Final Report RSC-4768

CR 167 832

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RADAR CROSS CALIBRATION INVESTIGATION

TAMU RADAR POLARIMETER CALIBRATION MEASUREMENTS

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TEXAS A&M UNIVERSITY
REMOTE SENSING CENTER
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RADAR SCATTEROMETER POLARIMETER SYSTEM (TAMU)

The Radar Polarimeter System (RPS) developed at the Remote Sensing Center at Texas A&M University is a short pulse, 20 MHz bandwidth, three frequency radar. The RPS operates at center frequencies of 10.003 GHz, 4.75 GHz, and 1.6 GHz and utilizes dual polarized transmit and receive antennas for each frequency. The basic lay-out of the RPS is different from the other truck mounted systems in that it uses a pulse compression IF section common to all three RF heads. Separate transmit and receive antennas are used to improve the cross-polarization isolation at each particular frequency. The receive is a digitally controlled gain modulated subsystem and is interfaced directly with a microprocesser computer for control and data manipulation. The block diagram of the RPS is presented in Figure 1.

GENERAL OVERVIEW OF THE RPS

The RPS that has been developed is a dual polarized short pulse radar. Each of the radar RF heads, the common IF section, the DC-power supplies, and a microprocesser computer are also housed inside separate enclosures for ease of maintenance. All of these modular enclosures are mounted on a truss, which rests atop the boom. All RF connections between boxes are made with 0.141 in. semirigid coaxial cable. Refer to the photograph shown in Figure 2 for the radar truss configuration.

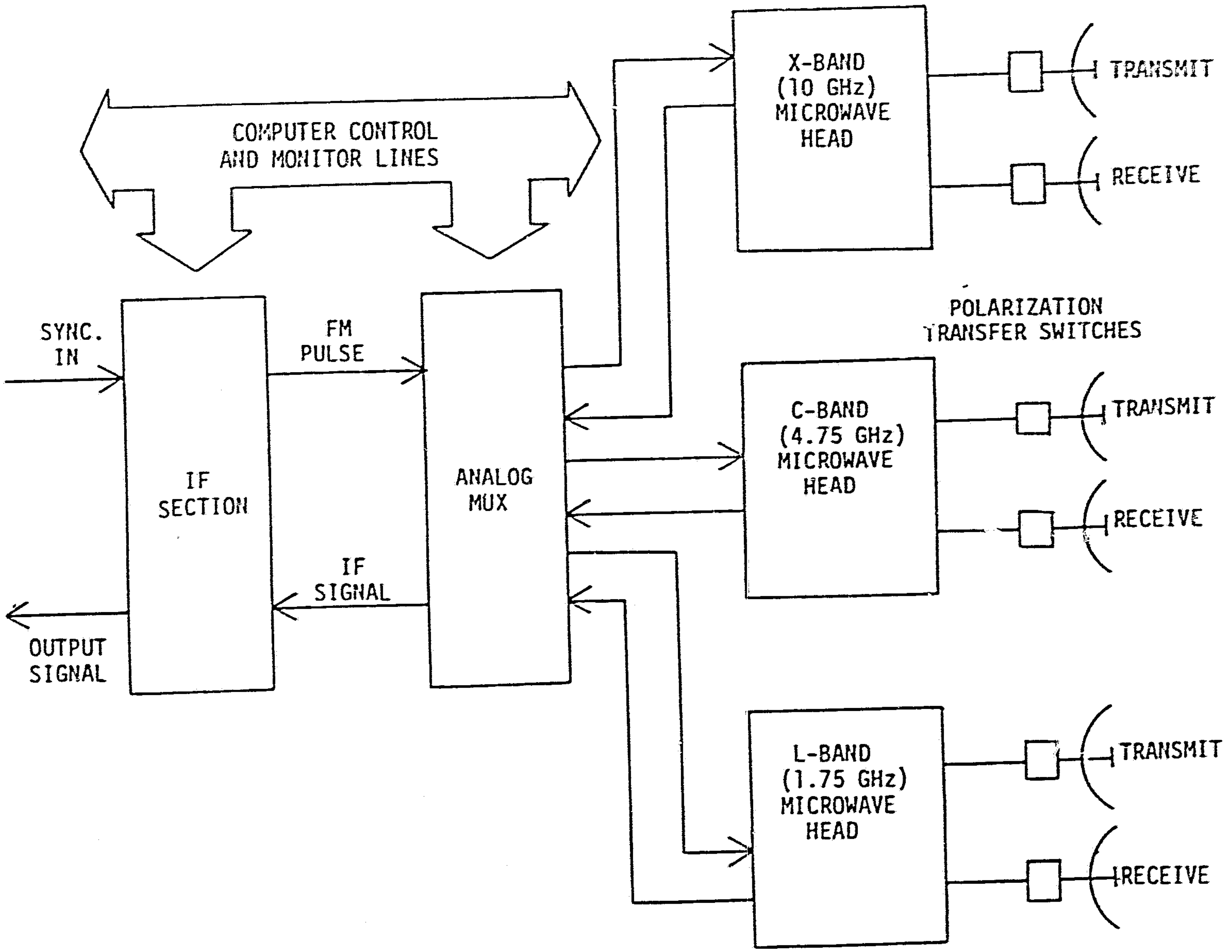

Figure 1: Block diagram of Radar Polarimeter System showing IF section, analog multiplexer, and microwave sections.

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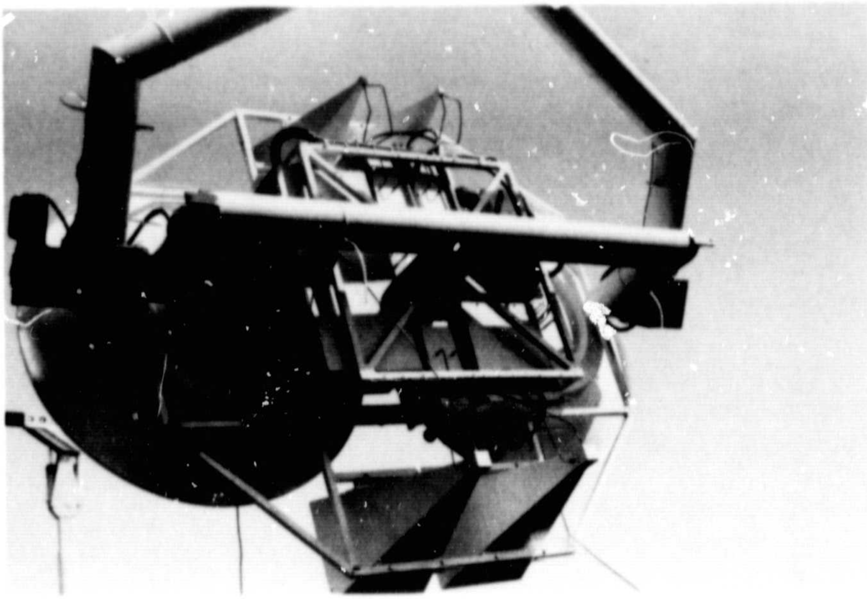

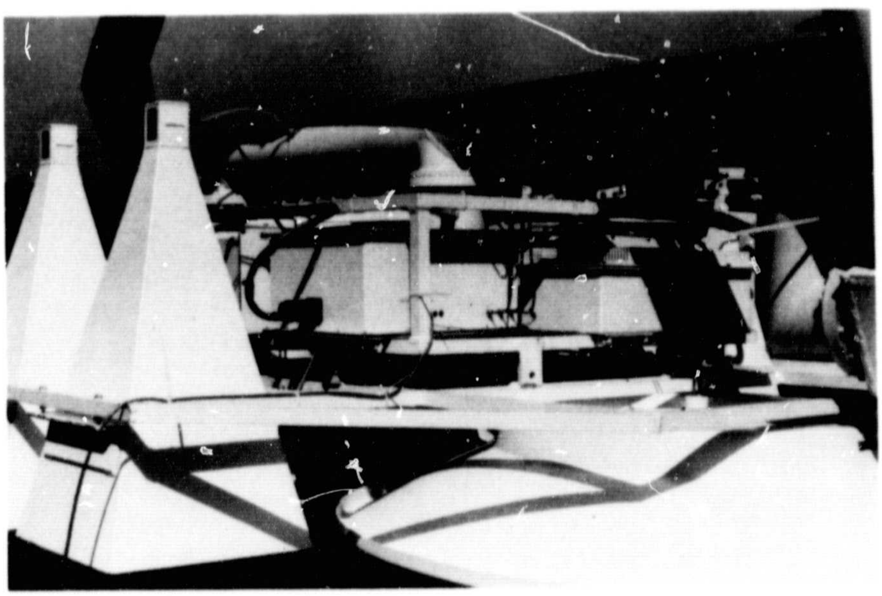

Figure 2. Configurations of the Radar Truss

The truss is mounted on a hydraulically activated boom capable of elevation to 55 feet, and azimuth rotation of 360 degrees. The elevation mechanism is capable of rotating the antennas from nadir to 270°. The angle of elevation is read by an inclinometer placed on the truss. The computer samples the inclinometer reading and converts the number to degrees elevation. This angle may then be displayed to the operator when needed and saved in the recorded data. The elevation system is capable of positioning the antennas to 0.25° of the desired elevation angle. While this is more than adequate for general measurements, calibration measurements of point targets require special considerations. The AC power is obtained from a generator mounted on the boom truck driven by a hydraulic motor.

A separate truck termed the data van houses another computer along with its peripherals which consist of a magnetic tape cartridge drive, dual floppy disk drive, a CRT for operator interface, and a line printer. The computer mounted on the truss is used for control of the radar heads and the IF section (see Figure 3). It also serves the purpose of initializing the system and preparing the RPS for data acquisition. The two computers are linked serially through an RS-232 cable. To summarize, the computer in the data van is used by the operator for selection of radar heads, selection of incident angle, selection of transmission and reception polarization, and storage and manipulation of data either on disk or on tape. The computer on the truss is mainly for monitoring and controlling the internal operation of the RPS.

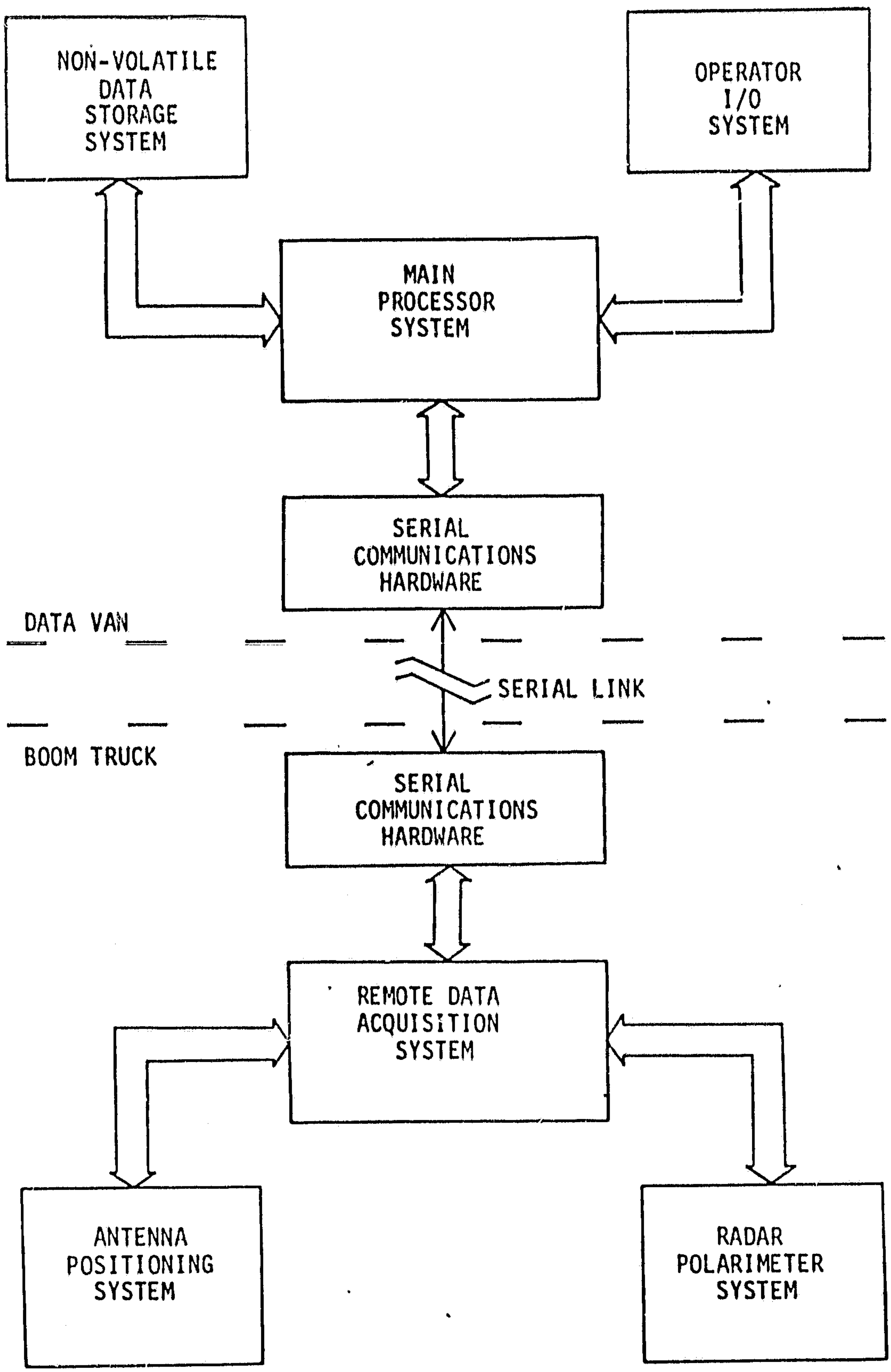

Figure 3: Block diagram of computer system and the peripheral hardware.

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THE IF SECTION

The IF Section of the RPS whose diagram is shown in Figure 4 can be categorized into three distinct subsections; the transmitting analog IF section, the receiving analog IF section, and the digital controller circuit for the IF section.

Each of the subsections is discussed below.

The Analog IF Section (Pulse expander)

As mentioned previously the RPS uses pulse compression techniques to generate high resolution short duration pulses. Due to the available surface acoustic wave (SAW) technology and system bandwidth consideration compressed pulses on the order of 50 nanoseconds are used. This corresponds to a system bandwidth of 20 MHz. The 50 nanosecond pulse also allows the transmitter to shut off for about 50 nanoseconds before the return pulse arrives at the receive antenna. The pulse expansion is accomplished using a Surface Acoustic Wave (SAW) delay line with a bandwidth of 20 MHz centered at 60 MHz. The drive signal required by this device is a pulse of 60 MHz carrier with 50 nanosecond duration. A double balanced mixer is used as a switch in generating this pulse as shown in Figure 5a. The 50 nanosecond pulse is generated on the digital board using synchronous counters. The clock frequency which drives this board is the same 60 MHz used to drive the filter. This guarantees that the mixer is turned on and off at the zero crossing of the 60 MHz signal. Because of the SAW characteristics a 50 nanosecond pulse is expanded to a 5 microsecond pulse. The expanded signal is then amplified and multiplexed into the proper radar head.

