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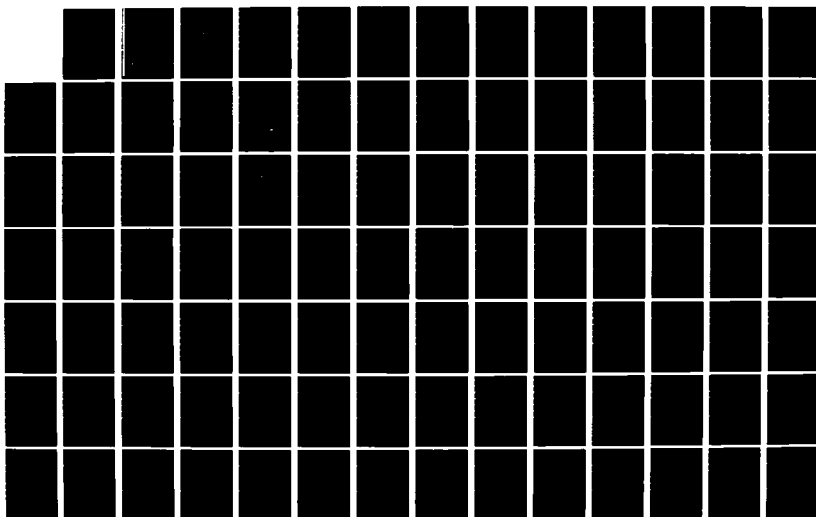
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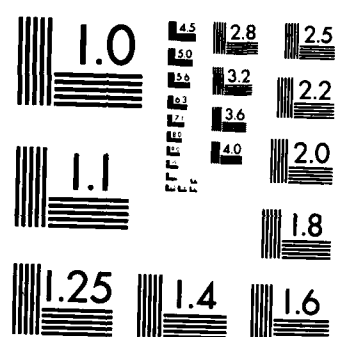
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HELICOPTER-BORNE SCATTEROMETER

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ABSTRACT

The HELOSCAT is a helicopter-borne FM-CW radar capable of acquiring differential radar cross-section data over a wide range of frequencies (4-18 GHz), polarizations (VV, HH, HV) and angles of incidence ($10^\circ - 70^\circ$). A technical description is provided.



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1.0 INTRODUCTION

The value of all-weather, day-night radar reconnaissance of sea ice has been well established by empirical means. Such techniques are used by scientists and Arctic operators in various countries of the Arctic basin. Although aircraft radar monitoring systems are in operational use, knowledge of the nature of the interaction between microwaves and ice is still sufficiently incomplete that design of future systems cannot yet be optimized. Furthermore, this knowledge is important to a fuller understanding of the observations made both by operational systems and experimental systems, both of which are radars designed for other purposes.

>The purpose of this report is to provide a detailed technical description of the University of Kansas helicopter-borne microwave active spectrometer (HELOSCAT). A major advantage of this calibrated system is the mobility of the helicopter platform--it has the advantages of both a ground-based system and an aircraft system without many of the inherent disadvantages. The Bell 206 helicopter was chosen as the best platform because of its wide availability in the High Arctic (and continental U.S., for that matter) and its low operating cost when compared to its sister aircraft, the Bell 205 and 212. Costs are in the range of \$350/flight hour with a fuel consumption of 30 gallons per hour. In contrast, the larger Bell 205 costs are \$1000/hour with a fuel consumption of 80 gallons per hour.

This system features the ability to acquire data at frequencies from 4 to 18 GHz with like- and cross-antenna polarizations and angles of incidence from 10° to 70°, as specified in Table 1. All control, including that of the angles and antenna polarizations, is from within the aircraft. Frequency selection may be performed both manually or via microprocessor. The microprocessor also multiplexes data from a fast true rms detector (0.1 second average) and an averaging true rms detector (1 second average). Information such as the modulation frequency of the oscillator control signal, the altitude determined by the HELOSCAT radar altimeter, a test-site code and the time of a measurement is placed onto digital cassette tape by the microprocessor. An automatic tracking loop is used to compensate for variations in aircraft altitude and attitude by locking the processing circuitry onto the target returns. Much work has been done to make the radar into a small, lightweight and easily installed package.

TABLE 1
HELOSCAT III SYSTEM SPECIFICATIONS

Type	FM-CW
Frequency Range	4-18 GHz
Modulating Waveform	Triangular
FM Sweep;	800 MHz
Transmitter Power	14-19 dBm
Intermediate Frequency	50 kHz
IF Bandwidth	13.5 kHz
Antennas:	Log-Periodic Feed Reflectors
No. 1	
Size	46 cm
Polarization	VV
Beamwidths (θ_e)	7.6°, 4.9°, 3.7° and 2.9° at 4.8, 7.2, 9.6 and 13.6 GHz
No. 2	
Size	61 cm
Polarization	HH
Beamwidths (θ_e)	5.4°, 3.7°, 2.7° and 1.9° at 4.8, 7.2, 9.6 and 13.6 GHz
No. 1/2	
Size	64 cm and 61 cm
Polarization	Cross
Beamwidths (θ_e)	6.3°, 4.2°, 3.2° and 2.3° at 4.8, 7.2, 9.6 and 13.6 GHz
Incidence Angles	10° to 70° from nadir
Calibration:	
Internal	Signal Injection (delay line)
External	Luneberg lens
Altitude	30 m for $\theta = 10^\circ$ to 50° 15 m for $\theta = 60^\circ$ and 70°

2.0 A BRIEF ACCOUNT OF RADAR CROSS-SECTION THEORY

A radar scatterometer is a device that accurately measures the strength of an observed signal which evolves due to the scattering properties of an observed region [1]. The radar backscatter is described in terms of the differential radar cross-section σ^0 . This representation is used because backscatter is assumed to be the incoherent collection of a very large number of separate scatterers. This says that the scatterers are sufficiently randomized in the resolution cell that the received power from each may be added to the power from all the others without consideration for phase.

2.1 Modified Radar Equation

When sensing a target where the radar parameters remain essentially unchanged from one part of the resolution cell to the other, the following modified radar equation may be applied [2]:

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma^0 A_{ILL}}{(4\pi)^3 R_T^4} \quad (1)$$

where:

- P_r = received power
- P_t = transmitted power
- G_t = transmit antenna gain
- G_r = receive antenna gain
- λ = wavelength
- σ^0 = differential scattering cross-section per unit area
- A_{ILL} = illuminated area
- R_T = range to target

2.2 Determination of Differential Scattering Cross-Section

The power for a radar may be measured directly by use of a square-law detector. This power may be related to the returned power at the receive-antenna port through an unknown constant, K_T , which represents the effects of the receiver gain as well as the attenuation and conversion losses between antenna and detector. We can then relate the detector power, P_T , to the returned power.

$$P_T = K_T^2 \left[\frac{P_t G_t G_r \lambda^2 \sigma^0 A_{ILL}}{(4\pi)^3 R_T^4} \right] \quad (2)$$

Immediately before and after recording the return from the target of interest, a coaxial delay line of loss L is switched into the circuit at the antenna ports to replace the path through the transmit antenna to the target and back through the receive antenna.

The power after square-law detection is given by:

$$P_{DLT} = K_T^2 P_t L \quad (3)$$

Taking the ratios of equations (2) and (3), we have:

$$\frac{P_T}{P_{DLT}} = \frac{G_t G_r \lambda^2 \sigma_{ILL}}{(4\pi)^3 R_T^4 L} \quad (4)$$

As can be seen in the above equation, variations in transmitted power and the effects of variations in cable loss, mixer conversion loss, receiver gain, etc., are removed.

To complete calibration of the system, the returns from a standard target of known radar cross-section are measured. The standard radar target used in the Arctic backscatter experiments is a Luneberg lens. The returned power of the standard radar target is given by:

$$P_{LENS} = K_c^2 \left[\frac{P_t G_t G_r \lambda^2 \sigma_{SRT}}{(4\pi)^3 R_c^4} \right] \quad (5)$$

where:

K_c = system constant K at time of calibration

R_c = range to standard radar target

σ_{SRT} = radar cross-section of standard radar target

The power detected through the coaxial delay line at the time of calibration using the standard radar target is given by:

$$P_{DLL} = K_c^2 P_t L \quad (6)$$

The ratio of equations (5) and (6) is given by:

$$\frac{P_{LENS}}{P_{DLL}} = \frac{G_t G_r \lambda^2 \sigma_{SRT}}{(4\pi)^3 R_c^4 L} \quad (7)$$

Note that variation in P_T and K_c do not appear in the ratio. Combining equation (7) with the inverse of equation (4) yields the following when solved for σ^0 :

$$\sigma^0 = \frac{P_T P_{DLL} R_T^4 \sigma_{SRT}}{P_{DLT} P_{LENS} R_C^4 A_{ILL}} \quad (8)$$

expressed in dB may be written as follows:

$$\begin{aligned} \sigma^0(\text{dB}) = & P_T(\text{dB}) - P_{LENS}(\text{dB}) - P_{DLT}(\text{dB}) + P_{DLL}(\text{dB}) \\ & + 40 \log(R_T/R_C) + \sigma_{SRT}(\text{dB}) - 10 \log A_{ILL} \end{aligned} \quad (9)$$

$P_T(\text{dB})$, $P_{DLT}(\text{dB})$, $P_{LENS}(\text{dB})$ and $P_{DLL}(\text{dB})$ are measured and recorded at the time of the experiment.

2.3 Illuminated Area

The illuminated area is calculated using the geometry shown in Figure 2.1. The projection of a radar beam in the form of an elliptical cone as seen on the ground is a skewed ellipse. The area of the ellipse is calculated as

$$A_{ILL} = \frac{\pi}{4} (\text{major axis})(\text{Minor axis})$$

Note that the major axis lies in the elevation plane and the minor axis lies in the azimuthal plane. From the geometry of Figure 2.1, expressions for the major and minor axes were derived.

$$\begin{aligned} M_{axis} &= R_T \cos \theta [\tan(\theta + \beta_E/2) - \tan(\theta - \beta_E/2)] \\ m_{axis} &= 2R_T \tan(\beta_A/2) \end{aligned} \quad (10)$$

and

$$A_{ILL} = (\pi/2) R_T^2 \cos \theta \cdot \tan(\beta_A/2) \cdot [\tan(\theta + \beta_E/2) - \tan(\theta - \beta_E/2)] \quad (11)$$

where:

- A_{ILL} = illuminated area
- M_{axis} = major axis
- m_{axis} = minor axis
- R_T = range to target
- θ = pointing angle of antennas off vertical
- β_E = effective gain product beamwidth in the elevation plane
- β_A = effective gain product beamwidth in the azimuthal plane

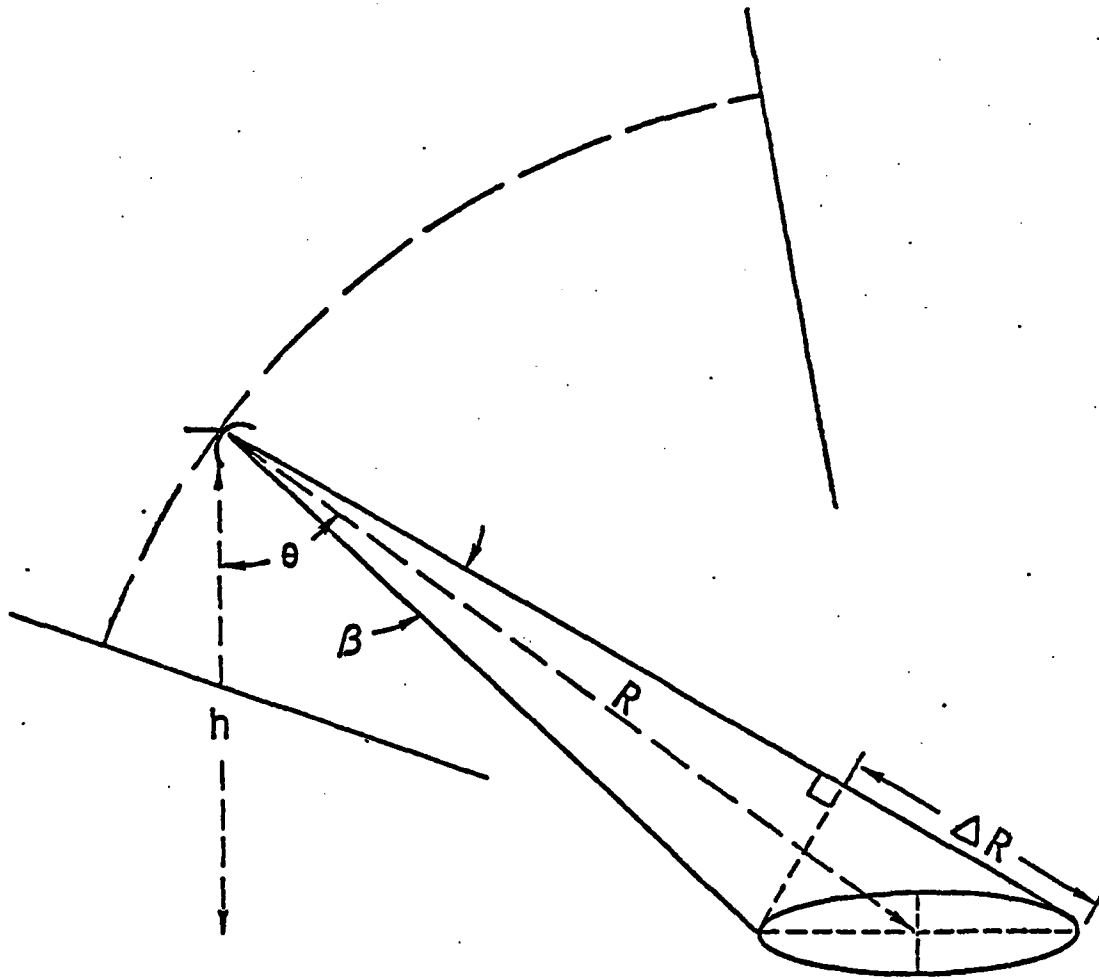


Figure 2.1: Radar System Geometry

2.4 Relationship Between Range and Oscillator Modulation Rate

For a given target at range R, the time that returned signals are delayed when referenced to the transmitted signal is $2R/c$. An illustration of the frequency relationship between the transmitted and received signals for triangular frequency modulation is shown in Figure 2.2. Using similar triangles it may be shown that:

$$\frac{2R/c}{f_{IF}} = \frac{1/(4f_m)}{\Delta f/2} \quad (12)$$

or

$$R = f_{IF}c/4\Delta f f_m \quad (13)$$

where:

R = equivalent free-space range to target

c = free-space velocity of light in m/sec

f_m = oscillator modulation frequency

f_{IF} = intermediate frequency

Δf = sweep width of RF signal

However, equation (13) does not account for the delay that occurs due to the travel of the radar signal within the radar itself. To account for this delay a range term associated with this time delay, R_D , must be added to equation (13).

