Third"→A$[3];"Fourth"→A$[4]
4: "Fifth"→A$[5];"Sixth"→A$[6];"Seventh"→A$[7]
5: "                    ":
6: "Plot label":
7: ent "1)Aircraft or 2)Ground Data?",X;if X=2;sfg 1;gto +3
8: "A/C":ent "Mission number?",M,"Line number?",O,"Run number?",R
9: fxd 0;prt "MX:",M,"Line:",O,"Run:",R
10: "Ground":ent "Date data taken?.Mo Day, Yr",D$;prt D$
11: ent "Name of data site?",S$;prt S$;spc 2
12: "                    ":
13: "Data entry":
14: ent "No of scat frequencies?",N
15: ent "No of look angles?",M;dim D[0:N,M]
16: for I=1 to N
17: dsp A$[I],"Scat Frequency(GHz)?"
18: ent "",F[I]
19: ent "Polarization?",P$[I]
20: next I
21: for I=1 to M
22: dsp A$[I],"Look Angle(deg)?"
23: ent "",D[0,I]
24: next I
25: for I=1 to N
26: fxd 1;if F[I]=4.75;fxd 2
27: spc ;prt "Freq:",F[I]
28: "Pol:              "→X$[1];P$[I]→X$[15];prt X$;spc
29: for J=1 to M
30: fxd 0;prt D[0,J]
31: dsp "Sigma 0 for",D[0,J],"deg?"
32: ent "",D[I,J]
33: fxd 1;prt D[I,J];spc
34: next J
35: next I
36: "                    ":
37: "Plot":
38: ent "Ready to plot?",X
39: "      Clear":wtb 6,27,69
40: "      Left margin":fmt 5x,z;wrt 6;wtb 6,27,77
41: "      Top of form":wtb 6,27,84
42: "      Form length":wtb 6,27,70,int(8*120/64),int(8*120)
43: "      Text width":wtb 6,27,87,int(8*120/64),int(8*120)
44: "      Plot origin":wtb 6,27,79,int(0/64),int(0),int(0/64),int(0)
45: "Set up graph":
46: "      Character fill":wtb 6,27,46,45,int(5/64),int(5),0
47: 276→X[1];856→Y[1];gsb "loc"
48: if flg1=0;fmt "AIRBORNE SCATTEROMETER";wrt 6
49: if flg1=1;fmt "JSC GROUND SCATTEROMETER";wrt 6
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
50: "Make box":
51: "Top":120+X[1];864+Y[1];gsb "loc"
52: 720+X[2];864+Y[2];gsb "plot"
53: "Bottom":120+X[1];192+Y[1];gsb "loc"
54: 720+X[2];192+Y[2];gsb "plot"
55: wtb 6,27,46,124,int(5/64),int(5),0
56: "Right side":720+X[1];192+Y[1];gsb "loc"
57: 720+X[2];864+Y[2];gsb "plot"
58: "Left side":120+X[1];864+Y[1];gsb "loc"
59: 120+X[2];192+Y[2];gsb "plot"
60: 220+X[1]
61: for I=1 to 5
62: 192+Y[1];gsb "loc"
63: wtb 6,124
64: X[1]+100+X[1]
65: next I
66: for I=0 to 60 by 10
67: 10(I-.9)+120+X[1];176+Y[1];gsb "loc"
68: fmt f2.0,z;wrt 6,I
69: next I
70: 360+X[1];160+Y[1];gsb "loc"
71: fmt "LOOK ANGLE";wrt 6
72: 60+6*len(S$)+X[1];128+Y[1];gsb "loc"
73: fmt c30;wrt 6,S$
74: if flg1=1;gto +4
75: 186+X[1];112+Y[1];gsb "loc"
76: fmt "Mission: ",f3.0,5x,"Line: ",f2.0,5x,"Run: ",f2.0
77: wrt 6,P,Q,R
78: 180+6*len(D$)+X[1];96+Y[1];if flg1=1;112+Y[1]
79: gsb "loc"
80: fmt c20;wrt 6,D$
81: 0+X[1];648+Y[1];gsb "loc"
82: fmt "S",/,"I",/,"G",/,"M",/,"A",2/,"Z",/,"E",/,"R",/,"O",/;wrt 6
83: wtb 6,124;fmt 2/,"D",/,"B";wrt 6
84: ent "0)Fixed or 1)Variable Scale?",X
85: if X=0;-35+L+Y;8+D;64+A
86: if X=1;gsb "var"
87: for I=0 to D
88: 84+X[1];I*A+192+Y[1];gsb "loc"
89: fmt f3.0,"-";wrt 6,Y;Y+5+Y
90: next I
91: wtb 6,27,79,int(120/64),int(120),int(192/64),int(192)
92: "                    ":
93: "Plot data":
94: for I=1 to N
95: if F[I]=1.6;wtb 6,27,46,46,int(2/64),int(2),4
96: if F[I]=4.75;wtb 6,27,46,46,int(10/64),int(10),4
97: if F[I]=13.3;wtb 6,27,46,42,int(8/64),int(8),0
98: 348+X[1];656-16I+Y[1];gsb "loc"
99: fmt f4.1,1x,c2,z
100: if F[I]=4.75;fmt f4.2,1x,c2,z
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
101: wrt 6,F[I],P$[I]
102: if F[I]=1.6;fmt 1x,8"-";wrt 6
103: if F[I]=4.75;444→X[1];Y[1]+4→Y[1];gsb "loc"
104: if F[I]=4.75;fmt 8".";wrt 6
105: if F[I]=13.3;fmt 1x,8"*";wrt 6
106: for J=1 to M
107: if J=1;10*D[0,1]→X[1];(A/5)(D[I,1]-L)→Y[1];gsb "loc"
108: if J>1;10*D[0,J]→X[2];(A/5)(D[I,J]-L)→Y[2];gsb "plot"
109: wtb 6,43,8
110: next J
111: next I
112: spc 5;dsp "Finished";end
113: "loc":wtb 6,27,65,int(X[1]/64),int(X[1]),int(Y[1]/64),int(Y[1]);re
114: "plot":wtb 6,27,97,int(X[2]/64),int(X[2]),int(Y[2]/64),int(Y[2]);re
115: "var":
116: -50→H;50→L
117: for I=1 to N
118: for J=1 to M
119: D[I,J]→T
120: if T>=H;T→H
121: if T<=L;T→L
122: next J
123: next I
124: (int(H/5)+1)*5→H;5(int(L/5)-1)→L
125: (H-L)/5→D;int(672/D)→A;L→Y
126: ret
```