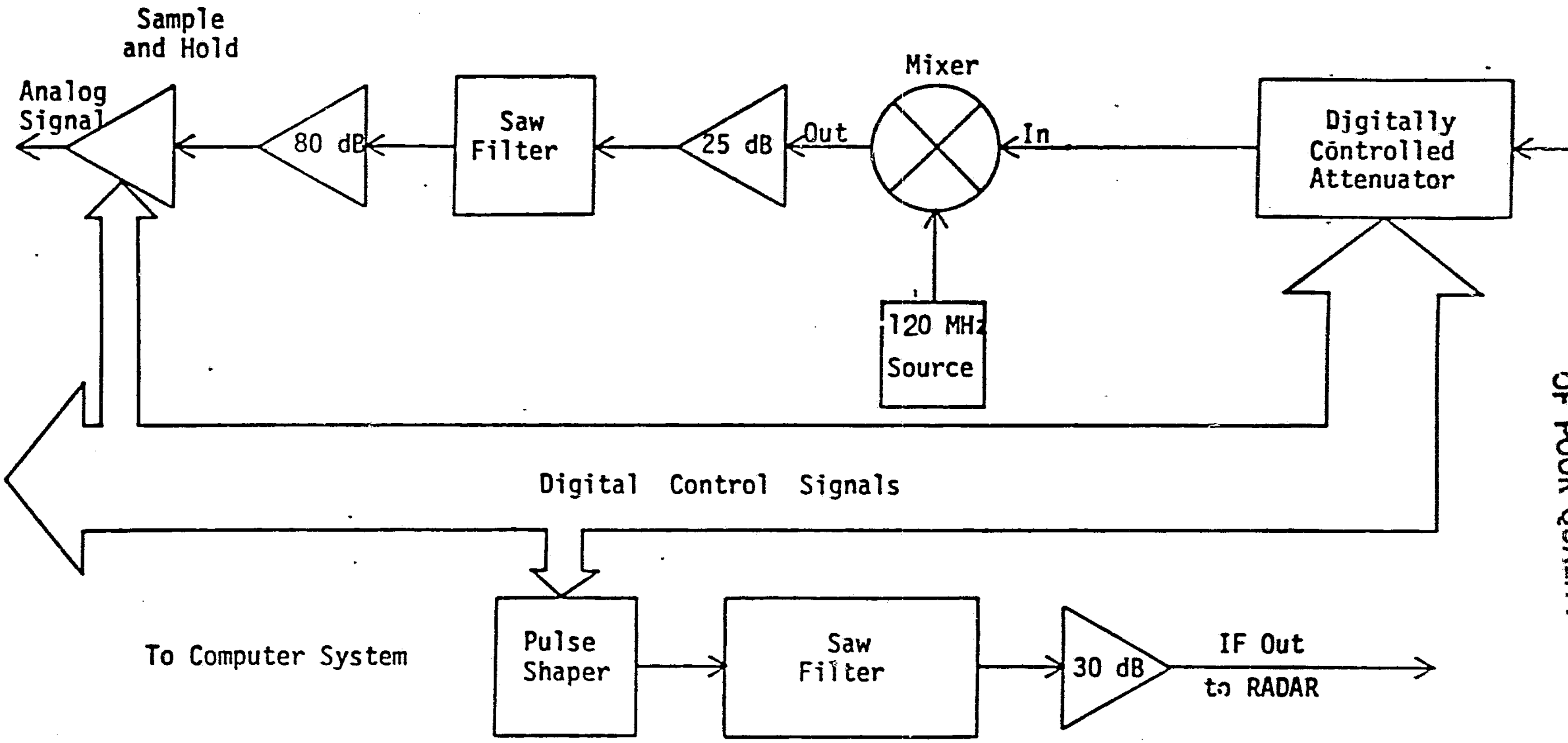

Figure 4 Block diagram of IF section configuration showing communication paths to computer.

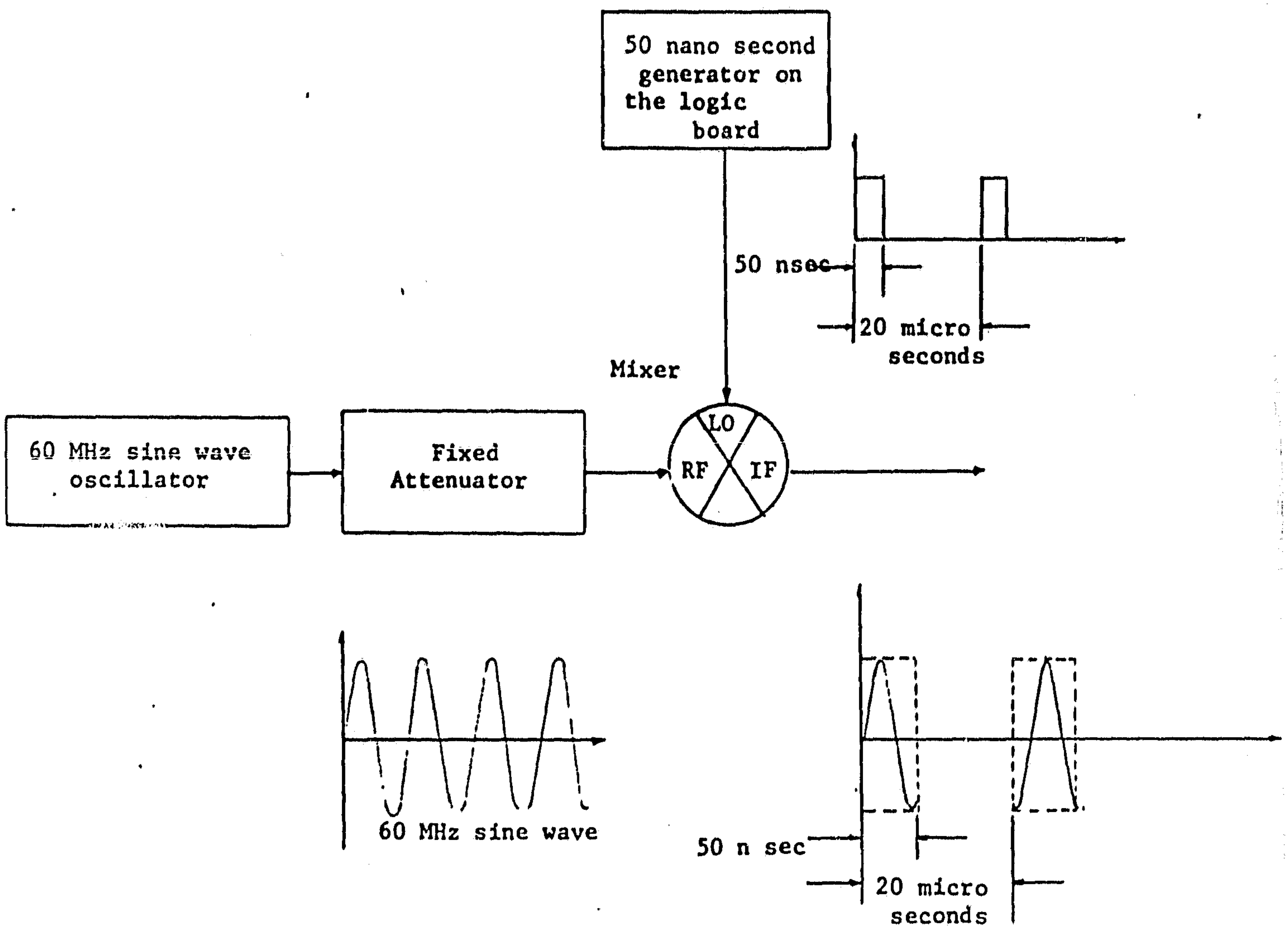

Figure 5a - The pulse generation circuit

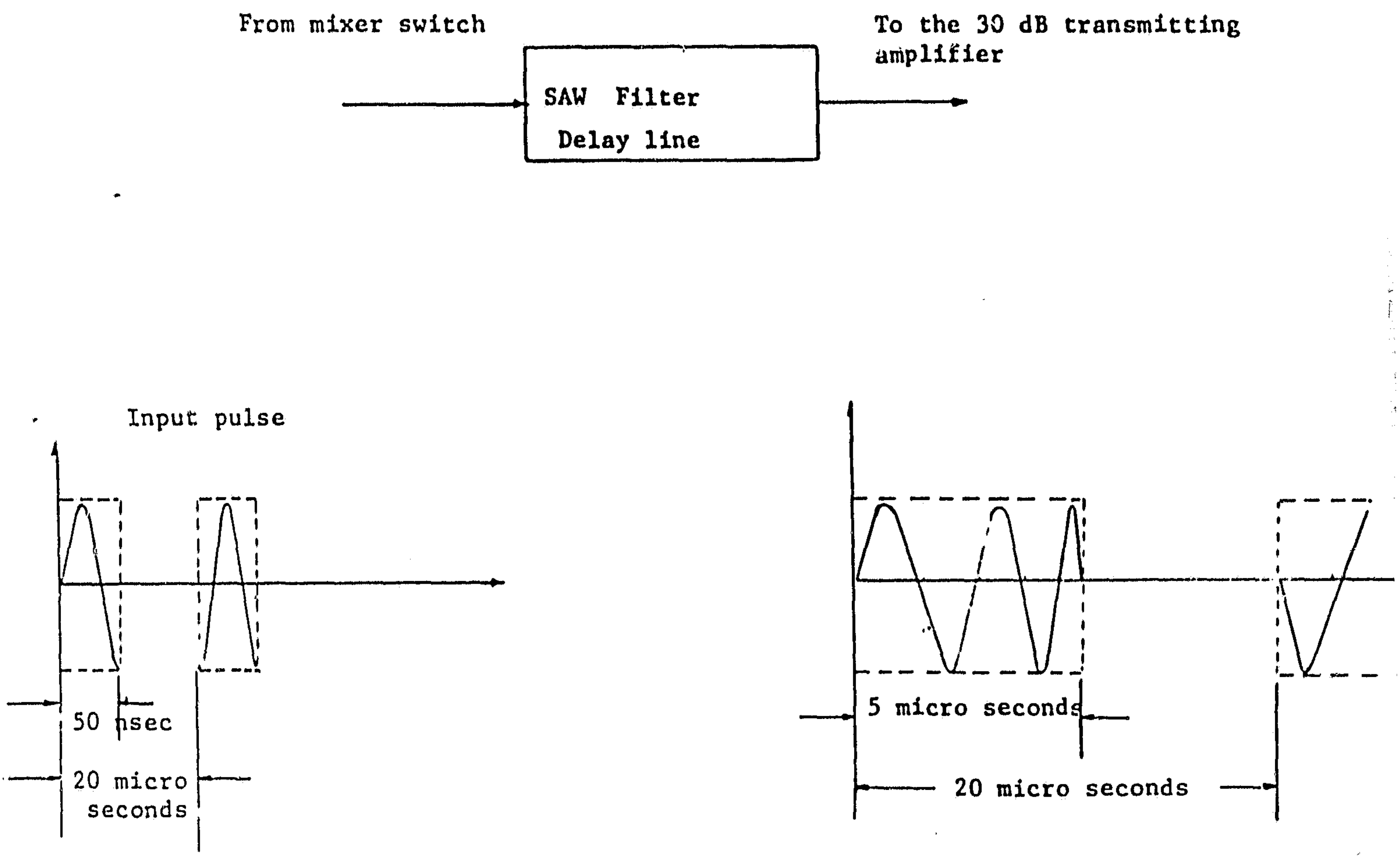

Figure 5b - Pulse Expansion circuit

The Receiving Analog IF Section

The receiving section de-multiplexes the down-converted return radar pulse and prepares the return pulse for compression. It then performs the integration, sample and hold, and scaling such that the output voltage level, which is a representation of the return radar energy, is compatible with the A/D converter on the computer.

After the proper RF head IF output has been multiplexed into the IF receiver section, it is passed through a 7 bit digital attenuator. This attenuator has a total of 53.5 dB attenuation in .5 dB steps. The attenuator specifications give accuracies of .25 dB on the higher attenuator values and $\pm$.1 dB on the lower values. The attenuator is the controllable element in a digital automatic gain control [DAGC] loop. As a result, the system has a capability of 53.5 dB dynamic range. By controlling the attenuator, the output of the system is forced to a predetermined value. The system output is then the digital number used to set of the digital attenuator to the value that will provide this predetermined level.

The IF system uses two identical SAW devices to perform both the pulse expansion and pulse compression. To achieve proper pulse compression, the incoming signal must go through a process call side band swapping. The signal is mixed with a 120 MHz crystal oscillator output as shown in Figure 6a and 6b. The effect of this operation is to take a pulse which has up-chirp (frequency increase with respect to time) characteristics and transform it to a pulse which has down-chirp (frequency decrease with respect to time) characteristics. In this manner, identical SAW filters can be used to both expand and compress the pulse.