$$R = f_{IF}c/4\Delta f f_m - R_D \quad (14)$$

2.5 Range Limiting by IF Bandpass Filter

A bandpass filter is used in the processing of the intermediate frequency return signals acquired from the earth scene. This filter limits signal processing to the intermediate frequencies which exist within its bandwidth or, equivalently, to the scatterers which are located within a resolution cell determined by the filter bandwidth. Normally the range of the return signal intermediate frequencies is limited by the filter action of the antenna pattern. However, IF filter limiting will occur when the radar beamwidth range resolution becomes greater than the IF filter resolution. The beamwidth resolution is given by:

$$\Delta R = R \cos\theta [\sec(\theta + \beta_E/2) - \sec(\theta - \beta_E/2)] \quad (15)$$

The filter resolution is given by:

$$\Delta R = \frac{R\Delta f_{IF}}{f_{IF}} \quad (16)$$

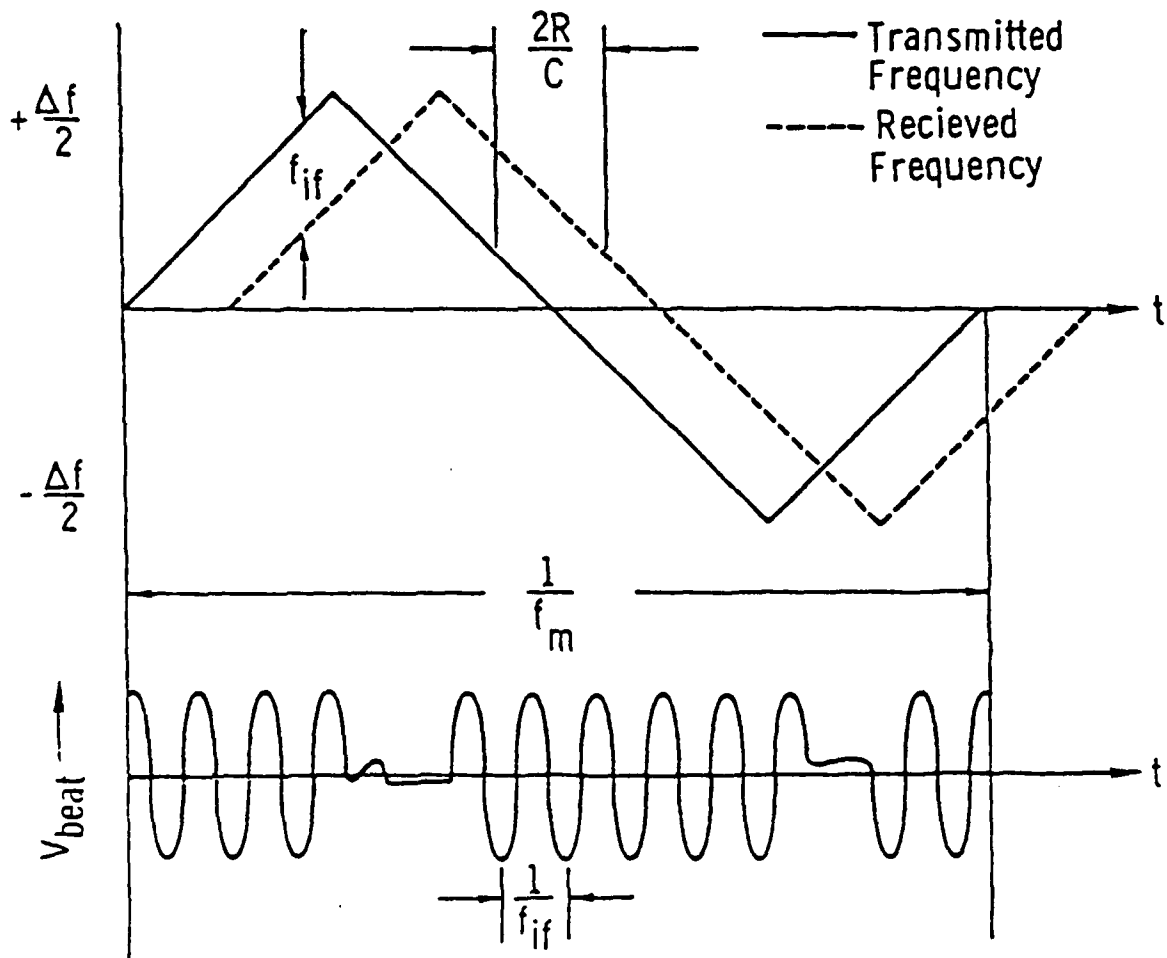
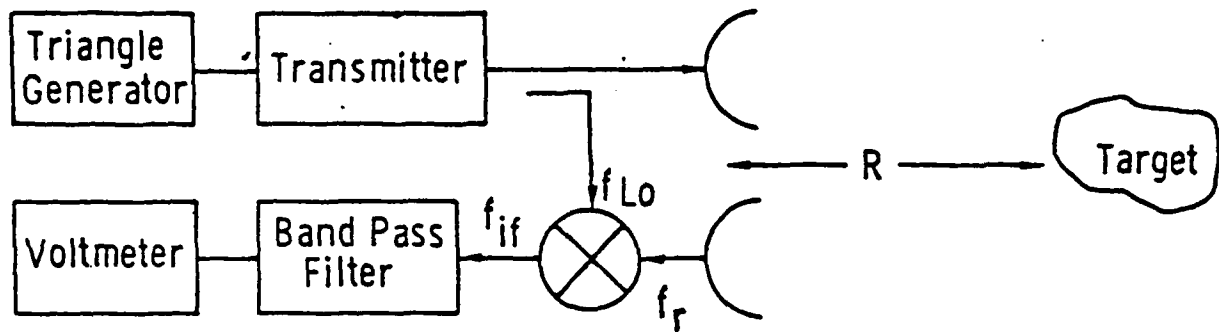


Figure 2.2: Simplified FM-CW Radar System

where Δf_{IF} = IF filter bandwidth.

If the incidence angle exceeds the value for which ΔR is the same in (15) and (16), the IF bandpass filter starts to cut off the returns from the ranges which correspond to the IF frequency of outside its bandwidth, resulting in the reduction of illuminated area. The following is a summary effect on illuminated area [3].

From Figure 2.3, a and b are the semi-major and semi-minor axes as given by equations (10) and (11). α_1 and α_2 are the range limits set by the filter and given by:

$$\alpha_1 = (R + R_D) \frac{1 - \Delta f}{2f_c} \quad (17)$$

$$\alpha_2 = (R + R_D) \frac{1 + \Delta f}{2f_c} \quad (18)$$

where f_c is the center frequency of the filter and Δf is the bandwidth of the filter. ℓ_1 and ℓ_2 are the distance from the center of the beam to the edges of the beam, and x_1 and x_2 are the distances to the range limits of the filter. K is the distance to the center of the ellipse. From Figure 2.3, the following equations are easily obtained:

$$\gamma = h \cdot \tan(\theta - \beta_E/2) \quad (19)$$

$$K = \gamma + a \quad (20)$$

$$\ell_1 = (h \cdot \tan \theta) - \gamma \quad (21)$$

$$\ell_2 = 2a - \ell_1 \quad (22)$$

$$x_1 = \begin{cases} h \cdot \tan \theta - \sqrt{\alpha_1^2 - h^2} & \text{if } \alpha_1 \geq h \\ h \cdot \tan \theta & \text{if } \alpha_1 < h \end{cases} \quad (23)$$

$$x_2 = \sqrt{\alpha_2^2 - h^2} - h \cdot \tan \theta \quad (24)$$

Depending on the relations between x_1 and ℓ_1 and between x_2 and ℓ_2 , the following four cases can arise.

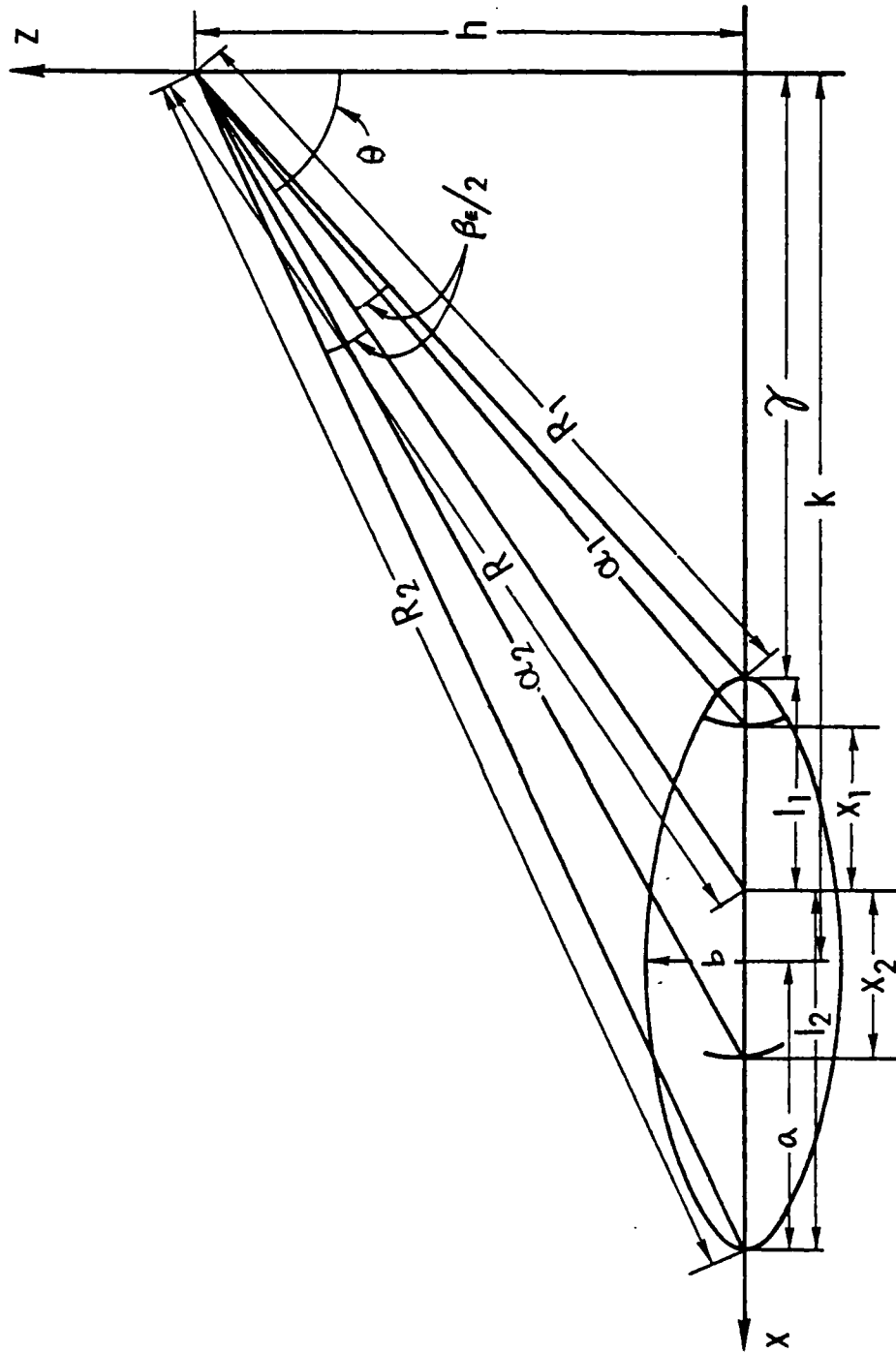


Figure 2.3: Geometric Representation of Radar Beam Showing Filter Cut-Off

Case 1:

The filter completely covers the antenna beamwidth (see Figure 2.4) when $x_1 > \ell_1$ and $x_2 > \ell_2$. This is the case treated in the beginning of this section.

Case 2:

The filter partially covers the radar resolution (see Figure 2.5) when $x_1 < \ell_1$ and $x_2 > \ell_2$.

$$G = h \cdot \tan \theta - x_1 \quad (25)$$

The equations for the ellipse and the equal range circle are given, respectively, by

$$\frac{(x - K)^2}{a^2} + \frac{y^2}{b^2} = 1 \quad (26)$$

and

$$x^2 + y^2 = G^2 \quad (27)$$

Solving these two equations for the intersection point Ψ ,

$$\Psi = [Kb^2 - \sqrt{a^2b^2K^2 - a^2(G^2 - b^2)(b^2 - a^2)}] / (b^2 - a^2) \quad (28)$$

The area which should be subtracted from the whole ellipse is,

$$\text{area} = 2 \left[\int_{\gamma}^{\Psi} b \sqrt{1 - (x-K)^2/a^2} dx + \int_{\Psi}^G \sqrt{G^2 - x^2} dx \right] \quad (29)$$

Solving equation (29), we have

$$\text{area} = \frac{ab}{2} (\theta_1 - \sin 2\theta_1) + \frac{G^2}{2} (2\theta_2 - \sin 2\theta_2) \quad (30)$$

where:

$$\theta_1 = \cos^{-1}((h - \Psi)/a)$$

$$\theta_2 = \cos^{-1}(\Psi/G)$$

Therefore, the resultant illuminated area for Case 2 is:

$$A_{ILL} = \pi ab - \text{area} \quad (31)$$

where area is given by equation (30).