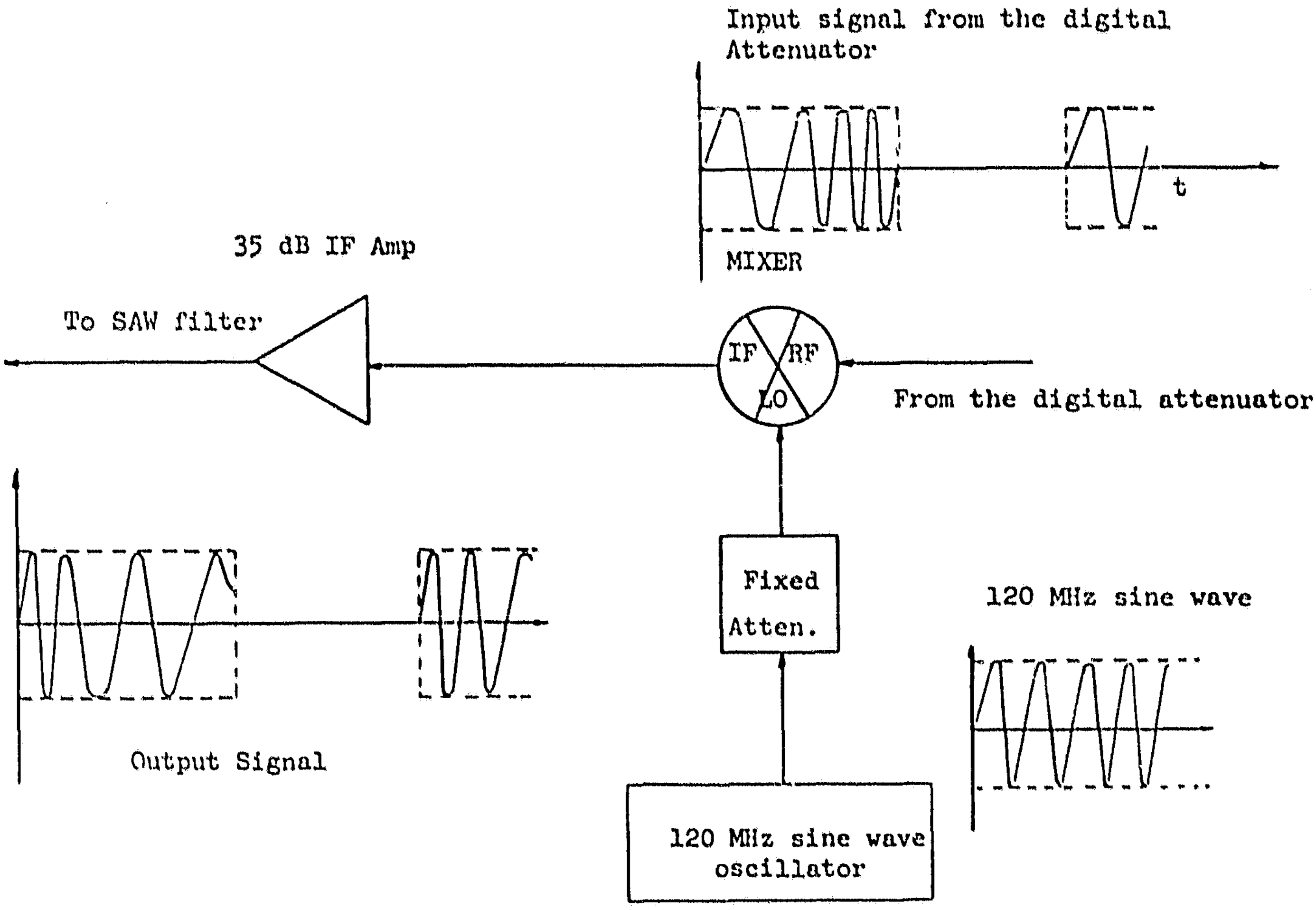

Figure 6a - The side band "swapping" circuit

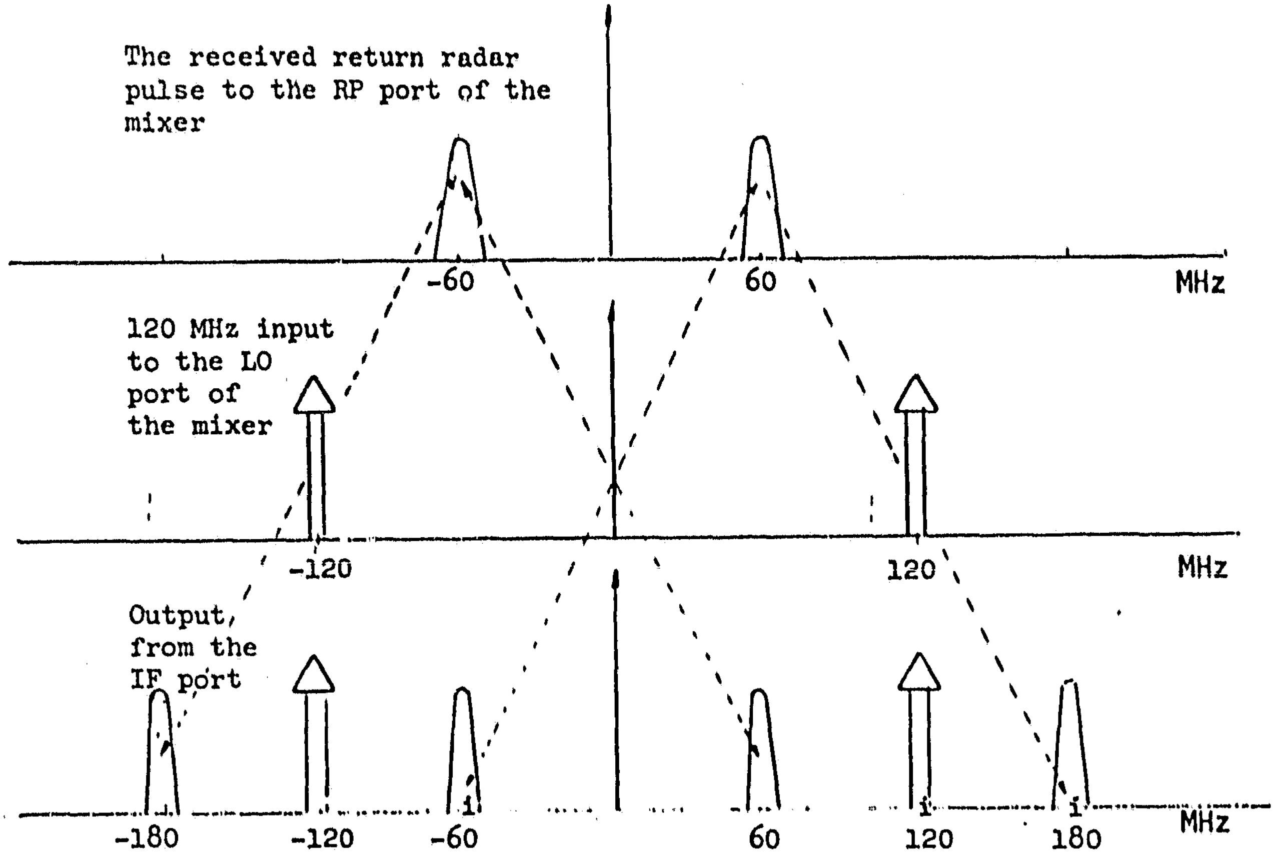

Figure 6 b - The side band "swapping" frequency representation

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The output of the SAW filter in the receive section is the compressed pulse of approximately 50 nanoseconds width (Figure 7a). The pulse is amplified by a low noise (< 1.5 dB NF) 80 dB gain amplifier. This output is passed through a programmable range gate. This circuit is controlled from the computer, has a 5 nanosecond rise time and a pulse resolution of 16.67 nonoseconds. The circuit eliminates unwanted direct feed through from the antennas and extraneous noise inputs from outside the gate window.

Because the energy level in each of the 50 nonosecond return pulses is so low, a very fast high gain integrator is used to bring the voltage to a level that can be handled by the analog to digital converter. The circuit diagram for the integrator is shown in Figure 7b. It's block diagram and signal characteristics are shown in Figure 7c. The output of the integrator is a negatively increasing "staircase". The circuit integrates ten pulses and is then reset to zero to keep the system from saturating. The output of the integrator is sent to the sample and hold circuit to be digitized and stored in the computer. It is this voltage that the DAGC will force to a predetermined value.

The Digital Controller Circuit:

The IF digital controller circuit accepts data from the computer, distributes power, provides timing, monitors the IF section, and controls both the transmitting and the receiving analog IF sections. It also serves the purpose of sending the digitized data

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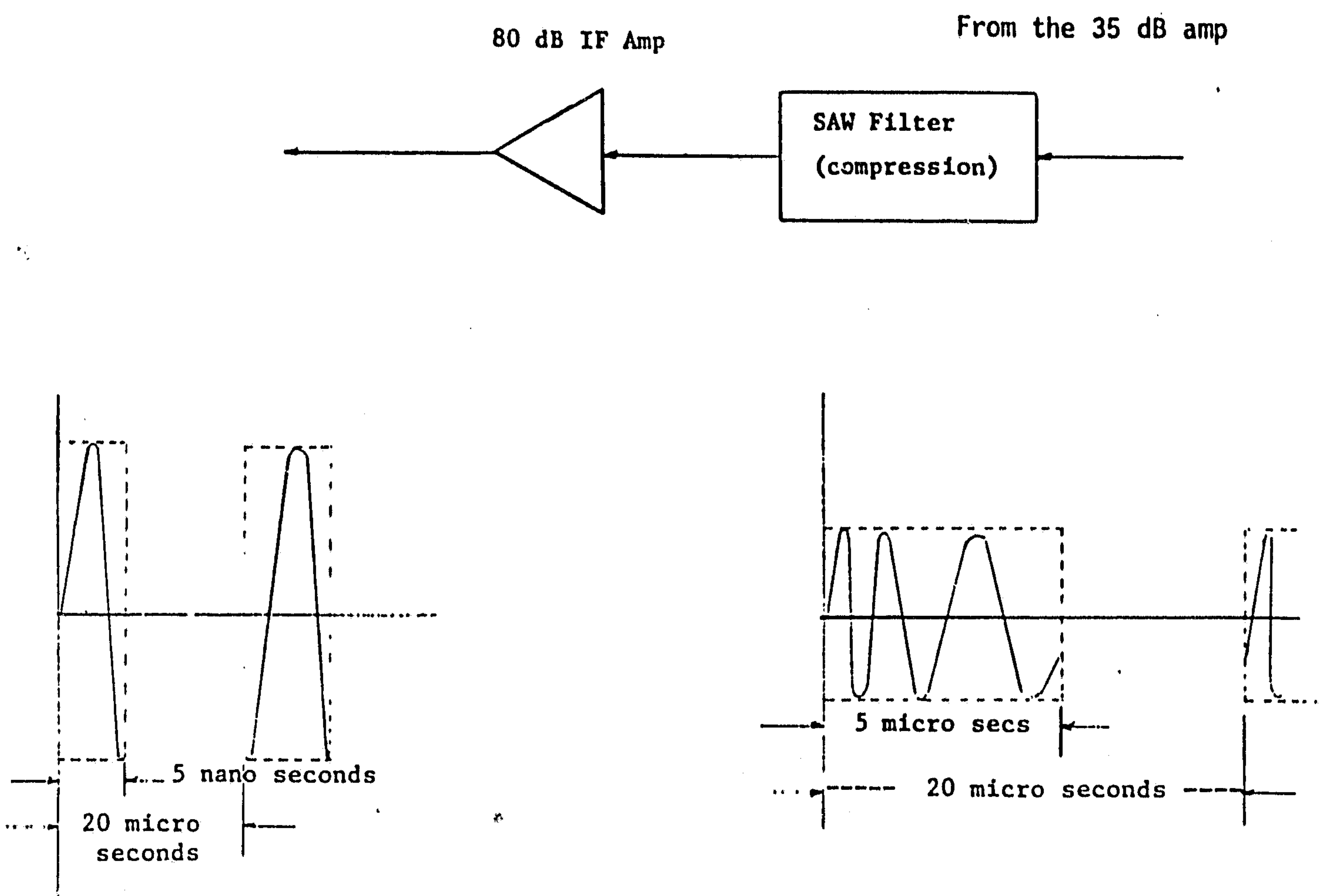

Figure 7a - The pulse compression circuit

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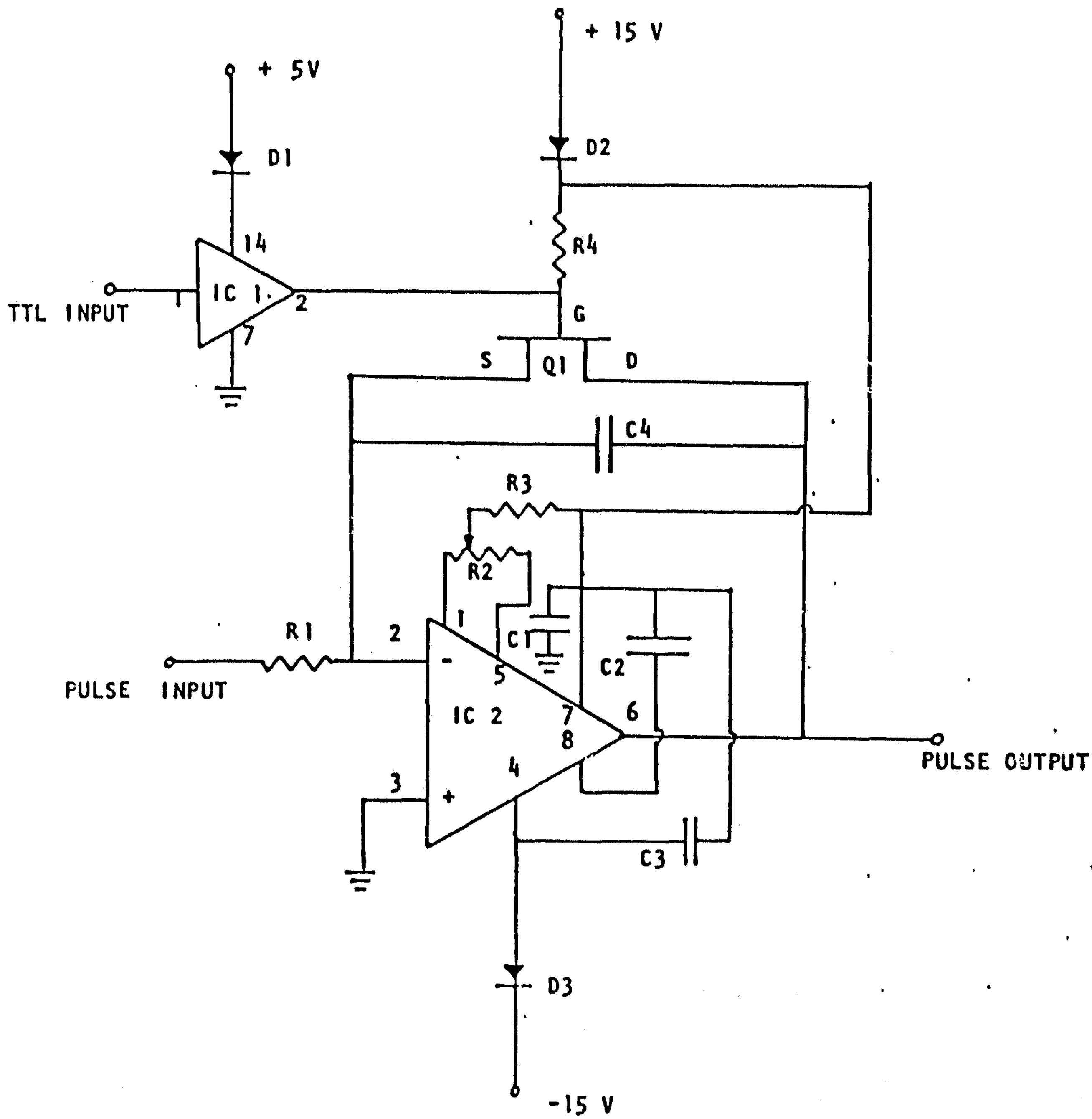

Figure 7b - INTEGRATOR AND RESET CIRCUITRY

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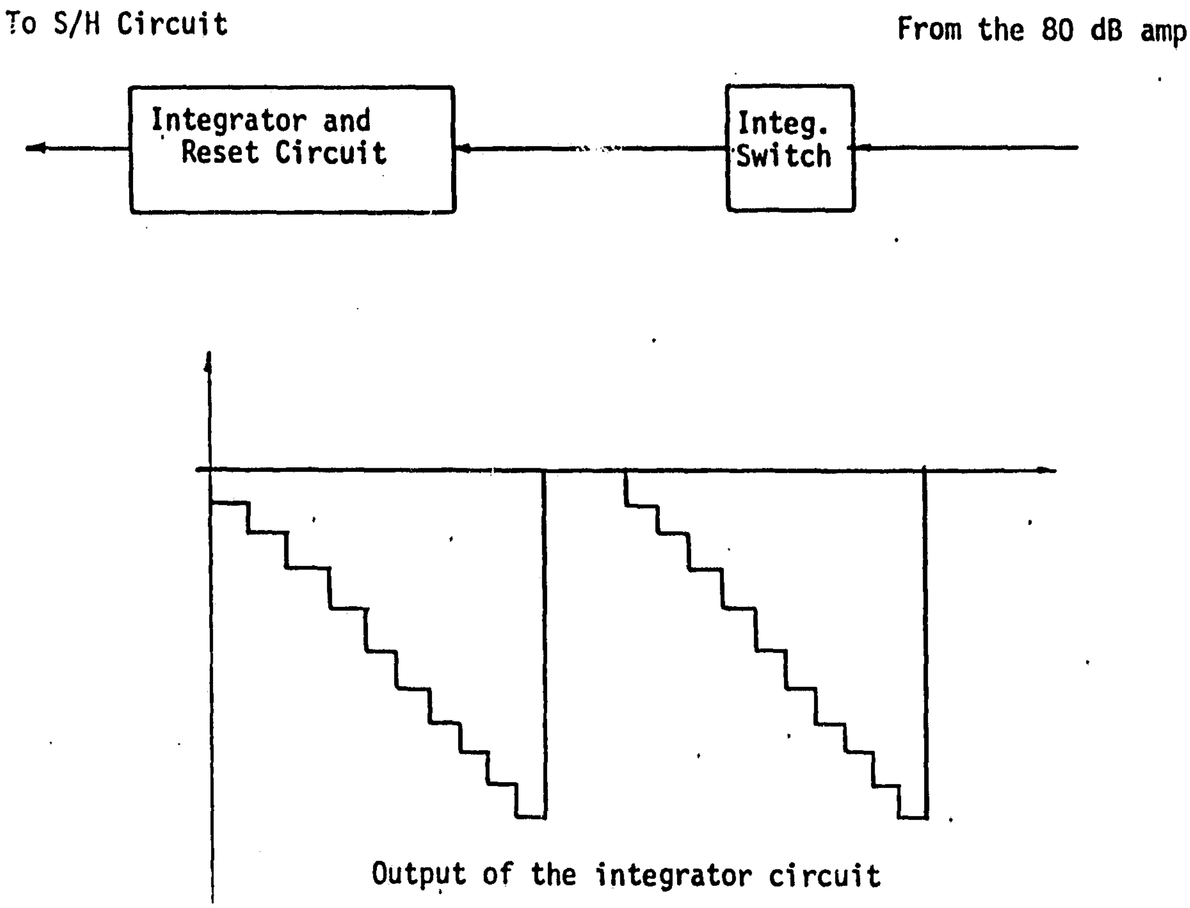
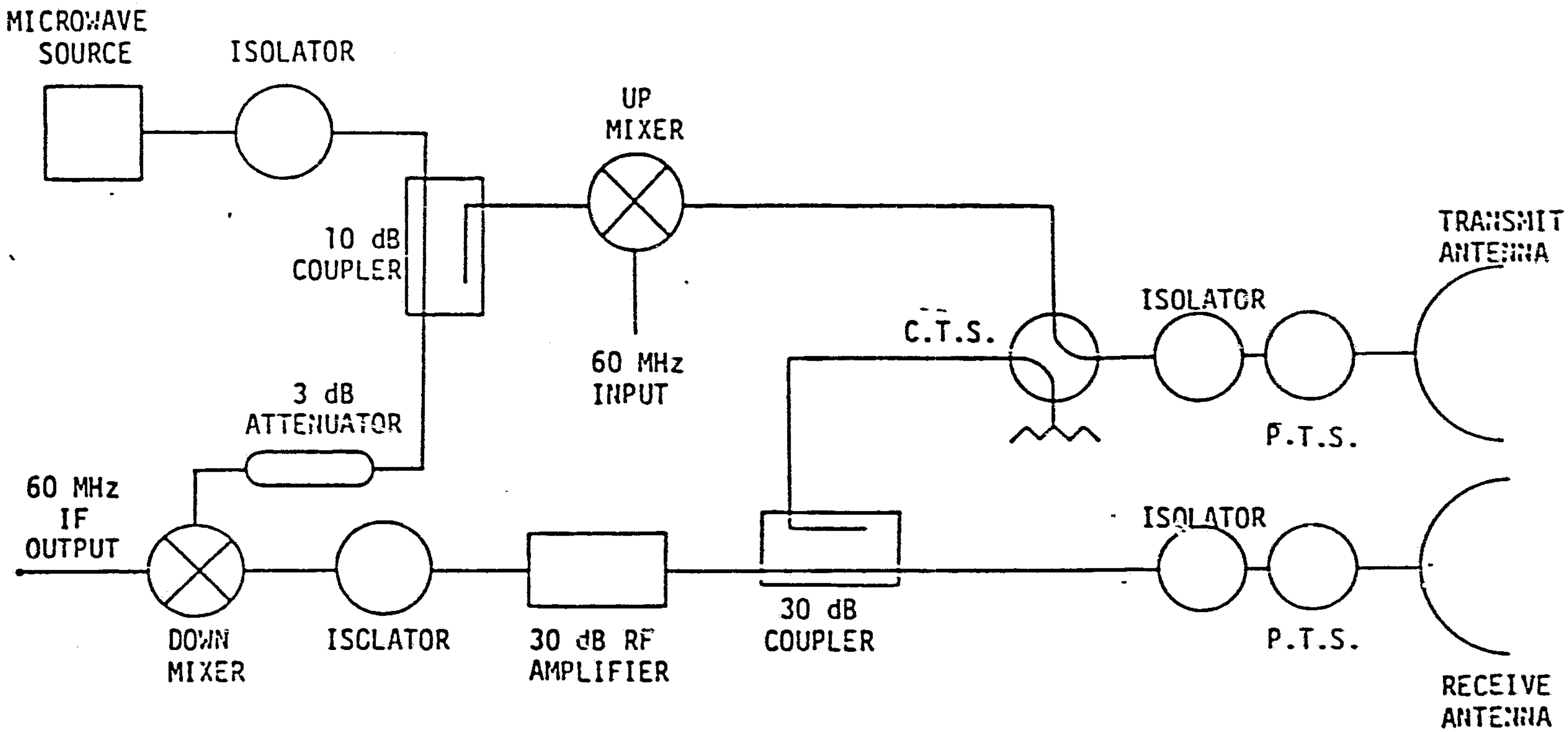