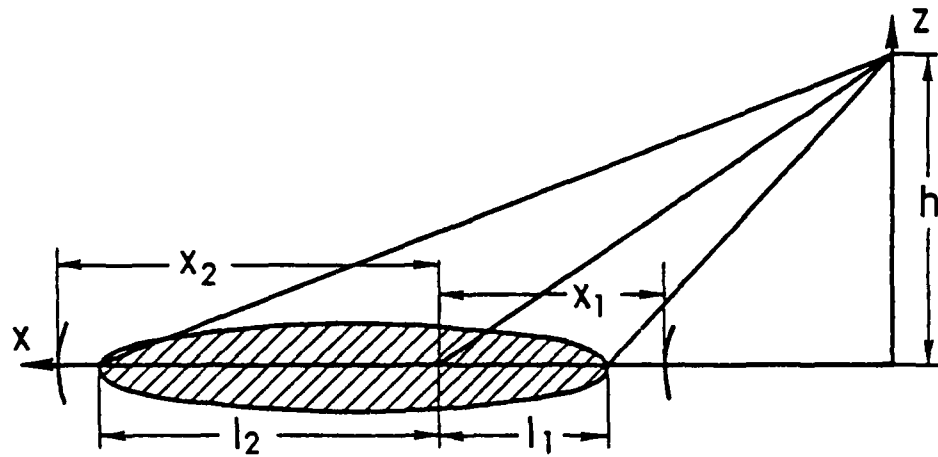


Figure 2.4: Shows Filter Completely Covering Radar Beam Resolution (Case I)

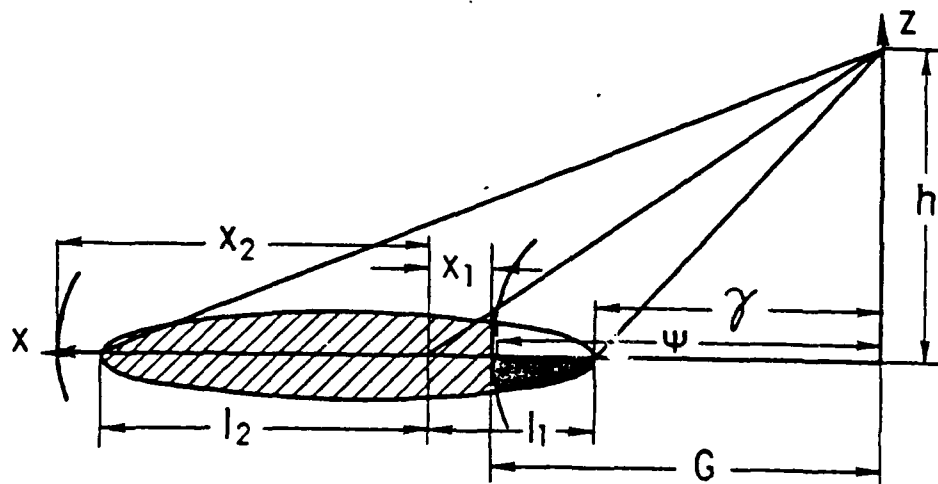


Figure 2.5: Shows Filter Partially Covering Radar Beam Resolution (Case II)

Case 3:

The filter partially covers radar resolution (see Figure 2.6) when $x_1 > l_1$ and $x_2 < l_2$. Now,

$$G = h \cdot \tan \theta + x_2 \quad (32)$$

The shaded area can be calculated along the same lines as in Case 2 and is given by

$$A_{ILL} = 2 \left[\int_{\gamma}^{\psi} b \sqrt{1 - (x-K)^2/a^2} dx + \int_{\psi}^G \sqrt{G^2 - x^2} dx \right] \quad (33)$$

Solving equation (33), we have

$$A_{ILL} = \frac{ab}{2} (\theta_1 - \sin 2\theta_1) + \frac{G^2}{2} (2\theta_2 - \sin 2\theta_2) \quad (34)$$

Case 4:

The filter resolution is completely inside the radar beam (see Figure 2.7) when $x_1 < l_1$ and $x_2 < l_2$. Here,

$$G_1 = h \cdot \tan \theta - x_1$$

$$G_2 = h \cdot \tan \theta + x_2 \quad (35)$$

and the illuminated area becomes

$$A_{ILL} = 2 \left[\int_{\psi_1}^{\psi_2} b \sqrt{1 - (x-K)^2/a^2} dx + \int_{\psi_2}^{G_2} \sqrt{G_2^2 - x^2} dx - \int_{\psi_1}^{G_1} \sqrt{G_1^2 - x^2} dx \right] \quad (36)$$

2.6 Effective Antenna Beamwidth

The effective beamwidths for the two-way antenna pattern is used in calculating the illuminated area. If the sidelobe levels are considered low enough to be neglected then the one-way antenna pattern may be fit with a Gaussian function, $G_S(\theta)$, and

$$G_S(\theta) = G_O \cdot \exp(-\theta^2/2\theta_O^2) \quad (37)$$

where:

G_O = gain of the antenna

θ = angle off axis

θ_O = constant.

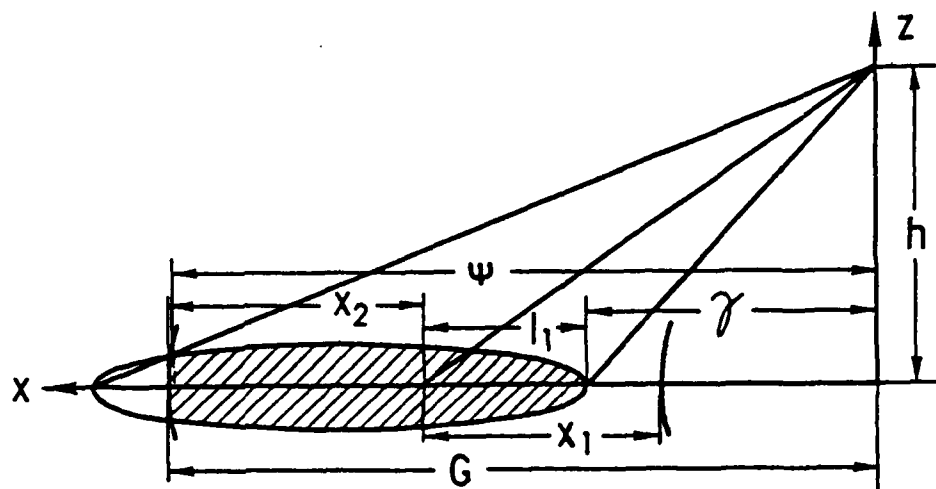


Figure 2.6: Shows Filter Partially Covering Radar Beam Resolution (Case III)

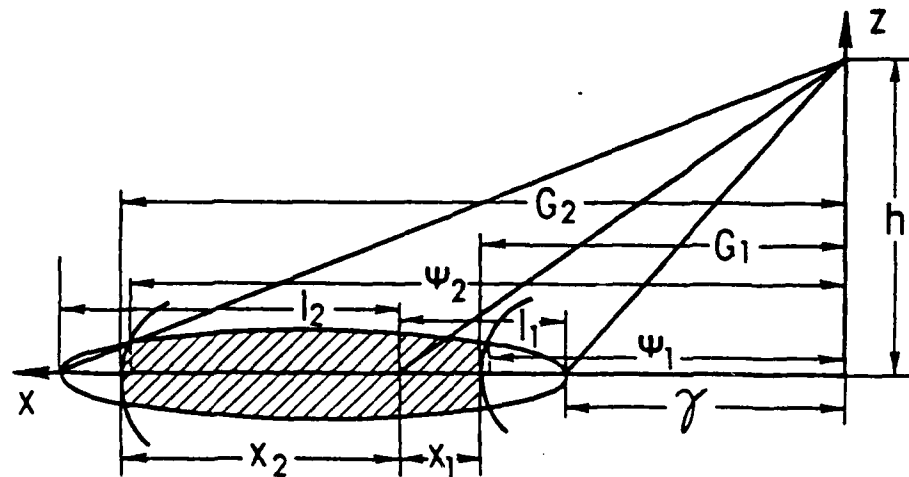


Figure 2.7: Shows Filter Contained in Radar Beam Resolution (Case IV)

Since at the half-power points, $\theta = \beta/2$, the gain is one-half G_0 , the Gaussian antenna pattern requires only a knowledge of β and can be expressed as

$$G_S(\theta) = G_0 \cdot \exp(-4 \cdot \ln 2 \cdot \theta^2 / \beta^2) \quad (38)$$

If two antennas with power patterns $G_1(\theta)$ and $G_2(\theta)$ are used for transmission and reception, the product pattern may be expressed as

$$G_{12}(\theta) = G_1 G_2 \cdot \exp[(-4 \cdot \ln 2) (\theta^2 / \beta_1^2 + \theta^2 / \beta_2^2)] \quad (39)$$

The gain will be reduced to one-half $G_1 G_2$ when $\theta = \beta_{12}/2$, therefore

$$\beta_{12} = \sqrt{\beta_1^2 \beta_2^2 / (\beta_1^2 + \beta_2^2)} \quad (40)$$

If the same antenna is used for transmission and reception, then $\beta = \beta_1 = \beta_2$ and

$$\beta_{12} = \beta / \sqrt{2} \quad (41)$$

In making the calculation of illuminated area it is assumed that all the power in the antenna pattern is concentrated into a cone with a gain of G_0 and a beamwidth of β_{EFF} . The effective beamwidth, β_{EFF} , can be obtained for any antenna pattern by integrating the volume and then dividing this volume by the maximum gain. Therefore,

$$\int_0^{2\pi} \int_0^\pi G(\theta) \sin \theta \, d\theta \, d\phi \triangleq \int_0^{2\pi} \int_0^{(\frac{\beta_{EFF}}{2})} G_0 \sin \theta \, d\theta \, d\phi \quad (42)$$

which reduces to

$$\begin{aligned} \int_0^\pi \exp(-4 \cdot \ln 2 \cdot \theta^2 / \beta_{12}^2) \sin \theta \, d\theta &\triangleq \int_0^{(\frac{\beta_{EFF}}{2})} \sin \theta \, d\theta \\ &= 1 - \cos(\beta_{EFF}/2) \end{aligned} \quad (43)$$

or

$$\begin{aligned} \beta_{EFF} &= 2 \cos^{-1} (1 - \int_0^\pi \exp(14 \cdot \ln 2 \cdot \theta^2 / \beta_{12}^2) \cdot \sin \theta \, d\theta) \\ &\approx 1.201 \beta_{12} \end{aligned} \quad (44)$$

3.0 GENERAL DESCRIPTION

The radar may be divided into five sub-systems: (1) the power and IF processing module (PIPM), which consists of a DC/AC converter, DC power supplies, IF signal-processing circuitry, and the tuning signal generators; (2) the data acquisition module (DAM), which houses a microprocessor, an A/D converter, a rapidly responding RMS detector, a frequency counter, an averaging RMS detector, a digital altitude display and a digital cassette recorder, and the external RF module (RFM), which houses the microwave componentry; (3) the wide-band parabolic dish antennae; (4) the antenna support structure and actuator; and (5) the radar altimeter. Each of these sub-systems is described in more detail. Descriptions of their functions or operation is in the main body of this report, whereas circuit board layouts, test procedures, and wiring diagrams are located in the appendix.

3.1 Description of the Interior Equipment Package

3.1.1 Inverter/Actuator Module

This module consists of a Flitetronics static inverter and actuator control circuitry. The static inverter converts the aircraft +28 V DC to 115 V AC at 400 Hz. An actuator controls the antenna look angle and requires +12 V DC for its operation. A dedicated series regulator is used for the DC-AC conversion. Dual relays allow directional control of the actuator.

3.1.2 DC Power Module

DC voltages are required for system operation. Series regulators convert the +28 V to +18, +15, +12. Three terminal regulators convert the -18 V to -15, -12, and -5. The -18 V and -5 V are obtained using AC-DC converters.

3.1.3 FM/IF Module

This module includes the electronic circuitry which produces the tuning signals which modulate the RF oscillators, circuitry which track target returns, and IF processing circuitry. Switches which select the mode of operation of the radar are also located here.

3.1.3.1 Oscillator Tuning Signal Generator

The external RF module contains two Yig-tuned oscillators which can cover the frequency bands from 4-18 GHz. These oscillators are frequency-modulated using a triangular waveform obtained from a waveform generator whose frequency can be voltage controlled. The triangle waveform and the output from a digital

to-analog converter are summed together to drive the oscillators to a given frequency and then sweep about this frequency. This center frequency may be manually set using a rotary switch located on the front panel of the data acquisition module or automatically set by the microprocessor.

3.1.3.2 Range-Tracker

The circuitry used to track the target returns, range tracker, is in its second generation. The original used in the TRAMAS system is described in RSL TM 331-19 [4]. Since the intermediate frequency coming out of the mixer is directly proportional both to the sweep rate and to the time delay associated with the range to the target, a range-tracker can keep the centroid of the IF response at a desired frequency by detecting the signal centroid and controlling the sweep rate. This is done by taking the range-tracker output voltage to the frequency control port of the triangle generator. A detailed discussion is included in Appendix F.

3.1.3.3 IF Processor

The mixer IF output is routed through a 35 kHz high-pass filter, an impedance transformer, an IF amplifier, and then a 50 kHz bandpass filter. The processed signal is then detected by an averaging true rms voltmeter which is sampled every 0.5 second and by a fast rms voltmeter which is sampled every 0.5 second. The bandpass-filter output is also used in locating the frequency centroid of the target return which is required by the range tracker.

3.1.3.4 Radar-Mode and Sweep-Rate Control Circuitry

This module provides most of the control switches for the various modes of operation and also the miscellaneous circuits for these purposes.

3.1.3.4.1 Radar Mode

A 2-deck, 5-position rotary switch provides the control voltages to set the radar into one of 4 modes of operation. The modes of operation are: delay-line calibration and VV, HH and VH antenna polarizations. The RF switches which are set by these control voltages are located in the external RF module. A description of these 4 operating modes is found in Section 3.3.

3.1.3.4.2 Oscillator Tuning Voltage Sweep Rate

The sweep rate of the oscillator tuning voltage may be controlled using the manual FM adjust located on this module. If the range-tracker is used, the sweep rate is adjusted via the range tracker. A reset to a selected sweep rate is provided in the tracking circuitry. This frequency is set by using the "track FM adjustment."

3.1.3.4.3 Sweep Width Select

A three-position slide switch located on the front panel of this module is used to select the width of the RF frequency sweep. For scatterometry the switch is set in the R0 position. The other two positions are for use when probing with radar. They increase the bandwidth over which the oscillators sweep.

3.2 Description of the Data Acquisition Module

In this module the processed target power returns are displayed and detected. The helicopter altitude and the sweep rate are also displayed. The RF center frequency select switch, the site encoder, the digital cassette recorder, and the computer reset are located on the front panel of the module. Housed inside the module is the Intel 8080-based microcomputer.

3.2.1 Fast RMS Detector

The mean square of a signal is obtained by squaring and averaging the squared instantaneous value over the sampling interval. The root-mean-square is obtained by taking the square root of the mean-square value. Commercial true root-mean-square detectors typically employ a square law detector and an RC or op-amp integrator to obtain the average value. These instruments have settling times greater than 1 sec, making them unsuitable for fast data acquisition. A fast-rms detector based on two standard settling times of less than 25 m/s was developed to allow data collection at 0.1 sec intervals. Errors are less than 1% to 2% in the final readings for input signals in the expected input range from 0.25 mV to 1.5 V. The outputs from each of the two rms modules are supplied to an A/D converter also located in the module. Channel 1 of the fast rms detector is valid for signals from 0.25 mV to 25 mV, while Channel 2 is valid for signals from 25 mV to 1.5 V.

3.2.2 A/D Converter

A miniature modular data acquisition system is used to convert the analog input signals into the output data which is buffered three-state for interfacing with the microcomputer. Two channels of fast true-rms, the altitude and the site encoder are read. The fastest read rate is 50 kHz, the resolution is 12 bits, and the pin-programmed input range is 0 to +5 V.

3.2.3 Microcomputer System

The Intel SBC-80/10 is a complete single-board computer system. The CPU, system clock, read/write memory, nonvolatile read-only memory, I/O ports and drivers, serial communications interface, bus logic and drivers all reside on the board. The central processor is the 8080A which contains 6 8-bit general purpose

registers and an accumulator. The board contains 1K of random-access-memory and 4K of read-only memory. There are 48 programmable parallel I/O lines. The memory and I/O capabilities were expanded by an additional 4K of random-access-memory, 8K of read-only-memory and 48 parallel I/O lines by adding the SBC-104 memory expansion board.

During data acquisition, the contents of the microcomputer memory are sent to a digital cassette recorder for permanent storage. The recorder interfaces to the CPU via one of the bi-directional parallel ports. It is controlled by software and provides its own error checking during read and write operations. The data is recorded using phase shift keying at a recording density of 800 bits per inch. With standard digital cassette tapes this allows over 150 minutes of data to be recorded per cassette side.