Figure 7c - The energy to voltage conversion process into the computer for storage or further processing. The entire digital controller circuit was implemented on a double-sided 8.5 in. x 10 in. printed circuit board. The logic controller circuit performs the following:

1. Controls the multiplexer switches -- digital signals are generated to select one of the three frequency bands (X, C, or L) where the radar signal will be transmitted.
2. Controls the de-multiplexer switches -- selects one of the three frequency bands from which the radar signal will be received.
3. Controls the digital attenuator -- controls how much attenuation should be put into the return signal in order to maximize the signal to noise ratio but not saturate any of the amplifiers in the IF section. This level is predetermined, but programmable.
4. Controls the integrator, receiver gate, transmit pulse.

THE RADAR HEADS

The radar head section of the RPS consists of the components shown in Figure 8. The microwave source that is used in each radar head correspond to the frequency of operation. An input to the radar head will be an IF signal from the IF section. The signal is then processed through the components shown, and up converted to be transmitted. The diagram also shows the different switches that are controlled by the computer on the truss. These switches are



P.T.S.-POLARIZATION TRANSFER SWITCH
C.T.S.-CALIBRATION TRANSFER SWITCH

Figure 8: Microwave circuitry showing transfer switches which must be controlled by the computer.

mechanical and controlled by a digital signal. A portion of the power from the microwave source is sent back to the IF section through a coupler when the head is in the calibration mode. This step is done to calibrate the system output power.

CHARACTERIZATION OF SELECTED SYSTEM PARAMETERS

This section will be devoted to the calibration procedure of the RPS.It consists of discussions of four topics; determination of the antenna focusing distance that yields the largest intercept area of the transmit and receive antennas the method by which each antenna pair were focused, determination of the minimum detectable signal, characterization of the stability of the radar heads and their transmit power, and documentation of the antenna polarization isolation.

ANTENNA FOCUSING DISTANCE

Using the specified beamwidth of each antenna and an elevation angle of 0 degrees (looking perpendicular to the earth), the area that will be enclosed by the beam can be calculated as shown in Figure 9. The intercept area between the transmit and receive antennas vary with range. The minimum operational range of the system is set by the pulse width of the system,. and indirectly by the height of the boom. Our minimum range at an incident angle of zero degrees is 55 feet, while the maximum range at an incident angle of 60° is 110 feet. Our attempt was to maximize the amount of overlap of the transmit and receive antenna beamwidth for all incident angles of interest. Table 1. presents the results of the calculation. One hundred percent beam-

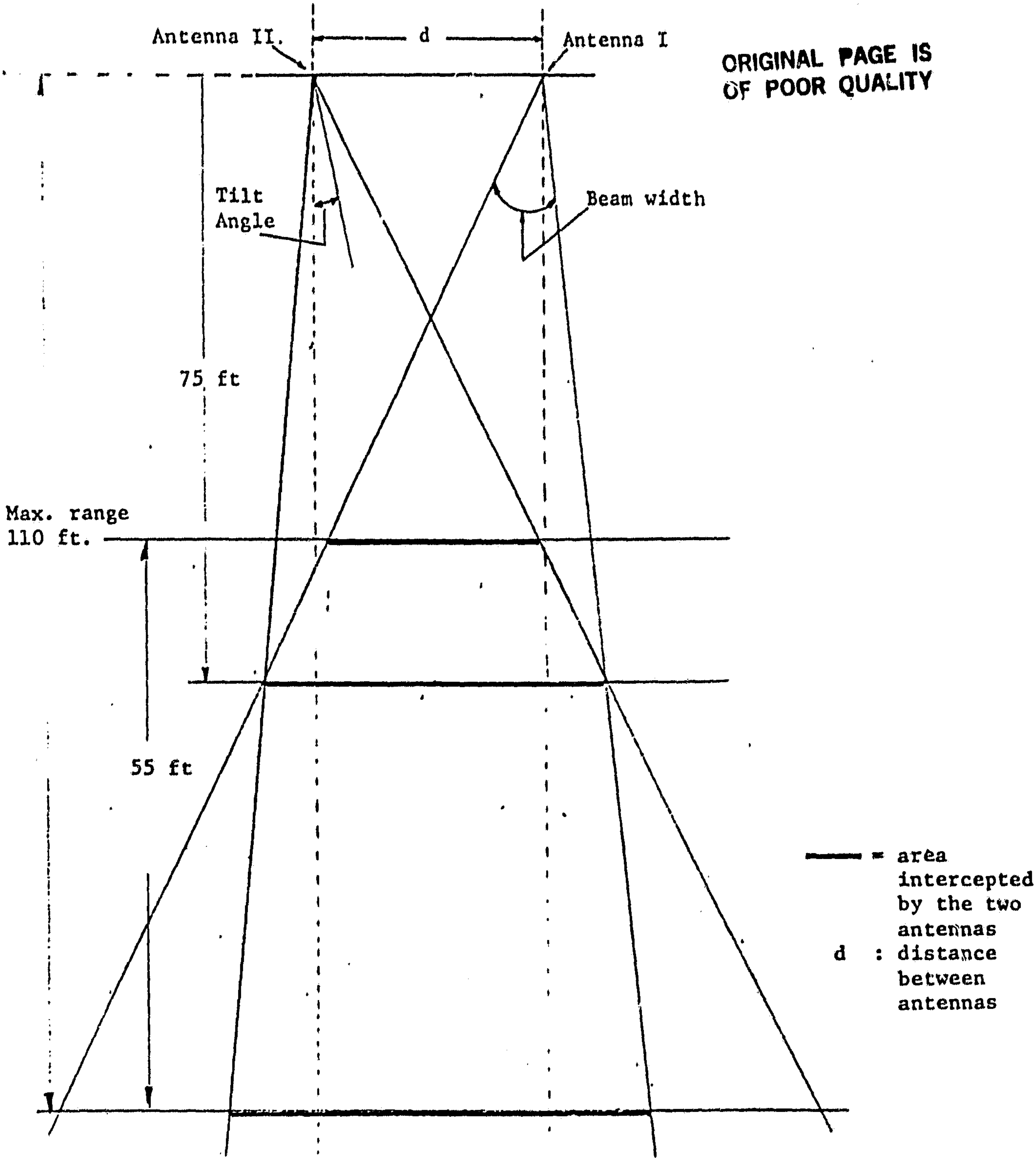


Figure 9 - The triangular method used to estimate the focusing height of the antenna sets.

BAND	FOCUSING HEIGHT	PERCENTAGE OF AREA COVERED	
		AT 55 ft.	110 ft
L	70 ft. (21.3 m)	90 %	88 %
	75 ft. (22.8 m)	91 %	91 %
	80 ft. (24.4 m)	87 %	90 %
C	70 ft. (21.3 m)	96 %	96 %
	75 ft. (22.8 m)	98 %	97.5%
X	70 ft. (21.3 m)	96 %	96.3%
	75 ft. (22.8 m)	96.8%	97 %

Table 1 - Different focusing height with their corresponding percentage of area covered by the two antennas.

width overlap was achieved by focusing the antenna at some nominal midrange value. Calculations of percent overlap were then made at both the minimum and maximum ranges. The results indicate that maximum overlap for all angles occurs when the antennas are focused at 75 feet.

FOCUSING EACH ANTENNA PAIR

Since the RPS employs a dual antenna system for each frequency of operation, the two antennas need to point at a common area. To focus the set of antennas, the method chosen is as follows. An antenna which is similar in characteristics to the ones being focused is placed at a distance of 75 ft. This antenna acting as a transmitter is connected to a source generator at a particular radar frequency. The transmitting antenna is placed perpendicularly and central to the antennas being focused. Figure 10 shows the set up procedure for focusing the antennas. Right triangle relations are used to place the transmitter antenna in the proper place. As seen from the picture, the transmitting antenna is placed on a supporting bracket. It is kept level by use of a bubble level placed on the antenna.

The transmitting antenna will generate a particular power pattern. The idea is to measure the power at the receivers having the same polarization as the transmitter, and try to maximize the received power reading by tilting the antenna in a certain direction. Once the peak power has been obtained, the other antenna in the set will also be adjusted to obtain a peak power reading. Since the two antennas in the set read the peak level with respect to the transmitter, the

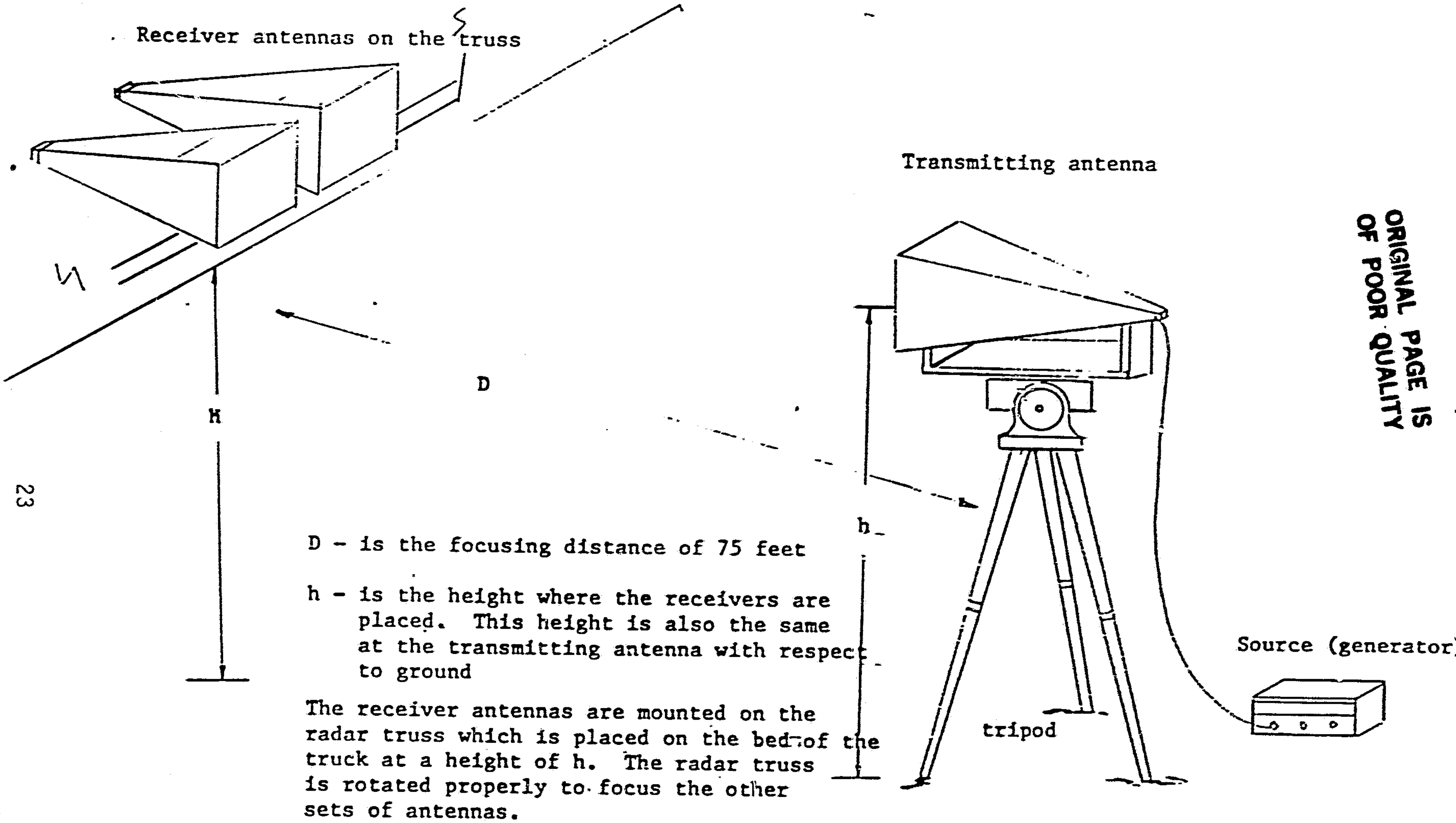


Figure 10 - the set up configuration for focusing the antennas

antennas are at a focusing point with respect to the power pattern generated by the transmitter.

This procedure was repeated for each of the three sets of antennas in the RPS.

Determining the Minimum Detectable Signal

The strength of the return radar pulse is proportional to the voltage level of the integrator output. The integrated values are interpreted as being saturated when the output of the sample and hold circuit (refer to the IF block diagram in Figure 4 previously shown) is -11.0 volts. Recall that it is this voltage that is maintained at a prdetermined level by controlling the digital attenuater. This level currently used is -2.5 volts. The value assures that no saturation will occur in the IF section.