The operator interfaces with the computer using a hand-held pocket terminal. It is capable of generating and transmitting all 128 ASCII codes. The codes are sent to the microcomputer as an 8-bit serial stream. A display section consists of 8 "starburst" LED display characters received from the processor. The terminal contains an internal 30 character buffer which can be displayed by moving the 8 LED "window" across it. Whenever possible, I/O was limited to fewer than 8 characters so that the window did not have to be moved.

The microcomputer software was written to acquire a real time data stream by sampling the various instruments, allow the writing of text records onto the cassette tape, allow the dumping of the recorded data into various formats, allow computer control of the RF frequency, provide a test loop to determine if all devices are being read properly by the computer, allow operator control of the digital cassette recorder, and provide time tags based on the computer's real time clock.

3.3 RF Module and Antennae

The RF oscillators and the microwave components of the radar are housed in this module. This module is located directly behind the 24-inch dish antenna. Rigid coax links the module to the feeds of the antennae and multiconductor and flexible coax cables link the module to the FM/IF module.

Two antennae are required by this radar which operates in four modes. Three of the modes control the antenna polarizations for transmission and reception. For HH-polarization, only the 24-inch dish is used; for VV-polarization the 18-inch

dish is used alone; if both antennae are used, the polarization is VH. In the fourth mode the RF signal is sent via flexible coax to the open-circuited delay line located in the FM/IF module for internal calibration.

3.4 Altimeter

A Bonzer Mini-Mark radar altimeter provides accurate altitude information from 45 to 1000 feet. It is mounted to the helicopter using the cargo-hook hard points. A three-conductor cable connects the altimeter to the back panel connector of the Data Acquisition Module, where a digital panel meter is used as the indicator for the altimeter. The altimeter output also goes to the A/D converter for recording.

REFERENCES

- [1] Ulaby, F.T., R.K. Moore and A.K. Fung, Microwave Remote Sensing: Active and Passive. Volume II: Radar Remote Sensing and Surface Scattering and Emission Theory, Chapter 10. Reading, Massachusetts: Addison-Wesley Publishing Company, 1982.
- [2] Ulaby, F.T., R.K. Moore and A.K. Fung, Microwave Remote Sensing: Active and Passive. Volume II: Radar Remote Sensing and Surface Scattering and Emission Theory, Chapter 7. Reading, Massachusetts: Addison-Wesley Publishing Company, 1982.
- [3] Batlivala, P. and H. Khamsi, "Calculation of Area for FM-CW Radar," Remote Sensing Laboratory Technical Memorandum 177-41, University of Kansas Center for Research, Inc., Lawrence, Kansas, 1973.
- [4] Milberger, S., "Technical Description of Radar Range Tracker in the TRAMAS," Remote Sensing Laboratory Technical Memorandum 331-19, University of Kansas Center for Research, Inc., Lawrence, Kansas, 1980.

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APPENDIX A
SPECIFICATIONS

A1 INVERTER/ACTUATOR MODULE

A1.1 400 Hz STATIC INVERTER

Input Voltage:	28 VDC + 2.0 VDC
Input Current:	31 A Full Load and 1 A No Load
Output Voltage:	115 VAC and 26 VAC
Power Output:	600 VA Continuous
Protection:	88 V Transients on 28 V Line for 1 ms
Efficiency:	70% at Full Load
Temperature:	-55° C to 70° C
Weight:	14.6 lbs.
Size:	8-1/2" W x 12" L x 4-1/16" H

<u>Pins</u>	<u>Description</u>
A	Output: 26 VAC
B	Output: 115 VAC
C	Output: Common AC return
D	Input: + 28 VDC
E	NC
F	Chassis Ground Input DC Return
G	NC
H	NC
I	Oscillator Sync.

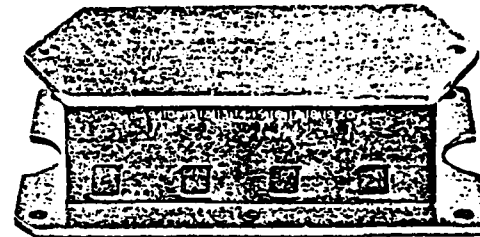
A1.2 12 VDC ACTUATOR

Manufacturer:	Saginaw
Part Number:	5703605
Rated Load:	750 lbs.
Current Draw:	22 A max
Stroke	4 inches
Travel Rate:	1.1 in /sec

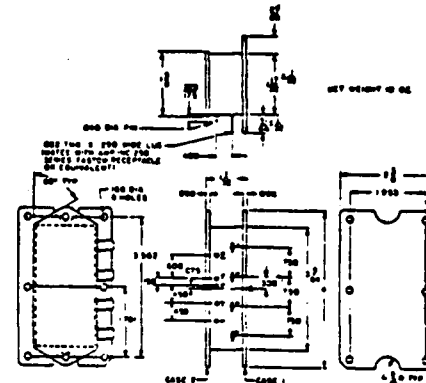
A1.3 VOLTAGE REGULATOR

DESCRIPTION

The LAS 7200 Series of Power Hybrid Voltage Regulators is designed for applications requiring a well regulated output voltage for load current variations up to 30 amperes. A key feature of the LAS series of Power Hybrid Voltage Regulators is its construction. A high degree of thermal isolation between the heat generating power elements and the heat sensitive control and reference elements is achieved by the placing of the power section on the heat-dissipating base of the unit, and the control stage on the heat-dissipating upper surface. This thermal isolation results in extremely low thermal drift characteristics for changes in power levels.



OUTLINE DRAWING



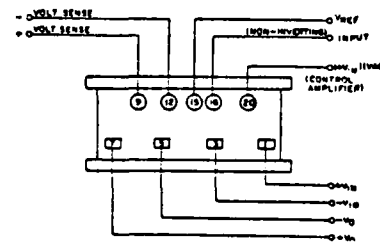
OUTLINE DRAWING, POWER HYBRID VOLTAGE REGULATOR, LAS 7000 SERIES

ELECTRICAL CHARACTERISTICS

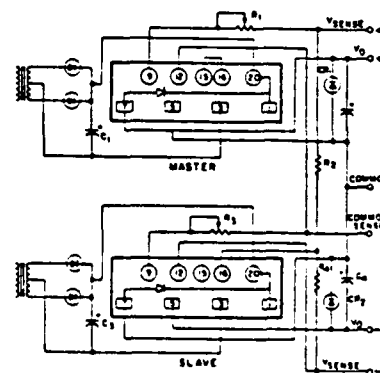
PARAMETER	SYMBOL	CONDITION	MIN.	MAX.	UNITS
Input voltage to pin (1)	$V_{in}(1)$		7.25	40.0	volts
Input voltage to pin (20)	$V_{in}(20)$		12.3	40.0	volts
Output voltage	V_o		4.75	29.4	volts
Input-output differential	$(V_{in}(1) - V_o)$		2.5	28.6	volts
Input-output differential	$(V_{in}(20) - V_o)$		7.60	28.6	volts
Output current	I_o			30.0	amps
Standby current	$I_o(1)$			40.0	mA
Standby current	$I_o(20)$			7.0	mA
Power dissipation	P_o	Plate #1 @ 25°C		400	watts
Thermal resistance junction—Case #1	θ_{JA}			0.44	°C/watt
Storage temperature	T_s		-55	+125	°C
Power transistor junction temperature	T_J			+200	°C
Regulation line*				0.016	%/ V_{in}
Regulation load*				0.2	%
Programming resistance				1000 nominal	ohms/volt
Programming voltage				one/one	volt/volt
Temperature coefficient				0.015	%/°C
Ripple attenuation*		$V_{in}(1)$ minimum I_o maximum	60		dB

LAS 7000 SERIES

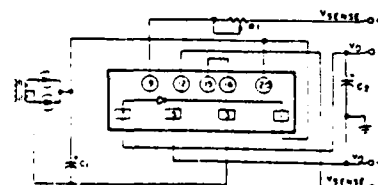
CONNECTION DIAGRAMS



9-PIN POWER HYBRID VOLTAGE REGULATOR



DUAL TRACKING POWER HYBRID VOLTAGE REGULATOR



POSITIVE POWER HYBRID VOLTAGE REGULATOR CIRCUIT

NOTES:

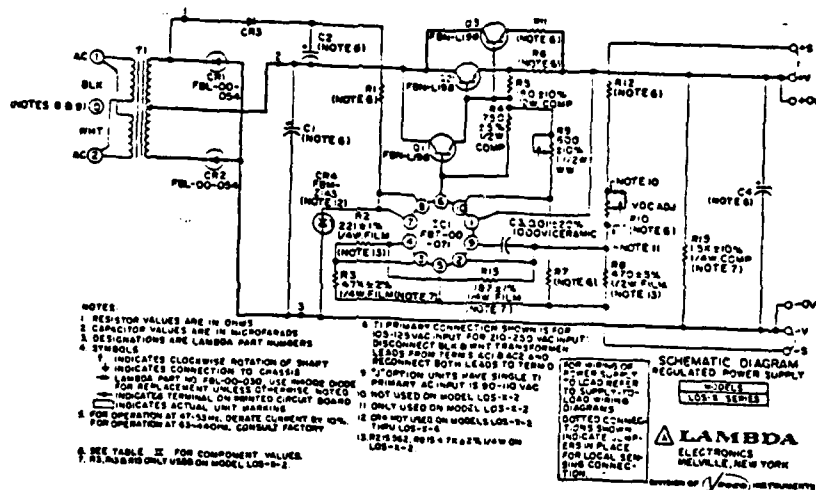
- Minimum value of input filter capacitors C1 and C3 is determined by: $C1, C3 = I_o \times (2000 \text{ mfd/amp})$ recommended
- Minimum value of output capacitors C2 and C4 is determined by: $C2, C4 = I_o \times (1100 \text{ mfd/amp})$
- Minimum value of output voltage adjust resistors R1 and R3 is determined by: $R1, R3 = 10.25 V_o \pm 1000 \Omega/V$ ohms wirewound. Use next highest standard value.
- Values of tracking reference voltage divider resistors R2 and R4 for all models are determined by:
 - $R2 = (2000 V_o - 2490) \text{ ohms} \pm 1\%, \frac{1}{2}W \text{ film}$
 - $R4 = 2.44K \text{ ohms} \pm 1\%, \frac{1}{2}W \text{ film}$
- Rectifiers CR1 and CR2 should be rated at peak inverse voltage of 50V and forward current equal at least to maximum

A2 LAMBDA DC POWER SUPPLY MODULE

Model:	LOS-X-5	LOS-X-20
Voltage:	5 + 5% V	20 + 5% V
Current:	9.0 A max	3.8 A max
Regulation:	.15%	
Ripple:	1.5 mV rms	
Noise:	5 mV p-p	
Temp. Coef.:	.03% /°C	
AC Input:	105-125 VAC at 47 - 440 Hz	
Input Power:	160 Watts	
Operating Temp.:	0° C to 60° C	

Overvoltage Protectors

Model:	L-12-0V-5	L-6-0V-20
Trip Voltage:	6.6 + .2 V	22.8 + .7 V
Current:	12 A	6 A



	Schematic Components									
	C1	C2	C4	R1	R6	R7	R10	R11	R12	
Models	10-100% ELECT	10-75% ELECT	10-75% ELECT	±3%, 3W WW	±5% 1W WW	1W COMP	±10% 1/4W WW	±5% 1/4W WW	1/4W FILM	
LOS-X-5	34,000 mf 15 vdc	47 mf 35 vdc	470 mf 16 vdc	200 ±5%, 1/4W COMP	0.10 3W	2.2K ±5%	1.2K	0.10 3W	Jumper	
LOS-X-20	12,500 mf 50 vdc	47 mf 60 vdc	220 mf 50 vdc	16K	0.30 2W	10K ±5%	50K	0.30 2W	768 ±1%	

A3. FM/IF Module

A3.1 IF Amplifier

Model: HP 465A

Freq: 5 Hz to 1 MHz

Output: > 10 volts rms open circuit; > 5 volts rms into 50 ohms
(+ 2 W).

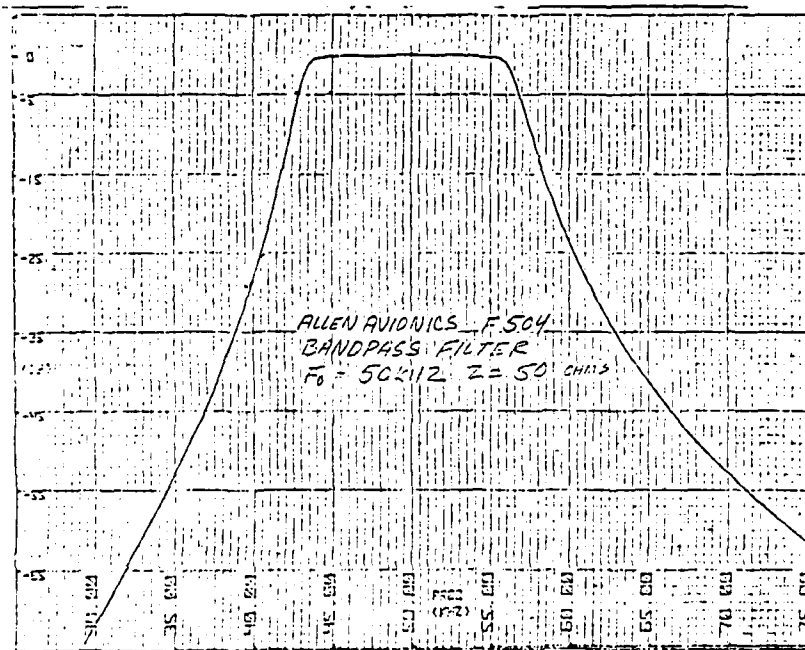
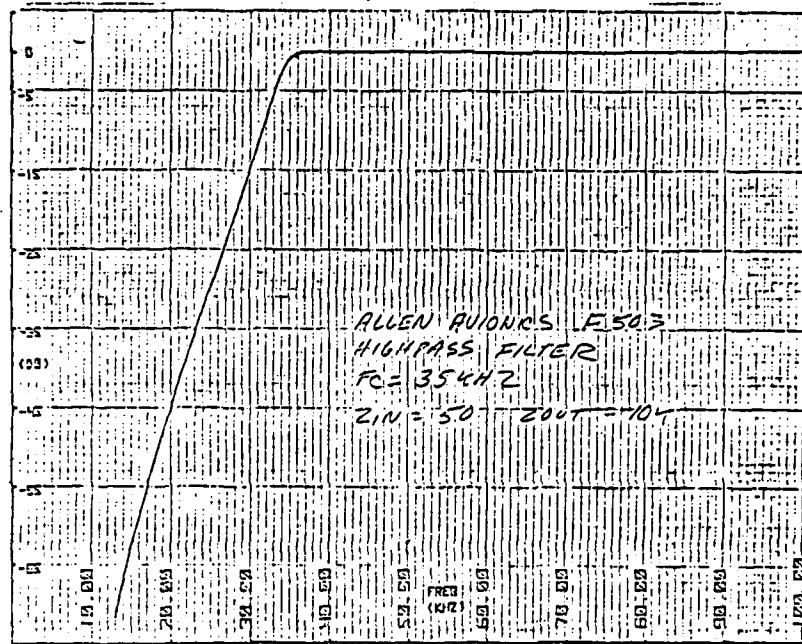
Impedance: 10 M ohm shunted by < 20 pF

Output Impedance: 50 Ω

Power: 115 or 230 V; 50 to 400 Hz; 10 watts

A3.2 IF Filters

<u>Manufacturer</u>	<u>High Pass</u>	<u>Band Pass</u>
Allen Avionics	F503	F504
Cut-off frequencies (fc) 3 dB max:	35 kHz	43.4 kHz, 56.8 kHz
Impedance range	50 Ω in; 10 K Ω out	50 Ω in; 50 Ω out
Maximum ripple	1 dB	1 dB
Maximum insertion loss	2 dB	2 dB



A4 DATA ACQUISITION MODULE

A4.1 DATEL MDAS-16 A/D CONVERTER

ANALOG INPUTS

Number of Channels	16 Single Ended (MDAS-16) 8 Differential (MDAS-8D)
Input Voltage Ranges	
unipolar	0 to +5V 0 to +10V
bipolar	$\pm 2.5V$, $\pm 5V$, $\pm 10V$
Common Mode Range, min.	$\pm 10V$
Max. Input Voltage, no damage	$\pm 15V$
Input Impedance	100 megohms
Input Bias Current	3nA, 10nA max 0 to 70°C
Input Capacitance	10 pF
OFF channel	
ON channel	100pF

ACCURACY

Resolution	12 Bits
Error, max. 50kHz sampling	$\pm 0.25\%$ of FSR
Nonlinearity, max.	$\pm 1/2$ LSB
Diff. Nonlinearity, max.	$\pm 1/2$ LSB
Gain Error	Adj. to zero
Offset Error	Adj. to zero
Temp. Coeff. of Gain, max.	$\pm 30ppm/^{\circ}C$
Temp. Coeff. of Offset, max.	$\pm 7ppm/^{\circ}C$ of FS
Diff. Linearity Tempco, max.	$\pm 3ppm/^{\circ}C$ of FS
Common Mode Rejec., min.	70 dB at 1 kHz
Monotonicity	0°C to 70°C
Power Supply Rejection	01%/V Supply

DYNAMIC CHARACTERISTICS

Throughput Rate, max	50 kHz
Acquisition Time	6 μ sec.
Conversion Time	14 μ sec.
Aperture Time, max	100 nsec.
Sample-Hold Droop, max	200 μ V/msec.
Feedthrough, max	01%
Channel Crosstalk (Mux.)	80 dB at 1 kHz

DIGITAL OUTPUTS

Parallel Data Out	12 parallel lines of buffered tri-state output data Drives 12 TTL loads Straight binary, offset binary and two's complement
Coding	Output data in MSB first, NRZ format. Straight binary and offset binary coding.
Serial Out	Drives 5 TTL loads Buffered output of address register
Mux Address Out	Drives 20 TTL loads Drives 5 TTL loads
Delay Out	Drives 5 TTL loads
Clock Out	Drives 5 TTL loads
EOC (Status)	Drives 4 TTL loads
MSB Out	Drives 5 TTL loads
LSB Out	Drives 5 TTL loads

DIGITAL INPUTS

Enable	Three separate inputs which enable tri-state outputs in 4 bit bytes 1 TTL load
Mux Address In	3 bit (MDAS-8D) or 4 bit (MDAS-16) binary address 1 LS TTL load
Strobe	1 LS TTL load with 10K pull-up resistor
A/D Trigger	1 LS TTL load with 10K pull-up resistor
A/D Trigger	1 LS TTL Load
Mux Enable	1 TTL load with 10K pull-up resistor
Count Enable	1 LS TTL load with 10K pull-up resistor
Load Enable	1 LS TTL load with 10K pull-up resistor
Clear Enable	1 LS TTL load with 10K pull-up resistor
MSB In	1 TTL load
Short Cycle	1 TTL load with 10K pull-up resistor

POWER REQUIREMENT

+15VDC	$\pm 0.5V$ @ 65mA
15VDC	$\pm 0.5V$ @ 60 mA
-5VDC	$\pm 0.25V$ @ 200mA

PHYSICAL ENVIRONMENTAL

Operating Temp. Range	0°C to 70°C
Storage Temperature Range	25°C to -85°C
Package Size	4.6 x 2.5 x 0.375 inches (116.8 x 63.5 x 9.5 mm)
Package Type	Steel shielded on 5 sides
Weight	6 oz (170 g)

NOTES: 1. All outputs are $V_{out}(0) \leq +0.4V$, $V_{out}(1) \geq +2.4V$
2. All inputs are $V_{in}(0) \leq -0.8V$, $V_{in}(1) \geq +2.0V$

ORDERING INFORMATION

Price	(1-9)	(100's)
MDAS-16	\$295.00	\$195.00
MDAS-8D	\$295.00	\$195.00

These modules are also available in extended temperature range versions designated with the suffix EX (-25°C to +85°C) or EXX (-55°C to 85°C) with hermetically sealed semiconductor components. Contact factory for price and delivery.

Included with each module is a mating right-angle 72 pin connector (AMP 3-86063-2). Additional connectors may also be ordered by the following number: 58-2082010 Connector \$10.00 each.

Trimming Potentiometers TP 20K \$3.00 each

Multiplexer expander modules are also available. The MDXP 32 adds 32 single ended or 16 differential channels with control logic. Price is \$199.00. The MDXP 32 1 is identical but without control logic. Price is \$179.00.

PIN CONNECTIONS for MDAS-16

	Top	Bottom		Top	Bottom
+15VDC	1T	1B	-15VDC	2T	2B
Analog Gnd	3T	3B	Analog Gnd	4T	4B
Ch 0 In	5T	5B	Ch 0 In	6T	6B
Ch 1 In	7T	7B	Ch 1 In	8T	8B
Ch 2 In	9T	9B	Ch 2 In	10T	10B
Ch 3 In	11T	11B	Ch 3 In	12T	12B
Ch 4 In	13T	13B	Ch 4 In	14T	14B
Ch 5 In	15T	15B	Ch 5 In	16T	16B
Ch 6 In	17T	17B	Ch 6 In	18T	18B
Ch 7 In	19T	19B	Ch 7 In	20T	20B
Amplifier In Hi	21T	21B	Amplifier In Lo	22T	22B
Range 1 Select	23T	23B	Range 2 Select	24T	24B
Sample Hold Out	25T	25B	Amplifier Out	26T	26B
Enable (Bits 1-4 Out)	27T	27B	Sum Junc (Bipolar Off)	28T	28B
Bipolar Offset	29T	29B	Enable (Bits 5-8 Out)	30T	30B
Ext. Offset Adjust	31T	31B	Ext. Gain Adjust	32T	32B
Enable (Bits 9-12)	33T	33B	Mux Enable	34T	34B
Serial Out	35T	35B	Count Enable	36T	36B
8 Out - MSB	37T	37B	8 In - Mux	38T	38B
4 Out - Address	39T	39B	4 In - Address	40T	40B
2 Out - Lines	41T	41B	2 In - Lines	42T	42B
1 Out - Lines	43T	43B	1 In - Lines	44T	44B
Drain Out	45T	45B	MSB Out (TTL)	46T	46B
MSB In (TTL)	47T	47B	Load Enable	48T	48B
Strobe	49T	49B	Clear Enable	50T	50B
A/D Trigger	51T	51B	EOC (Status)	52T	52B
A/D Trigger	53T	53B	MSB Out (TTL)	54T	54B
Short Cycle	55T	55B	8 Out - MSB	56T	56B
8 Out - MSB	57T	57B	8 Out - MSB	58T	58B
8 Out - MSB	59T	59B	8 Out - MSB	60T	60B
8 Out - MSB	61T	61B	8 Out - MSB	62T	62B
8 Out - MSB	63T	63B	8 Out - MSB	64T	64B
8 Out - MSB	65T	65B	8 Out - MSB	66T	66B
8 Out - MSB	67T	67B	8 Out - MSB	68T	68B
8 Out - MSB	69T	69B	8 Out - MSB	70T	70B
8 Out - MSB	71T	71B	8 Out - MSB	72T	72B
8 Out - MSB	73T	73B	8 Out - MSB	74T	74B
8 Out - MSB	75T	75B	8 Out - MSB	76T	76B
8 Out - MSB	77T	77B	8 Out - MSB	78T	78B
8 Out - MSB	79T	79B	8 Out - MSB	80T	80B
8 Out - MSB	81T	81B	8 Out - MSB	82T	82B
8 Out - MSB	83T	83B	8 Out - MSB	84T	84B
8 Out - MSB	85T	85B	8 Out - MSB	86T	86B
8 Out - MSB	87T	87B	8 Out - MSB	88T	88B
8 Out - MSB	89T	89B	8 Out - MSB	90T	90B
8 Out - MSB	91T	91B	8 Out - MSB	92T	92B
8 Out - MSB	93T	93B	8 Out - MSB	94T	94B
8 Out - MSB	95T	95B	8 Out - MSB	96T	96B
8 Out - MSB	97T	97B	8 Out - MSB	98T	98B
8 Out - MSB	99T	99B	8 Out - MSB	100T	100B

Three State Outputs

PIN CONNECTIONS for MDAS-8D

	Top	Bottom		Top	Bottom
+15VDC	1T	1B	-15VDC	2T	2B
Analog Gnd	3T	3B	Analog Gnd	4T	4B
Ch 0 In	5T	5B	Ch 0 In	6T	6B
Ch 1 In	7T	7B	Ch 1 In	8T	8B
Ch 2 In	9T	9B	Ch 2 In	10T	10B
Ch 3 In	11T	11B	Ch 3 In	12T	12B
Ch 4 In	13T	13B	Ch 4 In	14T	14B
Ch 5 In	15T	15B	Ch 5 In	16T	16B
Ch 6 In	17T	17B	Ch 6 In	18T	18B
Ch 7 In	19T	19B	Ch 7 In	20T	20B
Amplifier In Hi	21T	21B	Amplifier In Lo	22T	22B
Range 1 Select	23T	23B	Range 2 Select	24T	24B
Sample Hold Out	25T	25B	Amplifier Out	26T	26B
Enable (Bits 1-4 Out)	27T	27B	Sum Junc (Bipolar Off)	28T	28B
Bipolar Offset	29T	29B	Enable (Bits 5-8 Out)	30T	30B
Ext. Offset Adjust	31T	31B	Ext. Gain Adjust	32T	32B
Enable (Bits 9-12 Out)	33T	33B	Mux Enable	34T	34B
Serial Out	35T	35B	Count Enable	36T	36B
8 Out - MSB	37T	37B	8 In - Mux	38T	38B
4 Out - Address	39T	39B	4 In - Address	40T	40B
2 Out - Lines	41T	41B	2 In - Lines	42T	42B
1 Out - Lines	43T	43B	1 In - Lines	44T	44B
Drain Out	45T	45B	MSB Out (TTL)	46T	46B
MSB In (TTL)	47T	47B	Load Enable	48T	48B
Strobe	49T	49B	Clear Enable	50T	50B
A/D Trigger	51T	51B	EOC (Status)	52T	52B
A/D Trigger	53T	53B	MSB Out (TTL)	54T	54B
Short Cycle	55T	55B	8 Out - MSB	56T	56B
8 Out - MSB	57T	57B	8 Out - MSB	58T	58B
8 Out - MSB	59T	59B	8 Out - MSB	60T	60B
8 Out - MSB	61T	61B	8 Out - MSB	62T	62B
8 Out - MSB	63T	63B	8 Out - MSB	64T	64B
8 Out - MSB	65T	65B	8 Out - MSB	66T	66B
8 Out - MSB	67T	67B	8 Out - MSB	68T	68B
8 Out - MSB	69T	69B	8 Out - MSB	70T	70B
8 Out - MSB	71T	71B	8 Out - MSB	72T	72B
8 Out - MSB	73T	73B	8 Out - MSB	74T	74B
8 Out - MSB	75T	75B	8 Out - MSB	76T	76B
8 Out - MSB	77T	77B	8 Out - MSB	78T	78B
8 Out - MSB	79T	79B	8 Out - MSB	80T	80B
8 Out - MSB	81T	81B	8 Out - MSB	82T	82B
8 Out - MSB	83T	83B	8 Out - MSB	84T	84B
8 Out - MSB	85T	85B	8 Out - MSB	86T	86B
8 Out - MSB	87T	87B	8 Out - MSB	88T	88B
8 Out - MSB	89T	89B	8 Out - MSB	90T	90B
8 Out - MSB	91T	91B	8 Out - MSB	92T	92B
8 Out - MSB	93T	93B	8 Out - MSB	94T	94B
8 Out - MSB	95T	95B	8 Out - MSB	96T	96B
8 Out - MSB	97T	97B	8 Out - MSB	98T	98B
8 Out - MSB	99T	99B	8 Out - MSB	100T	100B

Three State Outputs

A4.2 Microcomputer

SBC-80/10 SPECIFICATIONS

DC POWER REQUIREMENTS

The DC power requirements are given in the table below.

	1	2
$V_{CC} = +5V \pm 5\%$	$I_{CC} = 4.0A \text{ max.}$	$I_{CC} = 2.9A$
$V_{DD} = +12V \pm 5\%$	$I_{DD} = 0.40A \text{ max.}$	$I_{DD} = 140mA$
$V_{BB} = -5V \pm 5\%$	$I_{BB} = 0.20A \text{ max.}$	$I_{BB} = 2mA$
$V_{AA} = -12V \pm 5\%$	$I_{AA} = 0.175 \text{ max.}$	$I_{AA} = 175mA$

Notes: 1 The values assume that four 8708 PROM's are present and that ten optional 220/330 Ω termination networks being driven low have been installed in the Parallel I/O Interface.

2 These values assume that the 8708 PROM's and optional termination networks are not present.

* Present system includes one 2708 EPROM and no optional terminating; therefore the power requirement would be close to case 2 above.

ENVIRONMENT

Temperature extremes can cause instability, or result in permanent damage to the circuits on the module. Ambient temperature must, therefore, be maintained within the limits of 0° C to 55° C. Exercise caution in locating the module, giving particular attention to radiant and conductive sources of heat. Remember that the module itself, when installed, will contribute some heat to the environment. Maintain an adequate clearance to permit the convective dissipation of heat from the elements on the card.

Relative humidity should not exceed 90%, non-condensing.

SPECIFICATIONS

MEMORY ADDRESSING

ROM/EPROM:

4K or 8K segments starting at any jumper-selectable base address on a 4K byte boundary. Refer to paragraph 2-10 for further details.

Note: All EPROM/ROM addresses must reside in the range of 0000_H to 7FFF_H or 8000_H to FFFF_H.

RAM:

4K, 8K, or 16K segments starting at any jumper-selectable base address on a 4K byte boundary. Certain addresses are disallowed for the 108/116 modules. Refer to paragraph 2-9 for further details.

Note: Base addresses 7000_H and F000_H not allowed for SBC 108. Base addresses 5000_H - 7000_H and D000_H - F000_H not allowed for SBC 116.