To determine the minimum detectable signal, the digital attenuator is set to its minimum attenuation. A variable attenuator and a 30 db coupler is connected to the transmit port of the radar head. The set-up is shown in Figure 11. The transmit power after attenuation is measured using a spectrum analyzer. At the same time, the output from the 30 dB coupler is fed back to the receiver in the radar head. The variable attenuator is adjusted until the output of the sample and hold circuit is -2.5 V. Once that point is reached, the minimum detectable signal is the power measured at the spectrum analyzer reduced by 30 dB. The measured minimum detectable signals for each radar heads are listed as follows:

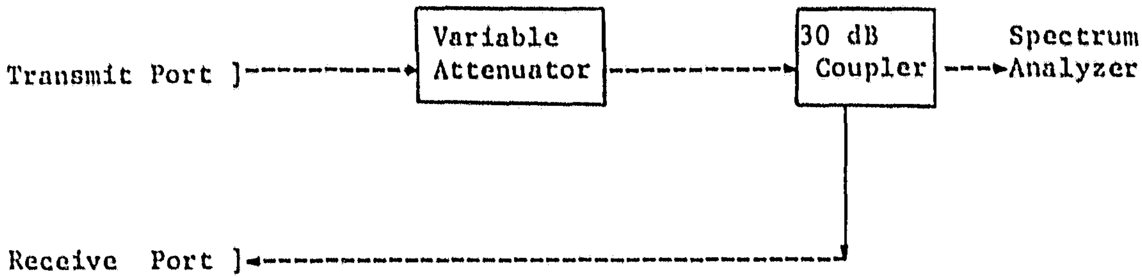


Figure 11 - The set up procedure to measure the minimum detectable signal

The Minimum detectable signal is the signal measured at the spectrum analyzer subtracted by 30 dB.

X-Band $P_{received} = -84$ dBm

$P_{transmit} = -24$ dBm

C-Band $P_{received} = -97$ dBm

$P_{transmit} = -10$ dBm

L-Band $P_{received} = -96$ dBm

$P_{transmit} = -8$ dBm

Table 2 - Measured Minimum Detectable Signals and Typical Output Power

	X Band	C Band	L Band
Power transmitted	-14 dBm	- 9 dBm	- 8 dBm
Min. Det. Signal	-84 dBm	-94 dBm	-97 dBm

From the measured values of the minimum detectable signals, an approximation of the radar cross section can be obtained. This is done by placing the appropriate system constants into the radar equation and solving for the radar cross section utilizing the minimum detectable power as the received power. The antenna gains were calculated based upon their operating frequencies, and both the transmit and receive antennas were assumed to have the same gain in each case. Approximate values of the minimum detectable radar cross section were computed at different ranges. These are shown in Table 3.

RF HEAD STABILITY

To determine the stability of the radar heads in terms of their transmit power and calibration power, the RPS was kept running for a

	S_o at 55 ft	S_o at 75 ft	S_o at 110 ft
L-Band	-45.13 dBm	-41.09 dBm	-35.65 dBm
C-Band	-50.63 dBm	-49.63 dBm	-44.30 dBm
X-Band	-33.81 dBm	-29.77 dBm	-25.27 dBm

Note: The calculations of the S_o at different height are based upon a constant return power.

Table 3 - Radar cross section calculation for the three different radar frequencies

period of 5 hours in the laboratory. A power meter was used to measure the transmit power, while a spectrum analyzer was used to measure the calibration power. Both systems were calibrated to a common source. Tables 4, 5 and 6 show both of the power measurements taken approximately every 15 minutes over a period of 5 hours. It can be seen that the power level on both ports are generally invariant with time. The transmit power in X Band is significantly lower than the other two because of an inoperative diode in the mixer, justifying the low reading. The power levels on all the radar heads are within the specification of the RPS, as seen from the radar cross-section values shown earlier.

POLARIZATION CHARACTERISTICS OF RPS ANTENNAS

The antenna characteristics of the RPS system are shown in Figures (8a-8L). These normalized antenna pattern plots also document the polarization isolation characteristics for each operational frequency. The worst case system is the X Band with 29 dB isolation in vertical polarization. The best antenna set is the L Band with better than 36 dB isolation across the entire beam width. The L Band dishes have the poorest antenna direct feedthrough.The X-band and C-band horns have no detectable transmitter/receiver crosstalk.

FREQUENCY : X BAND (10.0 GHz)

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TRANSMITTING POWER

VERTICAL DBM	HORIZONTAL DBM	CALIBRATION POWER DBM
-17.0	-17.0	-26.0
-17.0	-17.0	-26.5
-17.0	-17.5	-28.0
-17.5	-17.9	-28.0
-18.0	-18.0	-28.5
-18.0	-18.0	-30.0
-18.0	-18.0	-33.0
-18.2	-18.2	-33.0
-18.4	-18.2	-33.0
-18.4	-18.4	-33.0
-18.4	-18.5	-33.0
-18.4	-18.5	-33.0
-18.5	-18.5	-33.0
-18.5	-18.5	-33.0
-18.5	-18.5	-33.0
-18.6	-18.6	-33.2

Table 4 - Power measurement of the X Band radar head

FREQUENCY : L BAND (1.6 GHz)

TRANSMITTING POWER

VERTICAL DBM	HORIZONTAL DBM	CALIBRATION POWER
-8.0	-8.0	-58.0
-8.0	-8.0	-58.0
-8.0	-8.0	-58.0
-8.0	-8.0	-58.0
-8.0	-8.0	-59.0
-8.1	-8.1	-59.0
-8.1	-8.1	-59.0
-8.2	-8.2	-59.0
-8.2	-8.2	-59.0
-8.2	-8.2	-59.0
-8.25	-8.25	-59.0
-8.3	-8.3	-59.0
-8.3	-8.3	-59.0
-8.3	-8.3	-59.0
-8.3	-8.3	-59.0
-8.3	-8.3	-60.0

Table 5 - Power measurement of the L Band radar head

FREQUENCY C BAND (4.75 GHz)

TRANSMITTING POWER :

VERTICAL DBM	HORIZONTAL DBM	CALIBRATION POWER DBM
-8.0	-8.0	-38.0
-8.0	-8.0	-38.0
-8.0	-8.0	-38.0
-8.125	-8.2	-38.0
-8.2	-8.2	-38.2
-8.2	-8.2	-38.2
-8.3	-8.2	-38.8
-8.5	-8.3	-39.0
-8.5	-8.3	-39.0
-8.6	-8.4	-39.0
-8.6	-8.4	-39.0
-8.6	-8.5	-39.0
-8.6	-8.4	-39.0
-8.6	-8.5	-39.0
-8.6	-8.5	-39.0
-8.6	-8.55	-39.0

ALL POWERS ARE MEASURED BY USING THE POWER METER OVER A PERIOD OF 4.5 HOURS.

Table 6 - Power measurement of the C Band radar head

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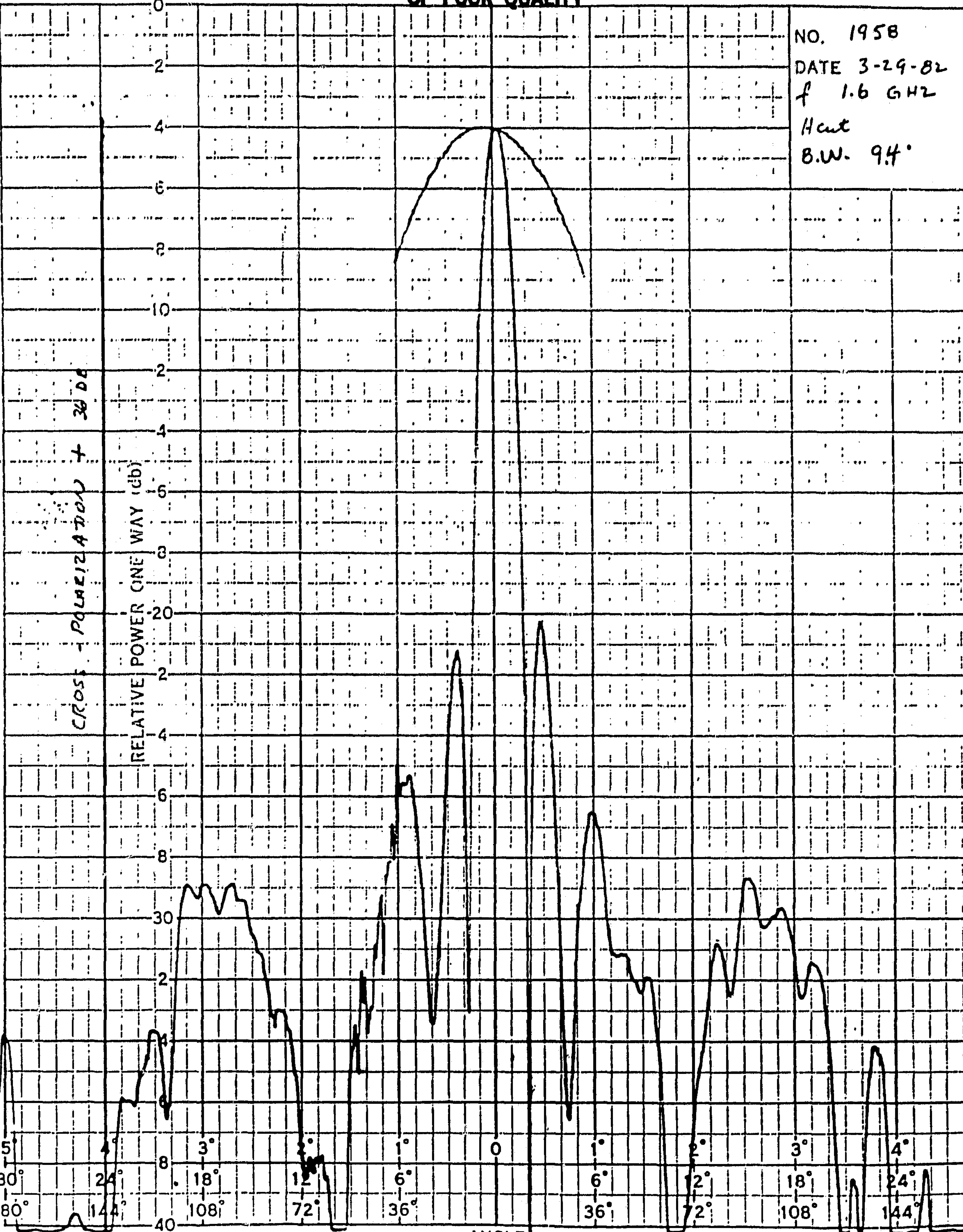