MEMORY RESPONSE TIME

Memory	Access (ns)	Cycle (ns)
RAM	575 max*	675 max*
EPROM/ROM	455 max	685 max

*Without Refresh Interruption

I/O ADDRESSING

Port	1	2	3	4	5	6	8255 No. 1 Control	8255 No. 2 Control	USART Data	USART Control
Address	X4	X5	X6	X8	X9	XA	X7	X8	XC	XD

Note: X is any hex digit assigned by jumper selection

I/O TRANSFER RATE

Parallel: Read or Write cycle time 760 ns max
Serial: (USART)

Frequency (kHz) (Jumper Selectable)	Baud Rate (Hz)			
	Synchronous		Asynchronous (Program Selectable)	
			- 16	- 64
153.6	--	--	9600	2400
76.8	--	--	4800	1200
38.4	38400	--	2400	600
19.2	19200	--	1200	300
9.6	9600	--	600	150
4.8	4800	--	300	75
6.98	6980	--	--	110

SERIAL COMMUNICATIONS CHARACTERISTICS

Synchronous

5-8 bit characters
Internal or external character synchronization
Automatic Sync Insertion

Asynchronous

5-8 bit characters
Break characters generation
1, 1½, or 2 stop bits
False start bit detectors

INTERRUPTS

Eight interrupt request lines may originate from the Programmable Peripheral Interface (4 lines), the USART (2 lines) or user specified devices via the I/O edge connector (2 lines) or Interval Timer.

INTERRUPT REGISTER ADDRESSES

Interrupt Mask Register	X1
Interrupt Status Register	X0

Note: X is any hex digit assigned by jumper selection

TIMER INTERVAL

1.003 ms ± 0.1% when 110 Baud Rate is selected
1.042 ms ± 0.1% for all other Baud Rates

INTERFACES

Bus: All signals TTL compatible
Parallel I/O: All signals TTL compatible
Serial I/O: RS232C
Interrupt Requests: All TTL compatible

CONNECTORS

Interface	No. of Pins	Centers (in.)	Mating Connectors
Bus	86	0.156	CDC VP801E43A00A1
Parallel I/O	50	0.1	3M 3415-000 or TI M312125
Serial I/O	26	0.1	3M 3462-000 or TI M312113
Aux Power	60	0.1	AMP PE5-14559 or TI M311130

Note: Connector heights and wire-wrap pin lengths are not guaranteed to conform to Intel OEM packaging.

PHYSICAL CHARACTERISTICS

Width: 12.00 in (30.48 cm) Depth: 0.50 in (1.27 cm)
Height: 6.75 in (17.15 cm) Weight: 14 oz (397.3 gm)

ELECTRICAL CHARACTERISTICS¹

Average DC Current

	without EPROM ²	with 8708 EPROM ³	with 2716 EPROM ⁴	RAM ⁵
VCC = +5V ±5% ICC	2.85A max	3.6A max	4.8A max	600 mA max
VDD = +12V ±5% IDD	450 mA max	700 mA max	450 mA max	400 mA max
VBB = +5V ±5% IBB	3 mA max	180 mA max	3 mA max	3 mA max
VAA = +12V ±5% IAA	60 mA max	60 mA max	60 mA max	Not Used

- Notes: 1. All current values given here include RAM power.
2. Does not include power required for optional EPROM, I/O drivers, and I/O terminators.
3. With four 8708 EPROMs and eight 220Ω/330Ω input terminators installed, all terminator inputs low.
4. With four Intel[®] 2716 EPROMs and eight 220Ω/330Ω input terminators installed, all terminator inputs low.
5. RAM chips and RAM control logic (powered via Auxiliary Power Bus).

AUXILIARY POWER

An Auxiliary Power Bus is provided to allow separate power to RAM for systems requiring battery backup of read/write memory. Selection of this Auxiliary RAM Power Bus is made via jumpers on the board.

MEMORY PROTECT

An active-low TTL compatible MEMORY PROTECT signal is brought out on the Auxiliary connector which, when asserted, disables Read/Write access to RAM memory on the board. This input is provided for the protection of RAM contents during system power-down sequences.

LINE DRIVERS AND TERMINATORS

I/O Drivers

The following line drivers and terminators are all compatible with the I/O driver sockets on the SBC 104/108/116

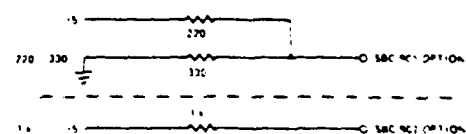
Driver	Characteristic	Sink Current (mA)	Driver	Characteristic	Sink Current (mA)
7438	I OC	48	7409	NI OC	16
7437	I	48	7408	NI	16
7432	NI	16	7403	I OC	16
7426	I OC	16	7400	I	16

Note: I = inverting, NI = non-inverting, OC = open collector

Ports 1 and 4 have 25 mA totem-pole drivers and 1 kΩ terminators

I/O Terminators

Terminators: 220Ω/330Ω divider or 1 kΩ pull up



Bus Drivers

Function	Characteristic	Sink Current (mA)
Data	Tri-State	50
Commands	Tri-State	25

ENVIRONMENTAL

Operating Temperature: 0°C to +55°C

A4.3 RMS VOLTMETERS

(a) Boonton

The Boonton has "AUTORANGING" capability; i.e., it automatically selects correct range for the voltage applied to the input connector (within the voltage and frequency limits).

Range: 300 V to 300 mV; +50 dBm to -70 dBm
 Bandwidth: 10 Hz to 20 MHz; 10 Hz to 100 kHz
 dBm accuracy (range = +50 - -60 dBm): (50 Hz to 100 kHz) = .2 dB
 Stability: 115 V $\pm$ 10%; 50 Hz to 400 Hz; 2 min warmup; 0° to 50° C
 Response: Crest Factor -6 at full scale; Waveform - complex + random
 Response Time: Fast - 1 to 2 secs; Slow - 4 to 6 secs

(b) Analog Devices TRMS-to-DC Converter (442J)

MODEL	442J	442K	442L
TRANSFER EQUATION	$V_o = V_i \sqrt{10^{-10}}$		
ACCURACY*			
Total Error: Sinewave Input, f $\leq$ 200kHz			
No External Adjustment			
Input Range: 0 to 2V _{rms}	2mV $\pm$ 15% of R _{dg.} max		
External Adjustment			
Input Range: 0 to 2V _{rms}	21mV $\pm$ 0.5% of R _{dg.} max		
10mV _{rms} to 2V _{rms}	10.5mV $\pm$ 0.5% of R _{dg.} max		
Additional Error: Sinewave Input			
20kHz $\leq$ f $\leq$ 500kHz			
With or Without External Adjustment			
For Any Input Range	1225 μ V $\pm$ 0.0025% of R _{dg.} $\pm$ (10mV - 200kHz) max		
vs. Temperature: 0 to +70°C, max	210 μ V/°C plus $\pm$ 0.01% of R _{dg.} /°C	210 μ V/°C plus $\pm$ 0.01% of R _{dg.} /°C	215 μ V/°C plus $\pm$ 0.01% of R _{dg.} /°C
vs. Supply Voltage	10.1mV/V		
Warm-Up Time	5 minutes		
FREQUENCY RESPONSE, SINEWAVE INPUT			
21% Reading Error			
Input: 1V _{rms}	300kHz		
2V _{rms}	700kHz		
1V _{rms}	300kHz		
0.1V _{rms}	120kHz		
0.01V _{rms}	80kHz		
0.001V _{rms}	25kHz		
-3dB Reading Error			
Input: 1V _{rms}	3MHz		
2V _{rms}	8MHz		
1V _{rms}	7MHz		
0.1V _{rms}	2MHz		
0.01V _{rms}	300kHz		
Internal Filter Time Constant	1.5ms		
External Filter Time Constant	15ms μ F		
Total Averaging Time Constant	1.5ms + 15ms μ F		
CREEP FACTOR			
20.2% Additional Reading Error	7		
20.5% Additional Reading Error	10		
INPUT SPECIFICATIONS			
Voltage			
Signal Range	210V _{peak} min		
Safe Input	2V _{dc}		
Impedance	2.5k Ω $\pm$ 10%		
OUTPUT SPECIFICATIONS			
Rated Output			
Voltage	+10.0V min		
Current	+5mA min		
Impedance	0.1 Ω		
Offset Voltage at +25°C	22mV max		
With External 20k Ω Error Pin	Adjustable to Zero		
POWER SUPPLY			
Voltage: Rated Specifications	215V _{dc}		
Voltage: Operating	50 to 180V _{dc}		
Current: Quiescent	212mA		
TEMPERATURE RANGE			
Rated Performance	0 to +70°C		
Operating	-25°C to +85°C		
Storage	-55°C to +125°C		
CASE SIZE	1.5" x 1.5" x 1.0"		
PRICE			
1000	\$48	\$124	\$148
10000	\$41	\$115	\$139

*Specifications same as Model 442J

*Error is specified as the sum of two components: a fixed term plus a percentage of output signal (reading). Refer to TOTAL ACCURACY page 1.

*Refer to OPTIONAL AC CALIBRATION PROCEDURE page 1.

*Refer to AC CALIBRATION PROCEDURE page 1.

*Connect optional filter capacitor between pin 1 and pin 2 (see Figure 2). Pin 1 is protected for shorts to ground and the positive supply voltage. Pin 2 is not protected for negative voltage greater than 1 volt.

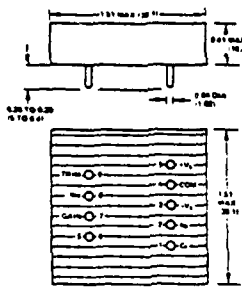
*Protecting for short circuit to ground and/or other supply voltage.

*Recommended power supply: Analog Devices Model 906, 541 (5-5).

*Specifications subject to change without notice.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).



Weight: 40 grams

MATING SOCKET AC1016
 PRICE (1-9) \$5.00

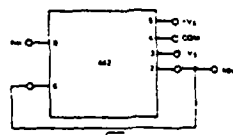


Figure 1. Wiring Connections for RMS Measurements (No External Trim)

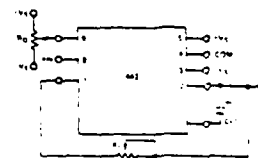


Figure 2. Optional External Adjustment for RMS Measurements

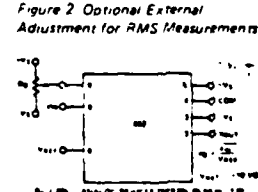
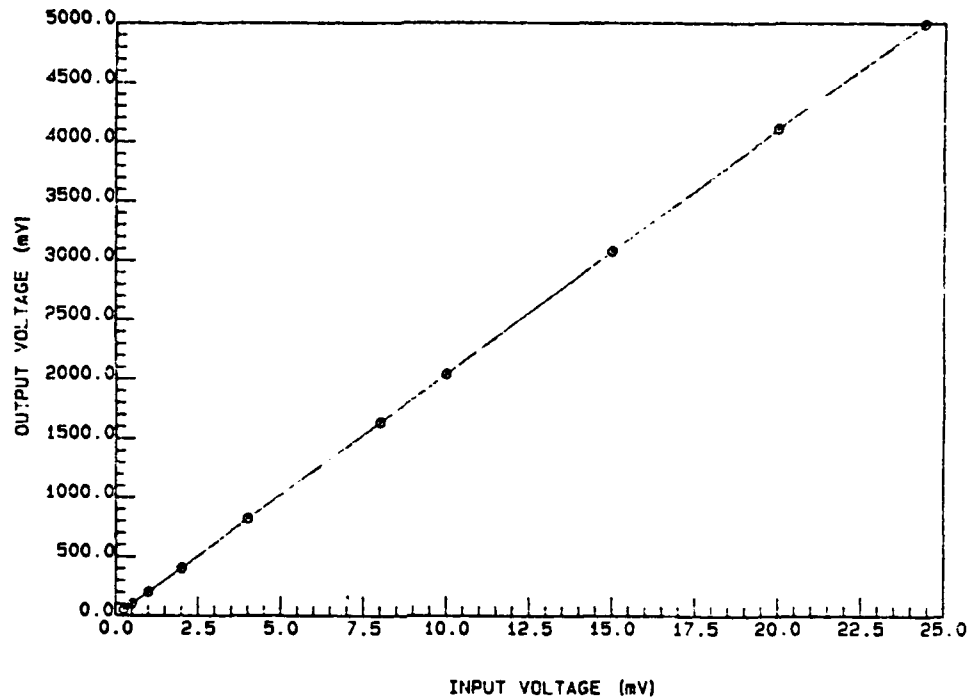
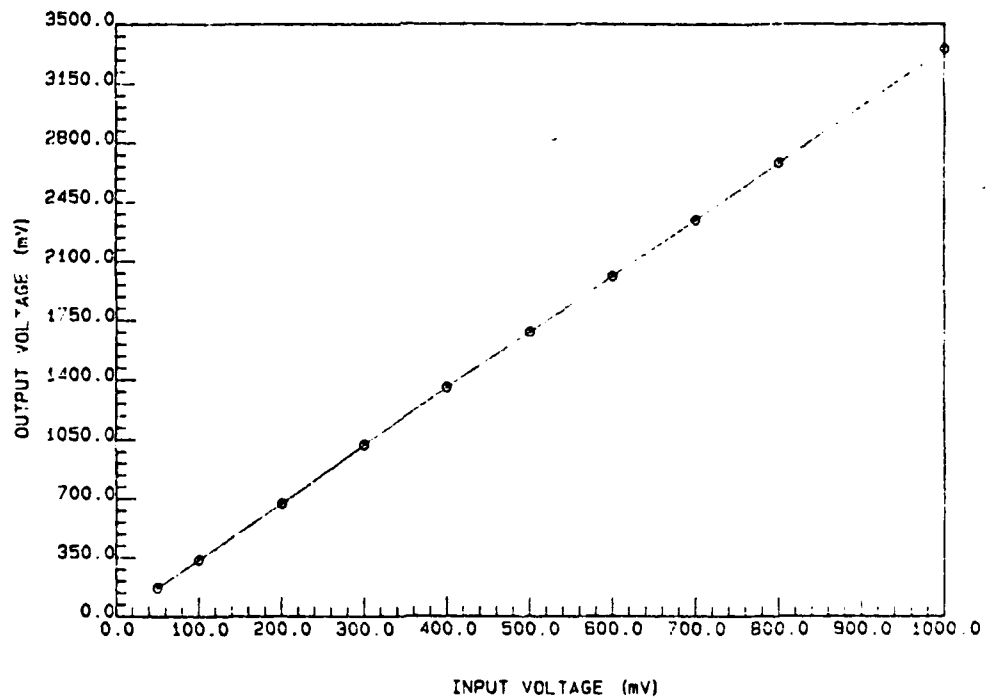


Figure 3. Wiring Connections for Mean Square Measurements with Adjustable Scale Factor (Vp/g)

(c) I/O Characteristics of True RMS Board



INPUT vs OUTPUT VOLTAGE FOR CHANNEL 1 AT 50 kHz



INPUT vs OUTPUT VOLTAGE FOR CHANNEL 2 AT 50 kHz

A4.4 FLUKE FREQUENCY COUNTER

OPERATING RANGES

Frequency:
5 Hz to 80 MHz

Period:
5 Hz to 1 MHz single and multiple period averages

Totalize:
1 count to 999999 counts

INPUT CHARACTERISTICS

Sensitivity:
25 mV, typically 15 mV rms sine wave, 5 Hz to 80 MHz
Frequency and totalize: 200 mV P-P pulse amplitude with minimum pulse width of 20 nsec. Duty cycle > 10%.
Period: 200 mV P-P pulse amplitude with minimum pulse width of 200 nsec. Duty cycle > 10%.

Impedance:
1 M Ω shunted by less than 30 pF for signal levels < 500 mV decreasing to approx. 220K shunted by less than 40 pF for levels greater than 500 mV.

Filter:
1 MHz (3dB point) lowpass

Attenuator:
Decreases sensitivity by 10

Overload:
250V rms 5 Hz to 1 kHz decreasing to 20V at 80 MHz

RESOLUTION

Frequency:
Four manually selected gate times of:
10ms (100 Hz resolution)
100ms (10 Hz resolution)
1s (1 Hz resolution)
10s (0.1 Hz resolution)

Autorange position will automatically seek to fill all 6 digits but will not select a gate time greater than 1 second (1 Hz resolution)

Period:
Manual selection of single period through 10^3 periods averaged ratios:
 10^0 single period (100 ns resolution)
 10^1 periods averaged (10 ns resolution)
 10^2 periods averaged (1 ns resolution)
 10^3 periods averaged (100 ps resolution)

Autorange position will automatically seek to fill all 6 digits. Autoranging will not select a period average of greater than 10^3 averages.

Totalizing:

Accumulates up to 999999 counts, then activates overflow indicator

TIME BASE CHARACTERISTICS

Frequency: 10 MHz

Stability:

Aging Rate: $< \pm 5 \times 10^{-7}$ month
Short Term: $< \pm 5 \times 10^{-4}$ over 1 second
Temperature: $< \pm 5 \times 10^{-4}$ 0°C to 50°C
 $< \pm 2 \times 10^{-4}$ (typical) 20°C to 30°C

Line Variation:

$< \pm 1 \times 10^{-7}$ for $\pm 10\%$ variation in line voltage

GENERAL

Display:

6 digit LED, leading zero suppression
Time between successive measurements is 200 ms plus measurement time

Annunciation:

MHz, kHz, msec, μ s overflow

Automatic Features:

AUTORANGE:

In both frequency and period modes, autoranging includes a unique 20% hysteresis in its switching thresholds, to eliminate redundant up range/down range commands. This allows measurements to be made on signals containing large amounts of FM and PM.

Hysteresis memory can be reset by depressing the reset button.

AUTORESET:

A new measurement sequence is started every time a front panel button is activated.

Operating Temp: 0°C to +50°C (0°C to +40°C for .01 Battery option if operated from line.

Storage Temp: -40°C to +60°C

Power Requirements:

115/230 VAC $\pm 10\%$ - 100 VAC available - 50, 60,

400 Hz - 6.5 watts line model - 8.5 watts battery model

Fuses:

1/4A AC-line version - 1/2 A slo-blo battery version

DIMENSIONS

Width:	8.55 inches	217.2 mm
Height:	2.52 inches	64.0 mm
Depth:	10.65 inches	270.5 mm
Weight:	2.75 lbs	1.2 Kg

DATA OUTPUT OPTION

8-4-2-1 BCD output from each digit, plus encoded decimal point and units annunciation information. All outputs CMOS Low Power TTL compatible, high true. Print command is provided.

BATTERY

NICAD rechargeable - discharge time 5 hours - charge time 14 hours @ 30°C ambient with unit inoperative

A4.5 DIGITAL CASSETTE RECORDER

DATA FORMAT:

Data format complies with ISO-3407, ECMA-34, JIS-C6281 and other similar standards.

Recording Format: Phase Encoding
 Recording Density: 800 bpi (32 bits/mm, nominal)
 Number of Tracks: Single Track

MECHANICAL CONSTRUCTION:

Tape Drive System: D.C. Motor Direct Reel Drive System
 Tape speed Detection System: Encoder Detection
 Cassette Insertion: Pocket Holder type
 Cassette Eject Mechanism: Manual Ejection by depressing EJECT Button
 BOT/EOT & Clear Leader Detector: Photoelectric Detector
 Magnetic Head: Single Track, Single Gap Read/Write Head

POWER REQUIREMENTS:

	Average Current Consumption	Maximum Current Consumption	Permanent Ripple Voltage
D.C. +12V $\pm$ 5%	1.0 A	1.8 A*	Less than 100mV _{p-p}
D.C. + 5V $\pm$ 5%	0.7 A	0.75A*	Less than 100mV _{p-p}

* Except for surge current at power-on.

GROUND ISOLATION:

Insulation resistance between
 0V power supply and frame
 ground 5 Meg Ohms or more, at 150V D.C.

ENVIRONMENTAL CONDITIONS:

Temperature range operating +5°C - 40°C; storage -15°C to +60°C
 Relative Humidity Range (non-condensing): operating 20% to 80%;
 storage 10% to 90%
 Vibration (operating): Less than 0.5G (less than 120 Hz)
 Impact: Less than 40G (less than 30 msec)
 Continuous: Less than 3G

OPERATIONAL CHARACTERISTICS:

Tape Speed (Slow): 15 ips (38.1 cm/s) $\pm$ 3%
 (Fast): 45 ips (114.3 cm/s) $\pm$ 4%
 IBG: 0.97 $\pm$ 0.24 inch (24.64 $\pm$ 6.10 mm)
 Erased Length 2.19 $\pm$ 0.27 inch (55.63 $\pm$ 6.86 mm)
 Initial Gap: 2.26 $\pm$ 0.40 inch (57.40 $\pm$ 10.16 mm)
 Readable IBG Length 0.7 inch (17.78 mm) or more
 Required tape length for
 Long IBG detection 15.0 - 22.2 inch (381.0 - 563.9 mm)
 Start distance for HIGH SPEED SEARCH: 2.4 inch (60.96 mm) or less
 Stop distance for HIGH SPEED
 SEARCH: 1.9 inch (48.26 mm) or less
 Nominal Data Transfer Rate: 12 k bits/sec
 Recording Density 800 bpi $\pm$ 4
 Threshold Level (at reference
 read level) (LOW): 18 $\pm$ 3
 (HIGH): 40 $\pm$ 5

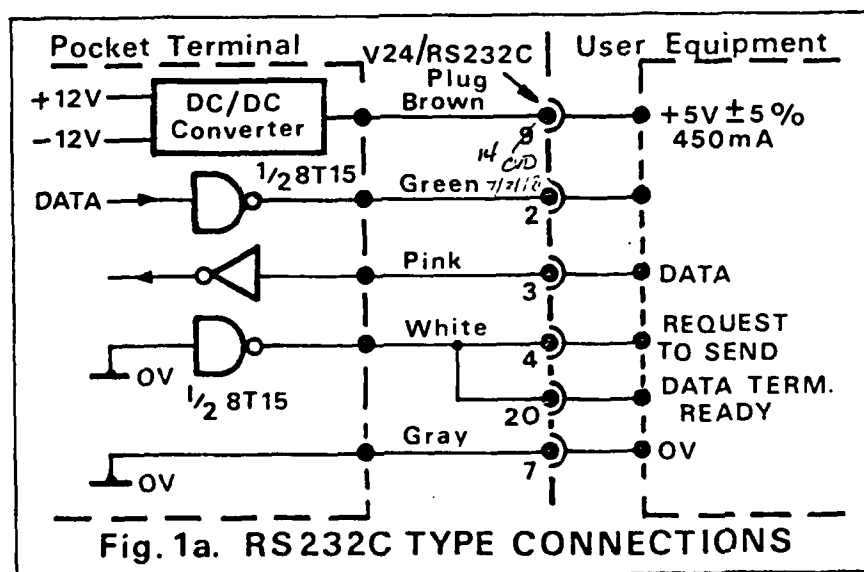
A4.6 POCKET ASCII TERMINAL

Specification

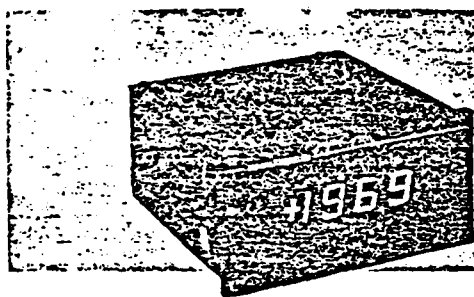
Memory:	last 30 characters received
Characters simultaneously displayed:	8 (7 at left home and right home positions)
Character set displayable:	64 ASCII characters and symbols
Formation:	16 segment "starburst"
Number of keys:	40
Transmittable codes:	128
Code transmitted:	8-bit ASCII (framed by 1 start bit, 1 or 2 stop bits)
Compatibility:	RS232 standard (20 mA loop to order)
Size:	6 in x 3 in x 1.4 in
Weight:	0.5 lb
Power supply:	5 V single rail at 400 mA typical

POWER

The Terminal requires a regulated power supply at $+5V \pm 5$ percent. The RS232/C version typically requires 450mA, and the 20mA loop version 400mA.

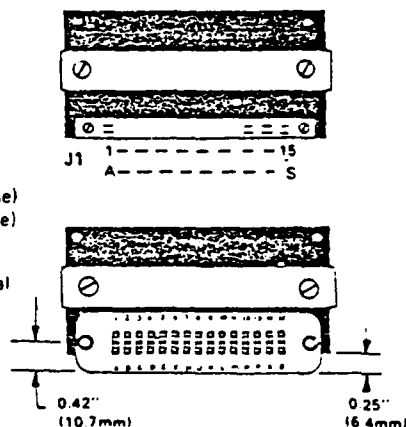


A4.7 ALTIMETER PANEL METER

**AN2570**

±1999 count

Full Performance, Low Cost

DIGITAL PANEL INSTRUMENTRear View - Bezel
Not Shown for
ClarityA. Standard
Card-Edge
Connector
(Solderable)Analogic Part No.s
15-300004P (For plastic case)
15-300004m (For metal case)B. Optional
Screw-Terminal
Connector
(Solderless)Analogic Part No.
PL-10-5535

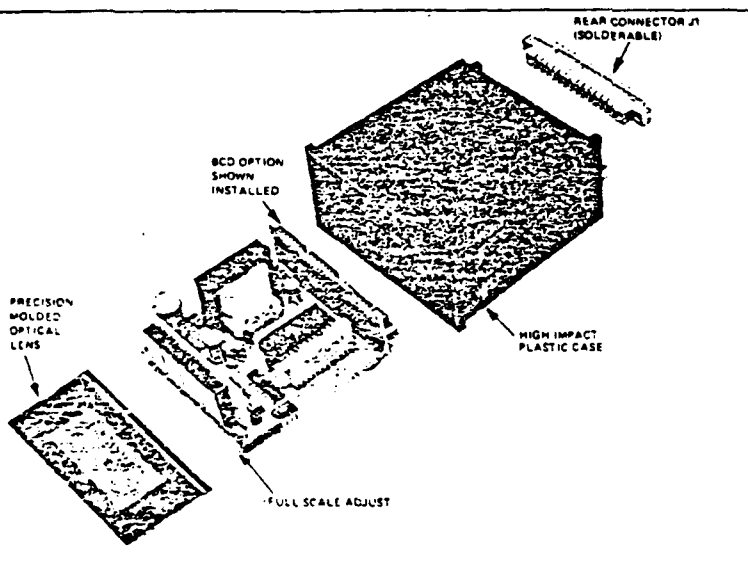
1. Rear Panel Connectors

J1 PIN DESIGNATIONS

Ratio Input	A	1	Signal IN (+)≠
Analog Ground≠	B	2	Signal Return (-)≠
Decimal Point 1	C	3	Decimal Point 2
Decimal Point 3	D	4	EOC/HOLD
BCD (2)*	E	5	BCD (1)*
BCD (8)*	F	6	BCD (4)*
BCD (20)*	H	7	BCD (10)*
BCD (80)*	J	8	BCD (40)*
BCD (200)*	K	9	BCD (100)*
BCD (800)*	L	10	BCD (400)*
PRINT*	M	11	DISPLAY TEST
BLANK/OVERRANGE	N	12	BCD (1000)*
-5.1VDC Output	P	13	POLARITY*
Digital Ground†	R	14	+5V†
AC Power IN†	S	15	AC Power or +8 to +28VDC IN†

POWER CONNECTIONS

+5VDC	Pin 14 for +5VDC, Pin R for Power Return
+8 to +28VDC	Pin 15 for +8 to +28VDC, Pin R for Power Return
110VAC	Pins S and 15
220VAC	Pins S and 15

**DECIMAL POINT
SELECTION**To display the desired
decimal point, simply
connect the appropri-
ate pin as shown to
Digital Ground (Pin R,
J1) using a jumper lead.

A5 RF MODULE

A5.1 MECHANICAL SWITCHES

Microwave Associates - Model 7530 PMD

Frequency (GHz)	Insertion Loss (dBs)	Isolation dBs	VSWR
4.0	0.2	80	1.20
8.0	0.3	70	1.25
12.4	0.4	65	1.4
18.0	0.5	60	1.5

Operating voltage: 20 to 30 VDC; Pull-in = 20 V; Drop-out = 2 V
 Coil resistance: 158 to 192 ohms

Hewlett Packard - Model #33311 B

Frequency (GHz)	Insertion Loss (dBs)	Isolation dBs	VSWR
DC-2	0.25	90	1.15
2-18	0.5	90	1.4

Operating voltage: 20 to 30 V
 Switching current: 120 mA at 24 V

A5.2 MIXERS

RHG Model DMI-18B; Serial #16-661-1

Frequency (GHz)	Noise Figure (dB)	Lo to Rf Isolation (dB)
1	9	> 20
12	10	> 20
18	10	> 20

WJ Model WJ-M 14

Frequency: 4 to 8 GHz
 SSB Conversion Loss: 8.0 dB max
 SSB Noise Figure: 8.0 dB max
 Isolation: > 20 dB
 Insertion Loss: 2 dB

A5.3 CIRCULATORS

Western Microwave	Model 3JC-8019	Model 3JC-4081
Frequency Range (GHz):	8-18	4-8
Insertion Loss (dB):	< .8	< .4
Isolation (dB):	> 15	> 21
VSWR	< 1.6	< 1.2

A5.4 DIRECTIONAL COUPLERS

NARDA	Model 4244	Model 4246
Frequency Range (GHz):	2-8	6.5-18
Coupling:	10	.6
Directivity (dB):	18	17
VSWR:	1.4	1.40
Insertion Loss:	1.00	0.8

A5.5 ISOLATORS

Western Microwave	Model 2JC-401	Model 2JC-818
Insertion Loss (dB):	.4	.3
Isolation (dB):	23	1.3
VSWR:	1.25	1.4

A5.6 RF OSCILLATORS: OPERATING INSTRUCTIONS AND SPECIFICATIONS

Installation

Bias voltage should be within ± 0.2 volts of the correct value to obtain specified operation. At 2 or 3 volts above the correct value the Zener diode, placed in the bias circuit to provide protection, will begin to draw excess current.