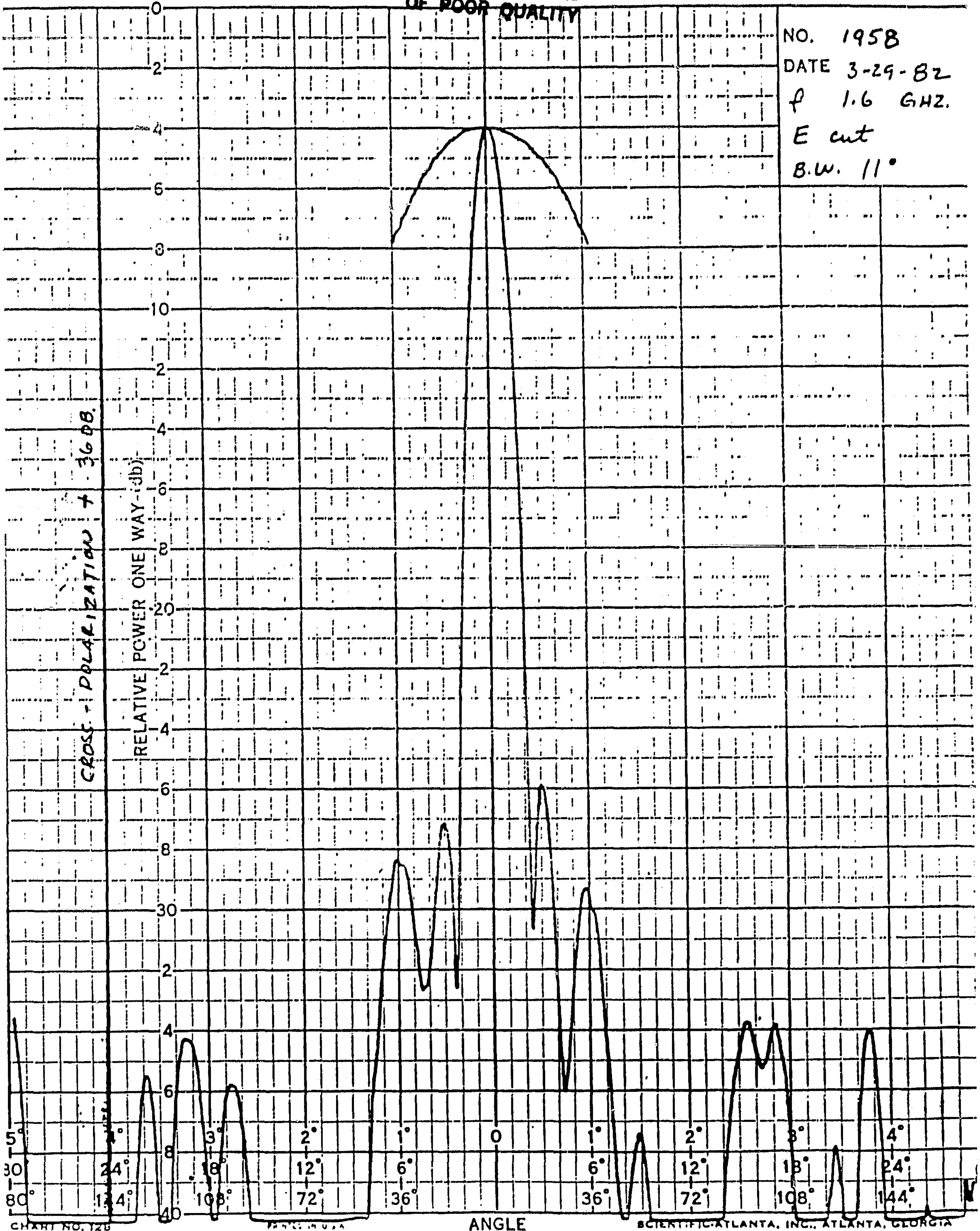
NO. 1958
DATE 3-29-82
f 1.6 GHZ.
E cut
B.W. 11°
CROSS - POLARIZATION + 36 DB.
RELATIVE POWER ONE WAY (db)
0
2
4
6
8
10
20
30
40
ANGLE
5°
4°
3°
2°
1°
0
30
24°
18°
12°
6°
180°
144°
108°
72°
36°
CHART NO. 120
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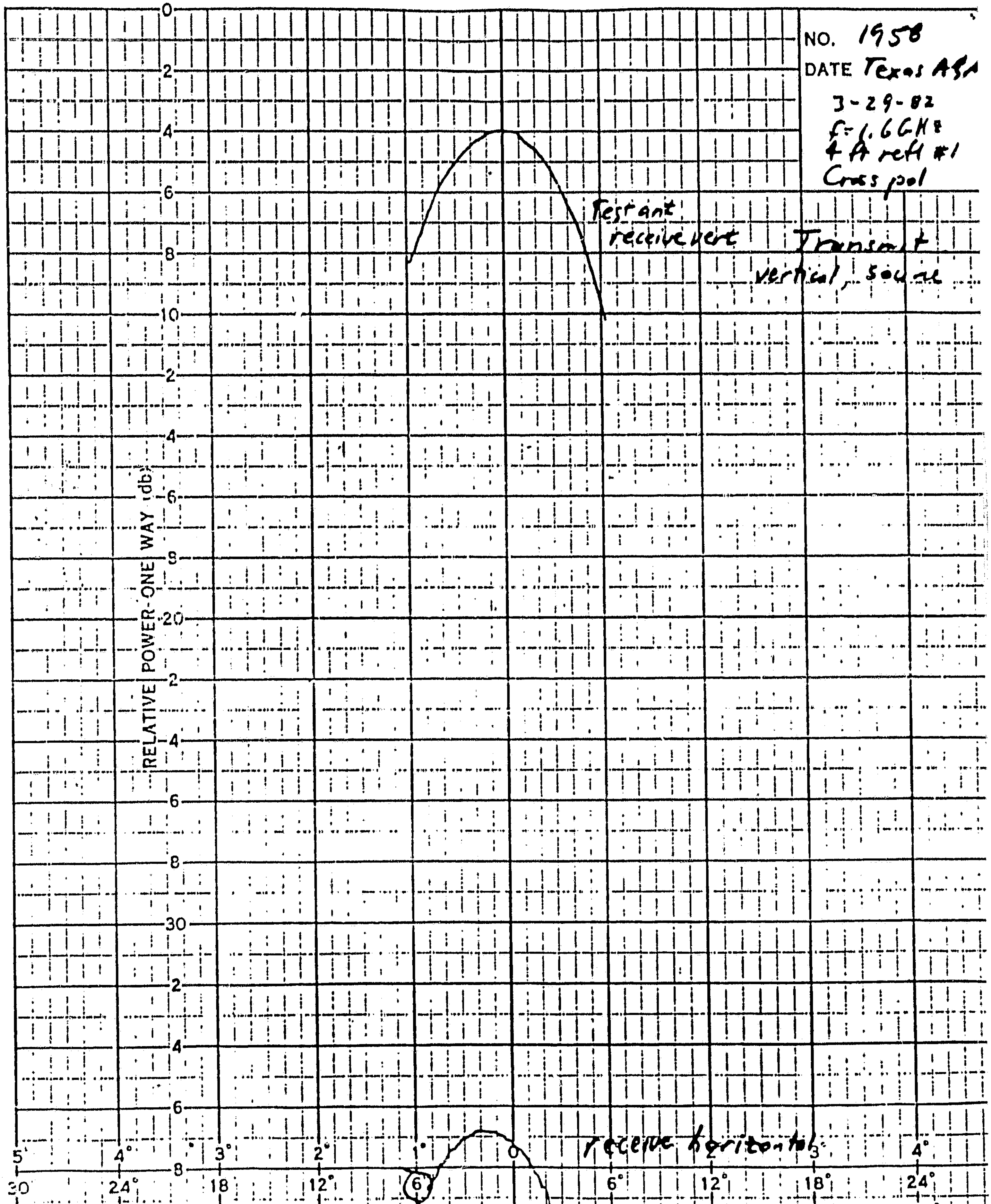
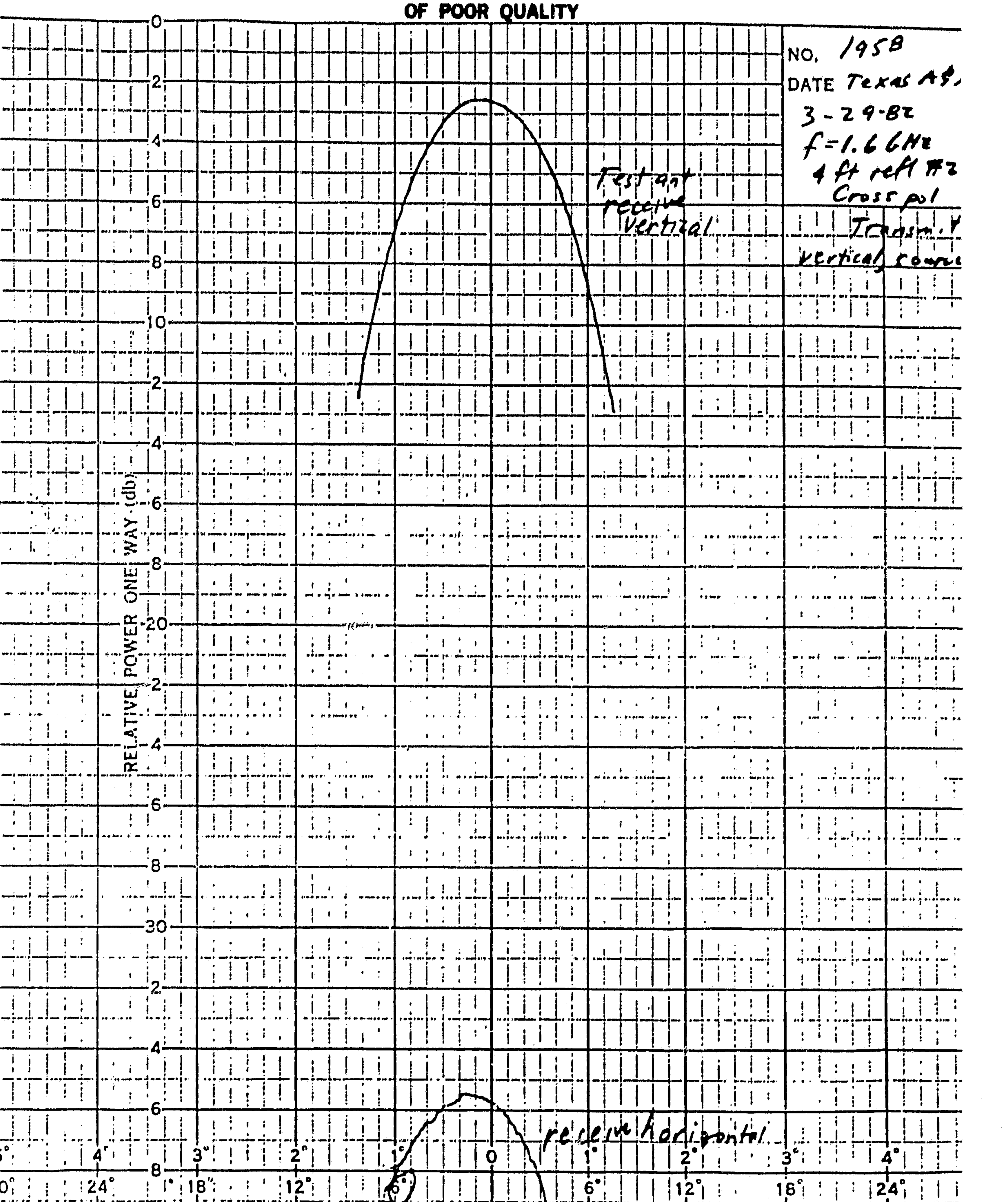
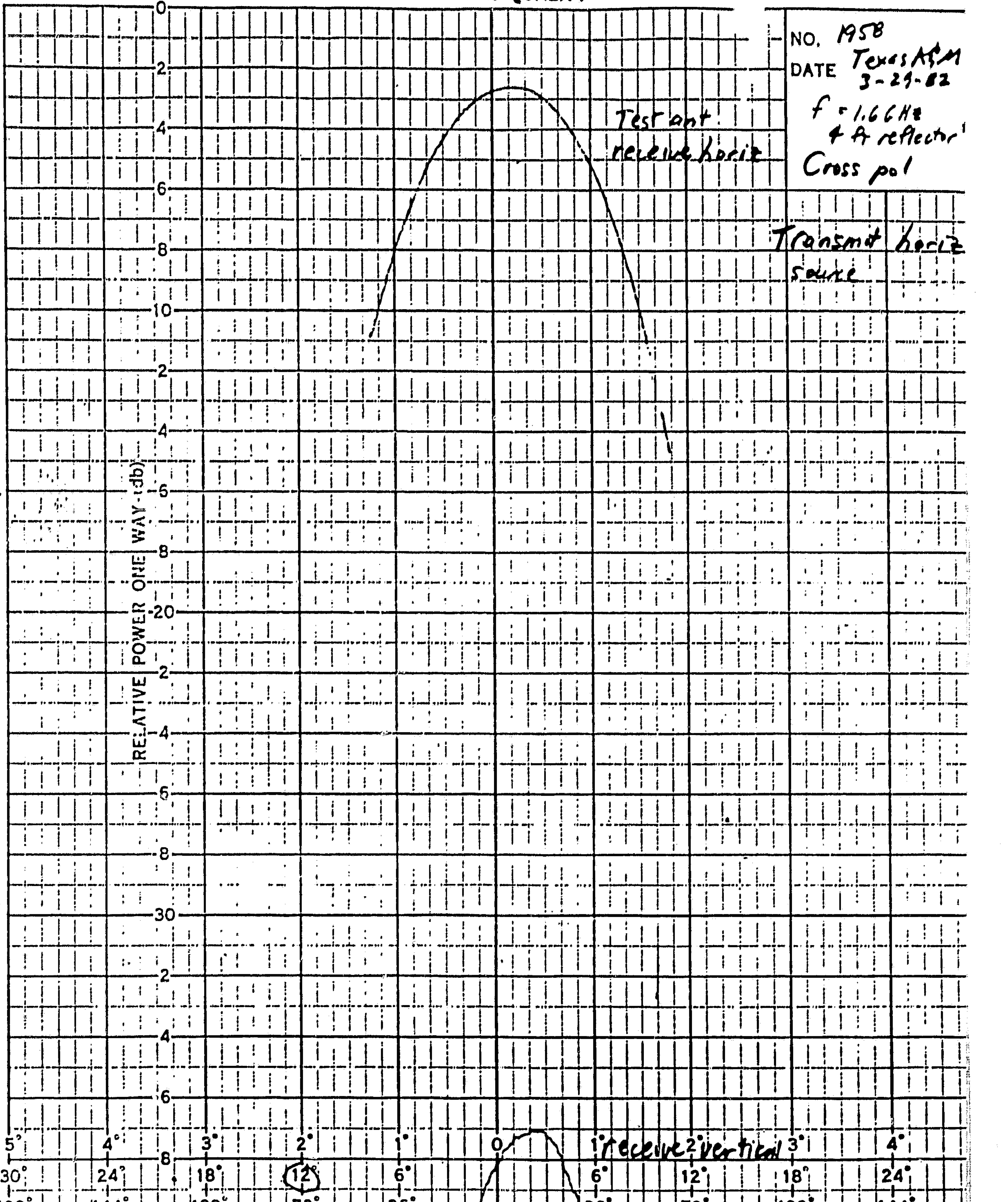
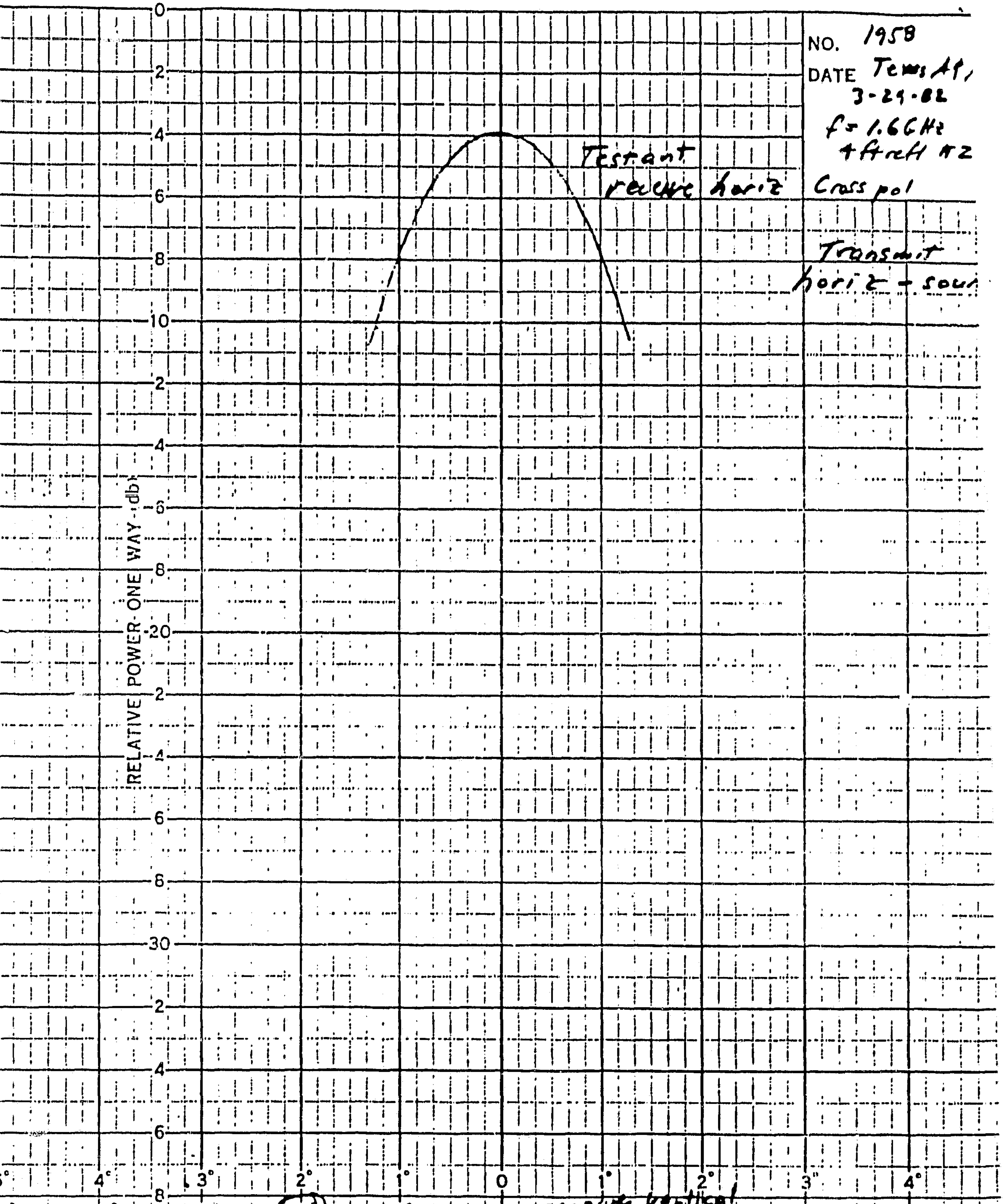



NO. 1958
DATE Texas A&M
3-29-82
f=1.6 GHz
4 ft refl #2
Cross pol
Test ant
receive
vertical
receive horizontal
RELATIVE POWER ONE WAY (db)


NO. 1958
DATE Texas A&M 3-29-82
f = 1.6 GHz
4 ft reflector
Cross pol
Test ant receive horiz
Transmit horiz source
receive vertical
RELATIVE POWER ONE WAY (db)


NO. 1958
DATE Texas At, 3-29-82
f= 1.6GHz
4ft refl #2
Cross pol
Testant
receive horiz
Transmit
horiz - sour
RELATIVE POWER-ONE WAY-(db)
0
2
4
6
8
10
20
30
4°
3°
2°
1°
0
1°
2°
3°
4°

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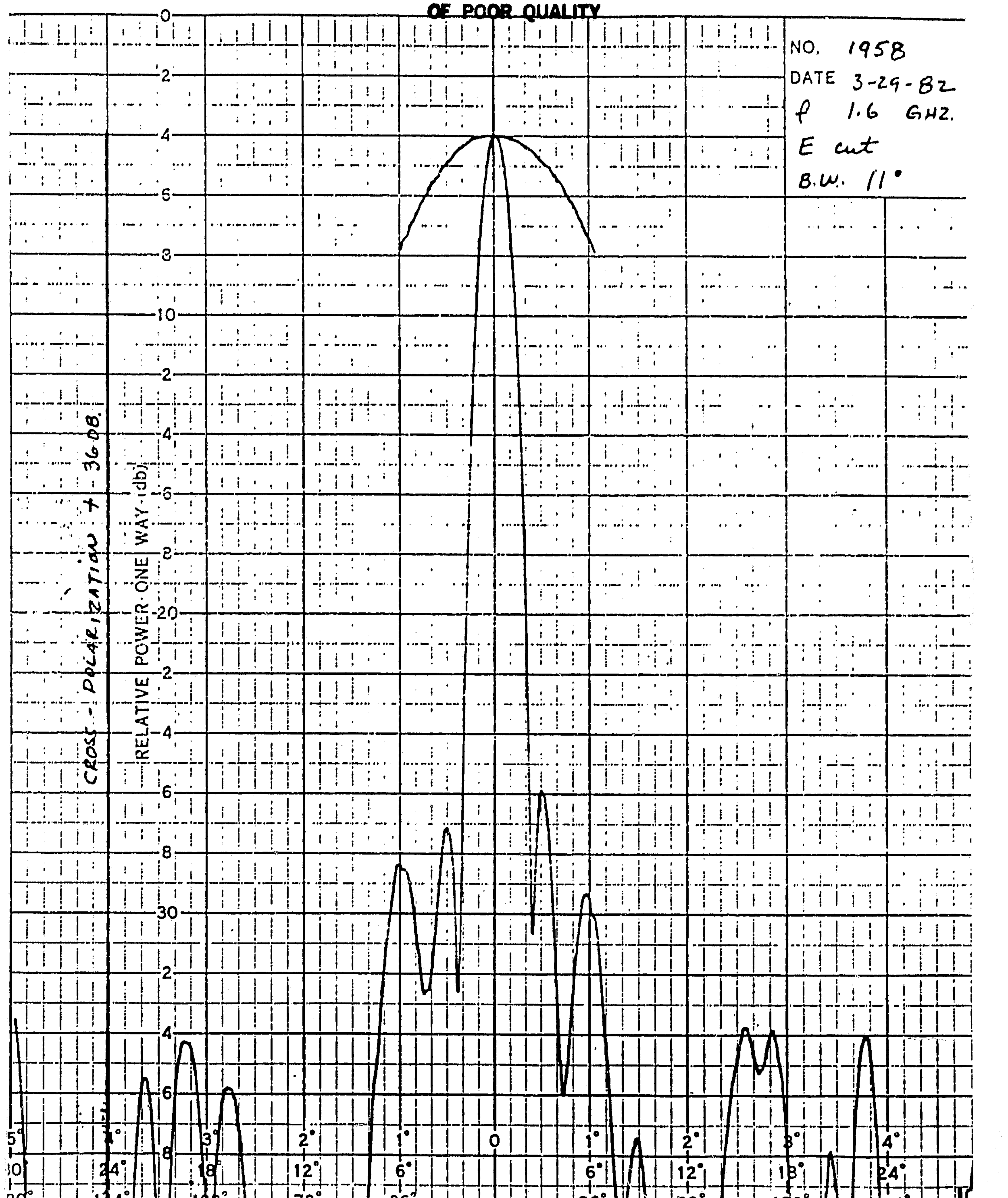

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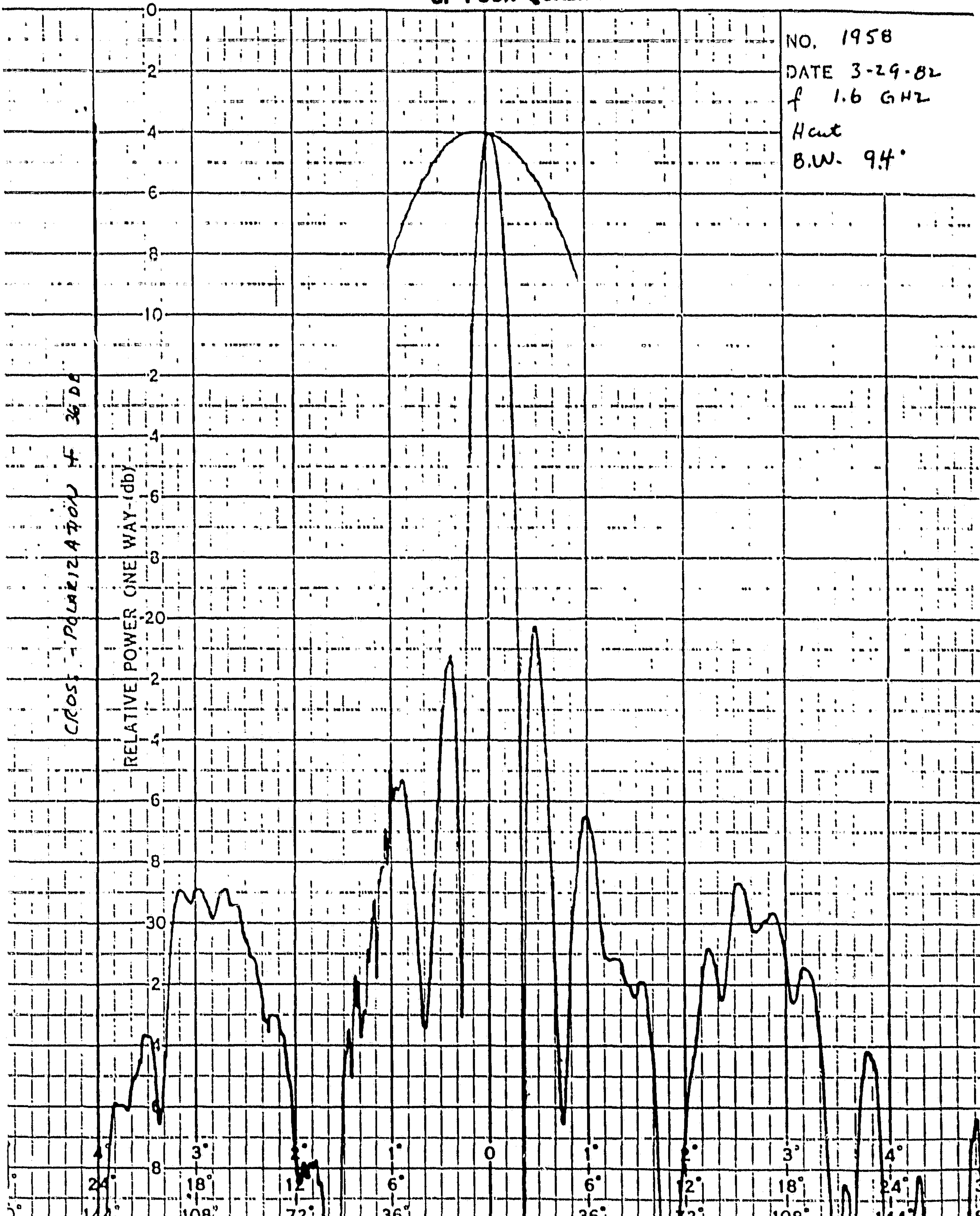

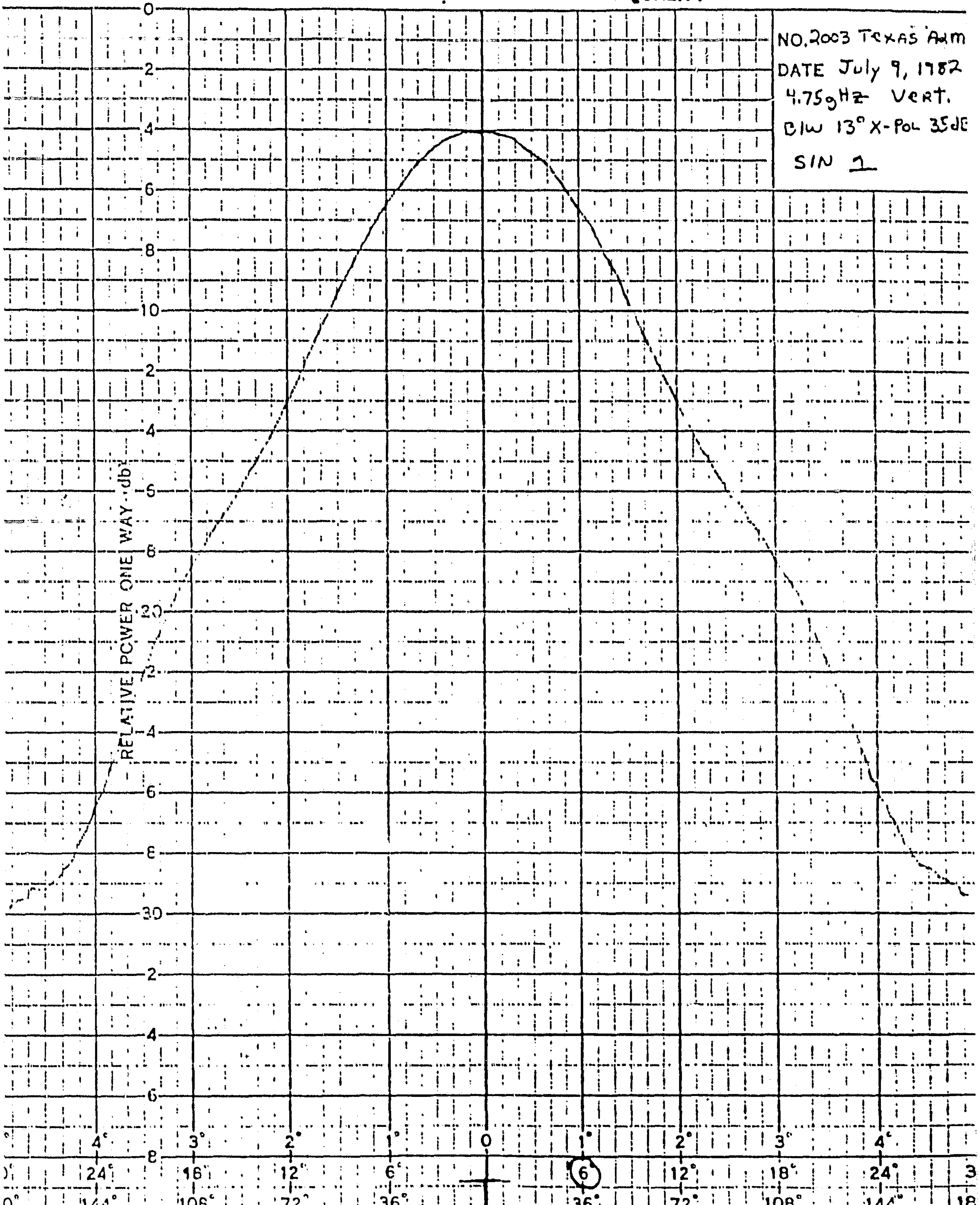
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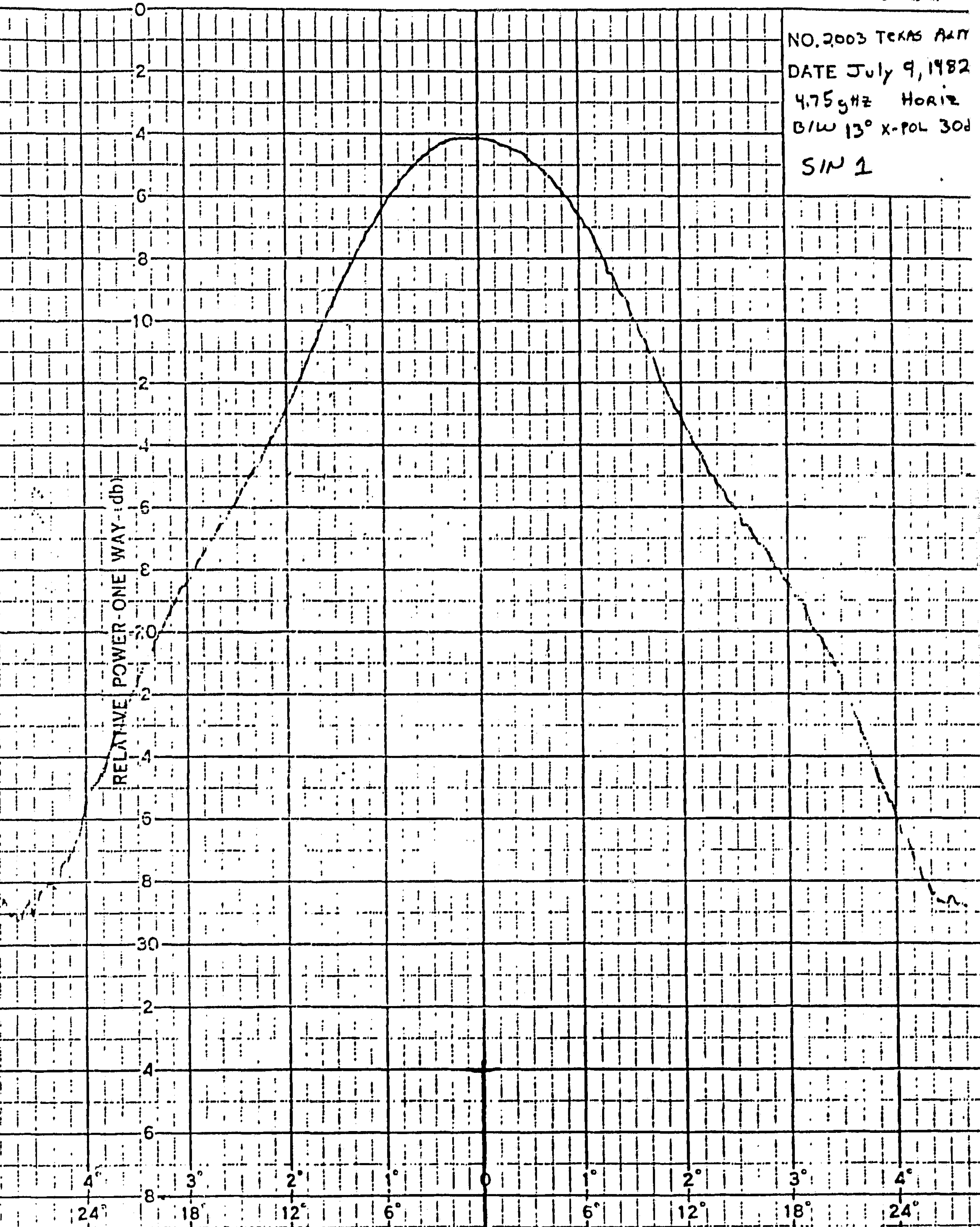
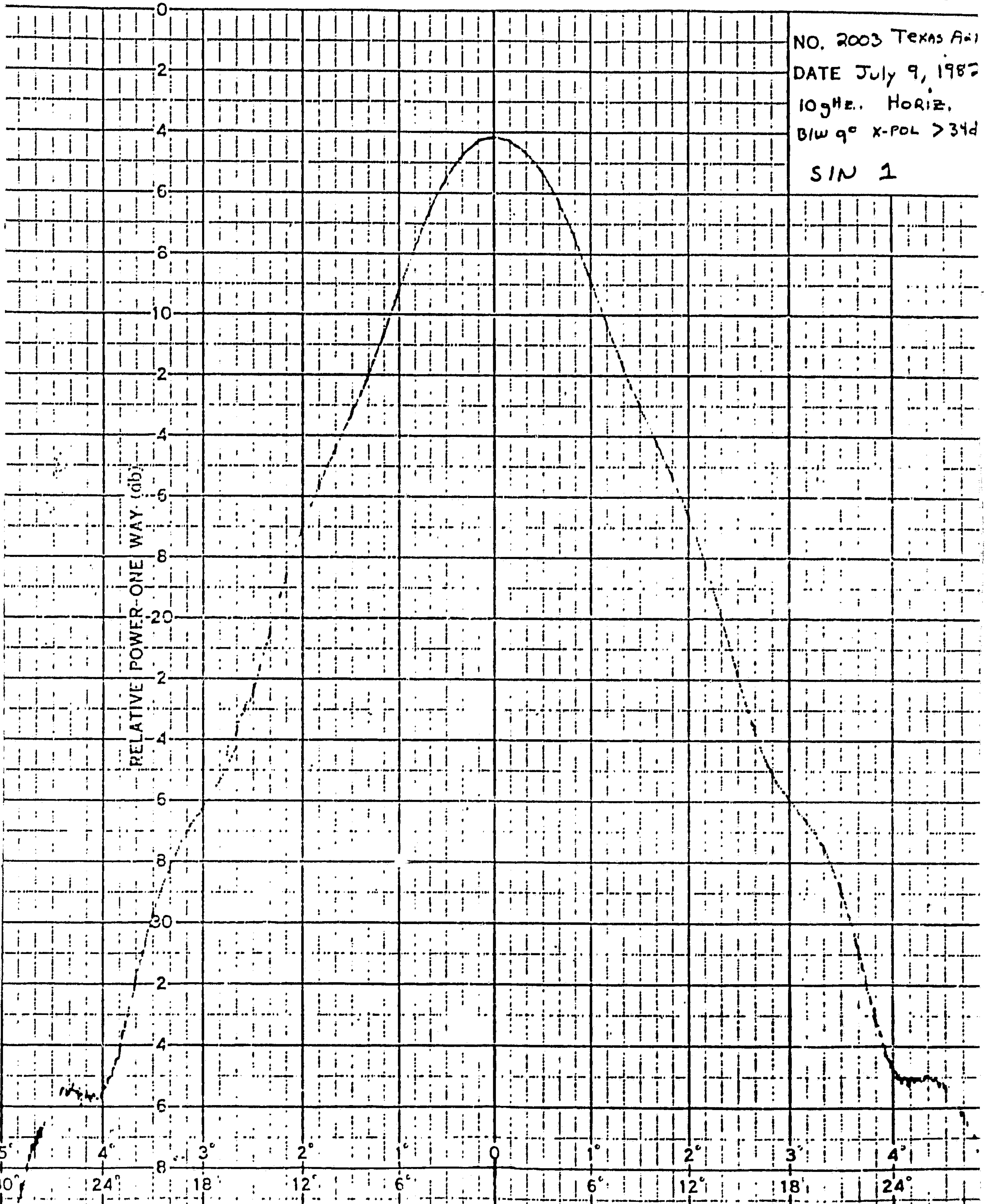
DATE July 9, 1982
4.75gHz Vert.
B/W 13° X-Pol 35dB
S/N 1
RELATIVE POWER ONE WAY db


NO. 2003 TEXAS A&M
DATE July 9, 1982
4.75 gHz HORIZ
B/W 13° X-POL 30d
S/N 1
RELATIVE POWER-ONE WAY-(db)
0
2
4
6
8
10
2
4
6
8
20
2
4
6
8
30
2
4
6
8
4°
3°
2°
1°
0
1°
2°
3°
4°
24°
18°
12°
6°
6°
12°
18°
24°


NO. 2003 Texas A&M
DATE July 9, 1982
10 gHz. HORIZ.
B/W 9° X-POL >34d
SIN 1
RELATIVE POWER-ONE WAY (db)
0
2
4
6
8
10
2
4
6
8
20
2
4
6
8
30
2
4
6
8
5°
4°
3°
2°
1°
0
1°
2°
3°
4°
30'
24'
18'
12'
6'
6'
12'
18'
24'

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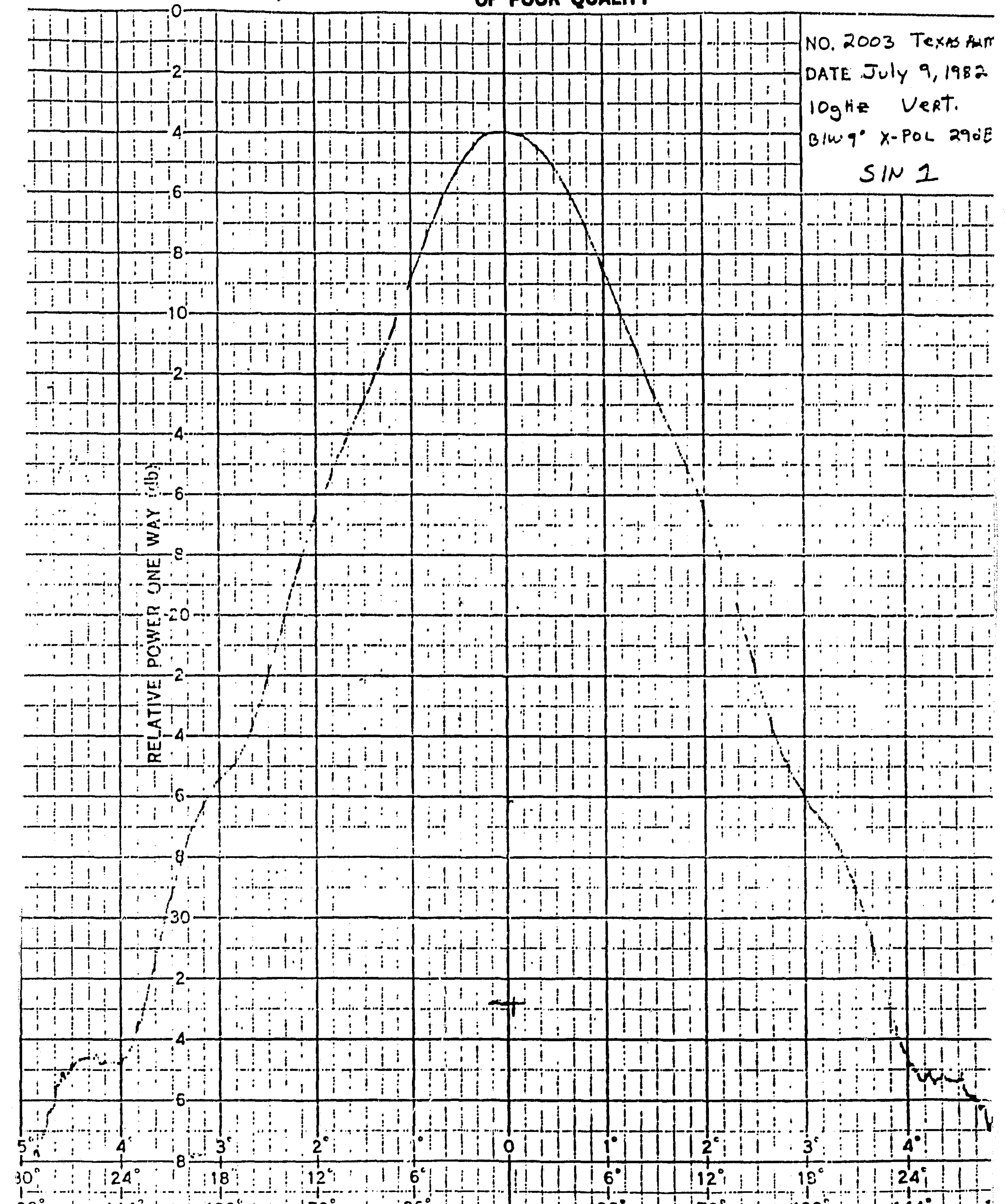

PLATFORM AND DATA ACQUISITION PROCEDURES

Truck Platform

The radar system is mounted atop a 55' knuckle boom. The system has the capability of scanning incidence angle from nadir degrees to 270°. When the antennas are in the nadir position the system beam widths are 15' from the nearest point of the truck bed. This allows the boom to swing in the azmuthal direction without interfering with the edge of the beam width of the antenna systems when they are pointed near nadir. The truck can scan in the azmuthal direction ±120°. All the movements from the platform are controlled by either manual selection at the boom control center or through the computer system through the keyboard terminal. The selection from manual to computer control is done by a switch at the base of the boom control system.

Radar System

There are two modes of operation for the radar system - manual and automatic. In the manual position, the operator selects the radar head, the polarization of the transmitter and the polarization of the receiver, whether the radar system is in calibration or operation, and manually selects the digital attenuator setting, all through the keyboard. Each of the operations is performed by selecting the output port which controls the specific function. In general this manual mode is used to test the radar system, perform calibration procedures. Generally the mode of operation is too slow to acquire data at a reasonable pace. It was designed simply to allow engineering measurements to be performed with the system. The second and more common approach is to allow the system to be in the automatic mode. In this mode the computer automatically controls the digital attenuator by implementing a digital automatic gain control. Each radar head is allowed to switch to the calibration loop before and after the system scan. The system is automatically scanned in the azmuthal direction. The computer selects when to start and when to stop the scan. Each of the radar heads are sequenced through all frequencies and polarization combinations. We have two procedures by which we can select incidence angle however. The computer can be requested to automatically scan a preselected number of angles or in a manual mode the operator can select a particular incident angle to collect data.

Radar Heads

The pulse repetition period of our radar system is one pulse every 20 microseconds. The gain of the IF receiver is increased by allowing 10 return pulses to be averaged and that output is sampled. The digital attenuator is controlled by sampling the output of the IF section with A to D converter and adjusting the digital attenuator to force the output to a predetermined value. This whole process requires some time and the final result is that we are capable of taking about 100 points per second, or 6000 points per minute. The way we invision our system working is that we will take an azmuthal scan of 90° in approximately 1.5 minutes or 1° per second. All points are stored on a tape and further analyzed and reduced to radar cross

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sections. This means that we are capable of taking 9000 points per scan. Most of those points are not independent however. In the data reduction we are able to average all of our individual points to obtain precise indicator of the radar cross section for the particular scan. Because we take data continuously throughout the scan we will then be able to calculate the statistics of the radar cross section for that particular scan. Those numbers are reduced and calculations of our measurement precision can then be made.

RESULTS FOR POINT TARGETS

The following section presents the results obtained from measurements from specific calibration targets. The targets measured included a 4' diameter sphere, 12" diameter luenburg lens, 2' diameter flat plate and 2' corner reflector. For our particular situation some measurements were made in Kansas (e.g., flatplate and corner reflector) and some measurements were made in College Station, Texas. Implication of that fact will be discussed at a later time. Measurement configuration for the 4' sphere is shown in Figure 9.

We present the results of our calibration effort in the following fashion:

Given the radar equation for point targets

$$\sigma_\rho = \frac{P_{Rp}}{P_T} \frac{(4\pi)^3 R}{G_R \; G_T \; \lambda^2}$$

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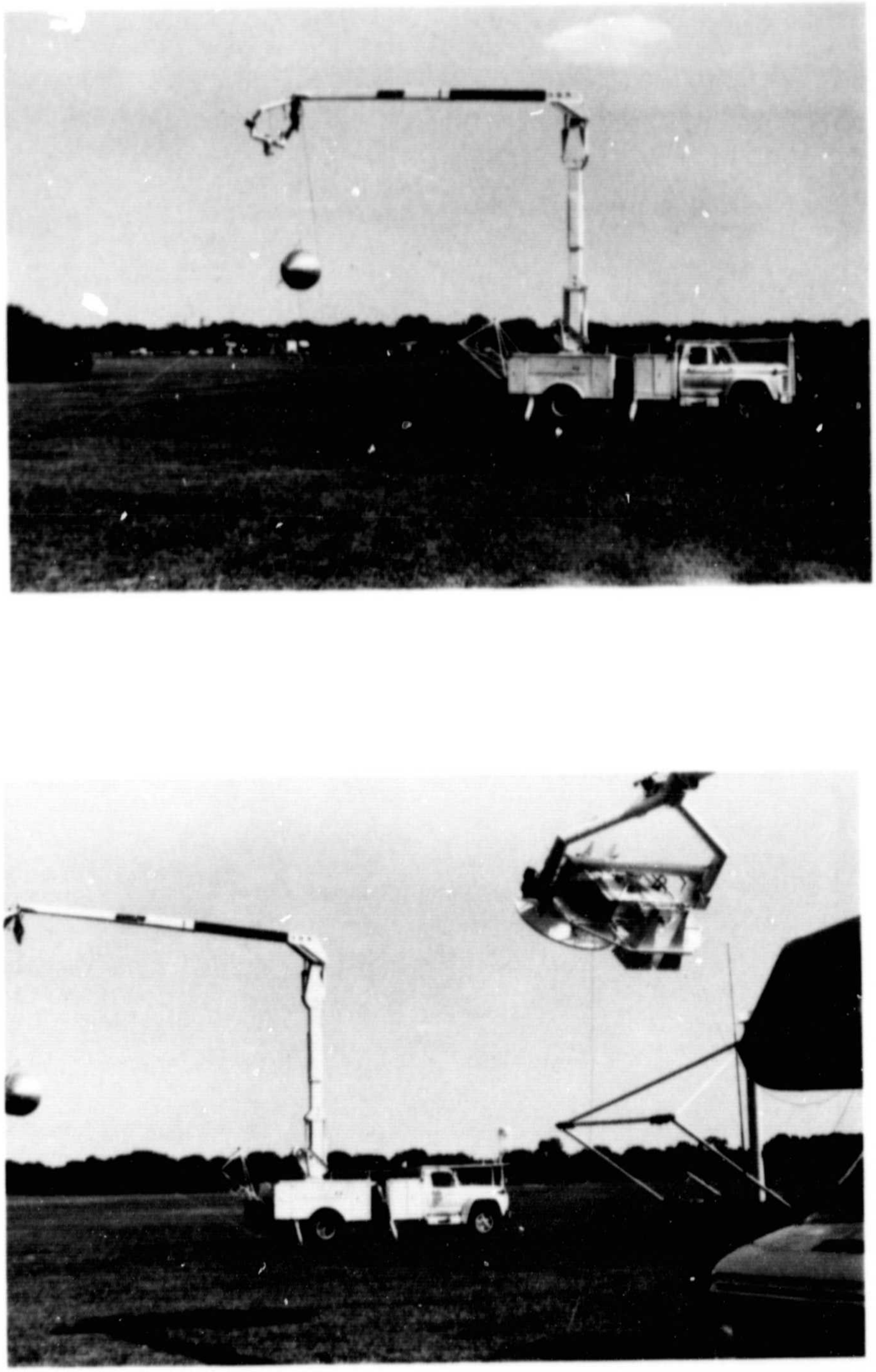

Figure 12. Target Measurement set up (4 ft. sphere).

But for our system we make an initial calibration measurement which is dependent on transmitter power P_T

$$P_{CA} = K_1 P_T$$

where P_{CA} = attenuator setting for the internal calibration.

Now sigma for the point calibration measurement can be expressed as

$$\sigma p = \frac{P_{Ap}}{\frac{P_{CA}}{K_1}} \frac{(K_o)}{G_R} \frac{R^4}{\lambda^2} \frac{(4\pi)}{G_T}$$

where P_{Ap} = attenuator setting for the measurement.

K_o = system loss or gain constant.

We simplify the expression and simplify constants such that:

$$\sigma p = \frac{P_{Ap}}{P_{CA}} K \frac{R^4}{\lambda^2}$$

$$K = K_o K_1 \frac{(4\pi)^3}{G_T G_R} = \text{system constant}$$

Our analysis consists of calculating the system constant K for each frequency; (X,L,C) and polarization (V,V & H,H) combination using the system measurements and the theoretical calculations for the point

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target radar cross sections. Ideally the calculated system constants should be the same for all cal targets (for individual frequency polarization combination). The results are shown in Table 7.

	L BAND		C BAND		X BAND	
	HH	VV	HH	VV	HH	VV
4' Sphere	-73.83	------	-63.12	-65.62	-40.5	
12" lens	-64.56	------	-60.54	-52.55	-----	-----
2' dia. plate	-56.72	-62.72	------	------	-27.2	-35.2
corner reflector	-67.40	-69.40	------	------	-30.46	-38.0

SYSTEM CONSTANTS

TABLE 7

CONCLUSIONS AND RECOMMENDATIONS

The system that Texas A&M University operates uses different principles compared to the other ground based systems that took part in the experiment. Our intent was to design a system with specifications that closely resemble those that would be used in a space borne SAR. In addition we used a design phlosophy that would tend to optomize the polarization measurement capability of the system, especially the ability to obtain improved cross polarized radar returns. The system uses pulse compression techniques utilizing Surface Acoustic Wave (SAW) devices that give the overall system an RF bandwidth of 20 MHz. The particular design parameters have several points of significance. First 20 MHz bandwidth will allow the system to operate in short range conditions (i.e. approximately 55'). Second, the pulse compression techniques improve the system signal to noise ratio by 20dB, and thirdly, the 20 MHz RF bandwidth allowed us to improve the antenna polarization isolation to acceptable levels (i.e. > 27 dB across the entire null to null beamwidth). These factors are significant in that the system will acquire ground based date using techniques and parameters that are characteristic of a space borne SAR (i.e., pulse compression. 20 MHz bandwidth).

It is significant to us that the measurments made in Kansas and here at Texas A&M were the first to be acquired with our system. It was the first time it had been in the field. We are confident now that the system will work the way it was designed to. Our hard target calibration measurement showed some variation in the calculated system gain constant. Some of this may be attributed to variation in the theoretical cross sections but certainly some can be attributed to the difficulty of aligning directly on the target. We found this troublesome especially at the high frequencies. In the future it would be wise to use a calibration target that was distributed in nature (e.g. Walt Brown's rocks). The requirement is that the calibration target should be no more difficult to align than the normal procedures one goes through to take data.