CAUTION: If the bias current exceeds the maximum bias current shown on the data sheet by as much as 50 milliamperes, the protective Zener will be endangered. For GaAs oscillators, a current peak up to 200 mA higher than the value recorded on the data sheet may be observed at low (-2 to -4V dc) negative bias levels, however.

If excess current is drawn, check for high bias voltage or reversed bias polarity.

Heaters

Heaters are often included in the oscillator to minimize such temperature effects as frequency drift and power output variation. These heaters are self-regulating and may be operated from an unregulated voltage within the range of 22 to 30 volts. Transients of up to 80 volts in accordance with Figure 6 of MIL-STD-704-A will not normally damage the heater.

Mounting

The oscillator may be mounted in any orientation. The unit (particularly units that tune above 4 GHz) should be mounted to a smooth heat sink capable of dissipating up to 10 watts without raising the temperature at the base of the unit adjacent to the heat sink above the specified operating temperature range. (Use of heat sink compound (e.g., Dow Corning 340) is recommended on mounting surface).

YIG-TUNED GaAs OSCILLATOR

Type No.: 5157-300D

Serial No.: 1027 (ER)

Operating Conditions:

Heater Voltage:	+28.0 Vdc	Current:	180 mA at -54° C
Bias Voltage:	± 18.00 Vdc	Current:	1050/500 mA

Test Data:

Tuning Vdc	Calculated Frequency (GHz)	Δ Frequency (MHz) +25° C	Power Output (mw) +25° C
0	8.00	0	30
1	9.00	-10	58
2	10.00	-13	62
3	11.00	-10	68
4	12.00	-6	64
5	13.00	-3	46
6	14.00	-2	49
7	15.00	+1	41
8	16.00	+2	29
9	17.00	+1	21
10	18.00	-3	19

Hysteresis: 11 MHz

YIG-TUNED GaAs OSCILLATOR

Type No: 5157-300 DF

Serial No: 1092

Operating Conditions:

Heater Voltage: +28.0 Vdc

Current: 170 mA

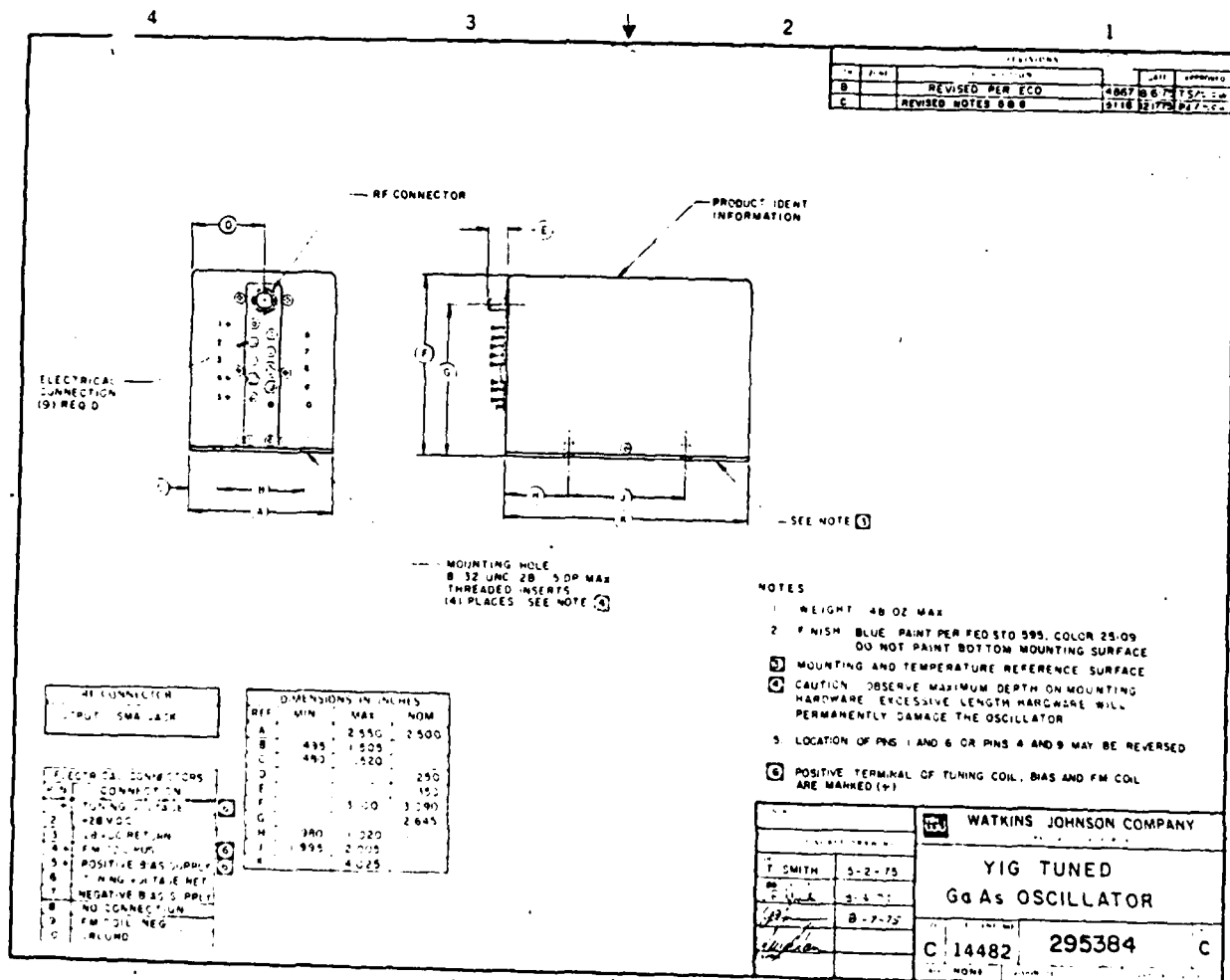
Bias Voltage: +18.00 Vdc

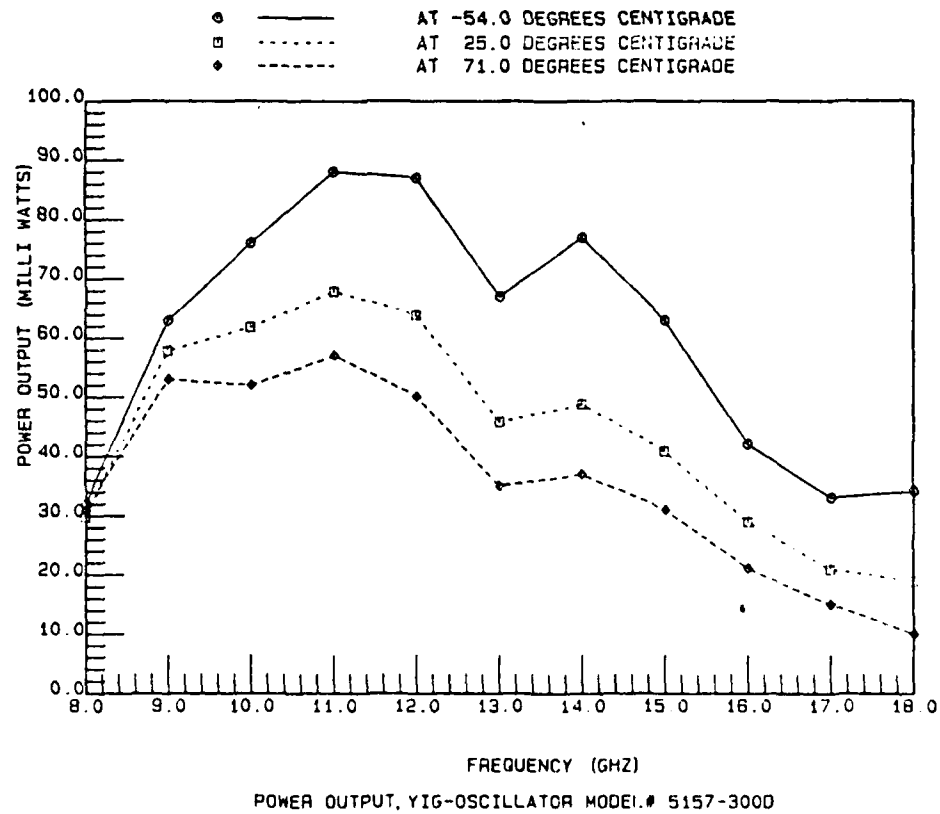
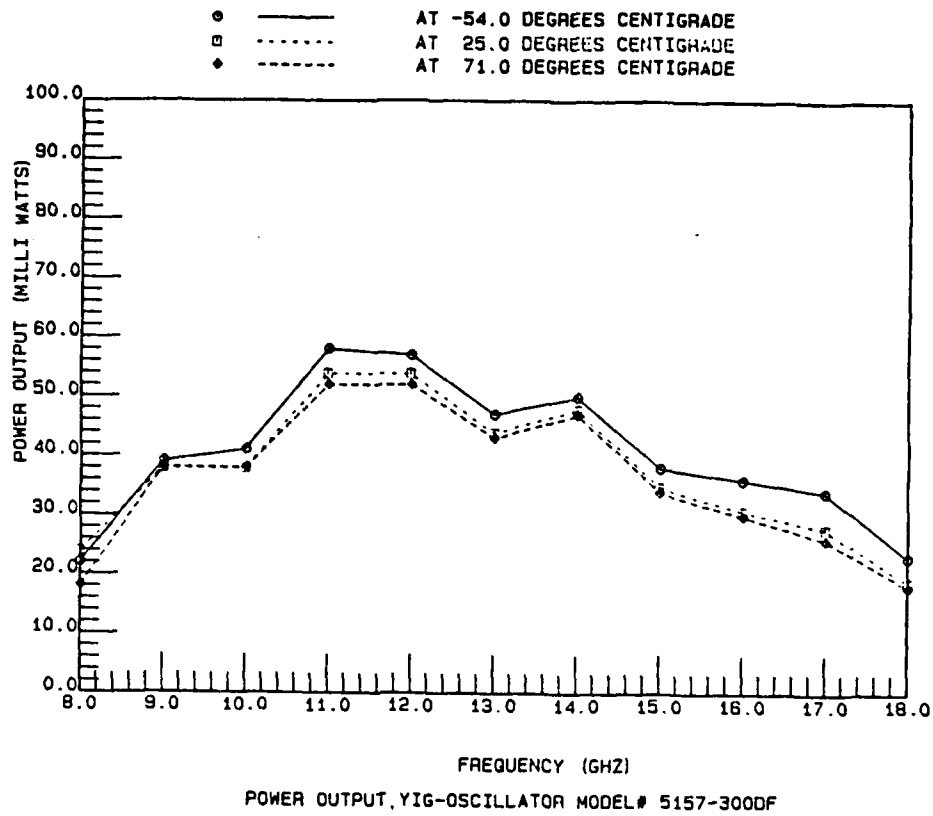
Current: 500 mA

Test Data:

Tuning Vdc	Calculated Frequency (GHz)	Δ Frequency (MHz) +25° C	Power Output (mw) +25° C
0	8.00	0	24.0
1	9.00	+1	38.0
2	10.00	+9	38.0
3	11.00	+7	54.0
4	12.00	+9	54.0
5	13.00	+13	44.0
6	14.00	+9	48.0
7	15.00	+16	35.0
8	16.00	+10	31.0
9	17.00	+5	28.0
10	18.00	0	19.0

Hysteresis: 8.0 MHz





YIG-TUNED TRANSISTOR OSCILLATOR

Type No.: 6708-304F

Serial No.: 1094 (Catalog Item)

Operating Conditions:

Heater Voltage: 28 Vdc

Current: 26 mA

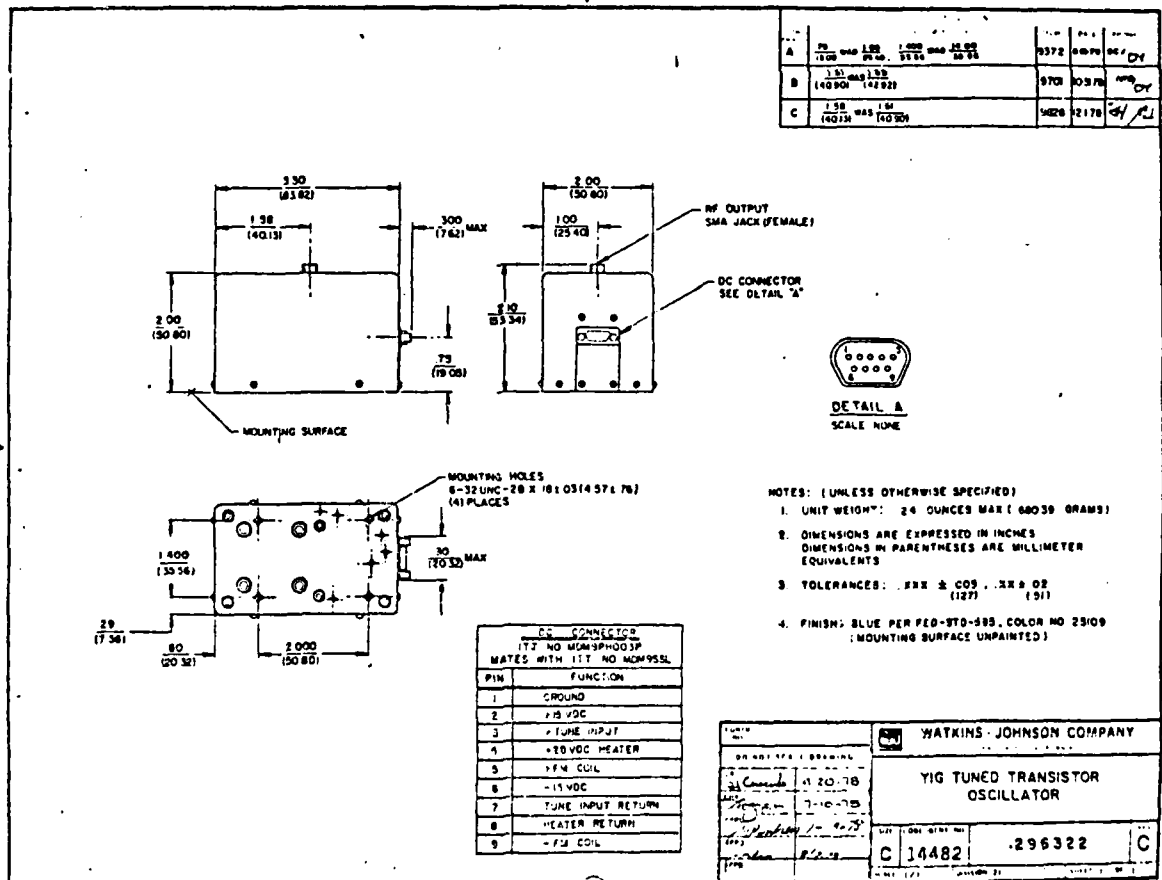
Transistor Voltage: +15 Vdc; -15 Vdc

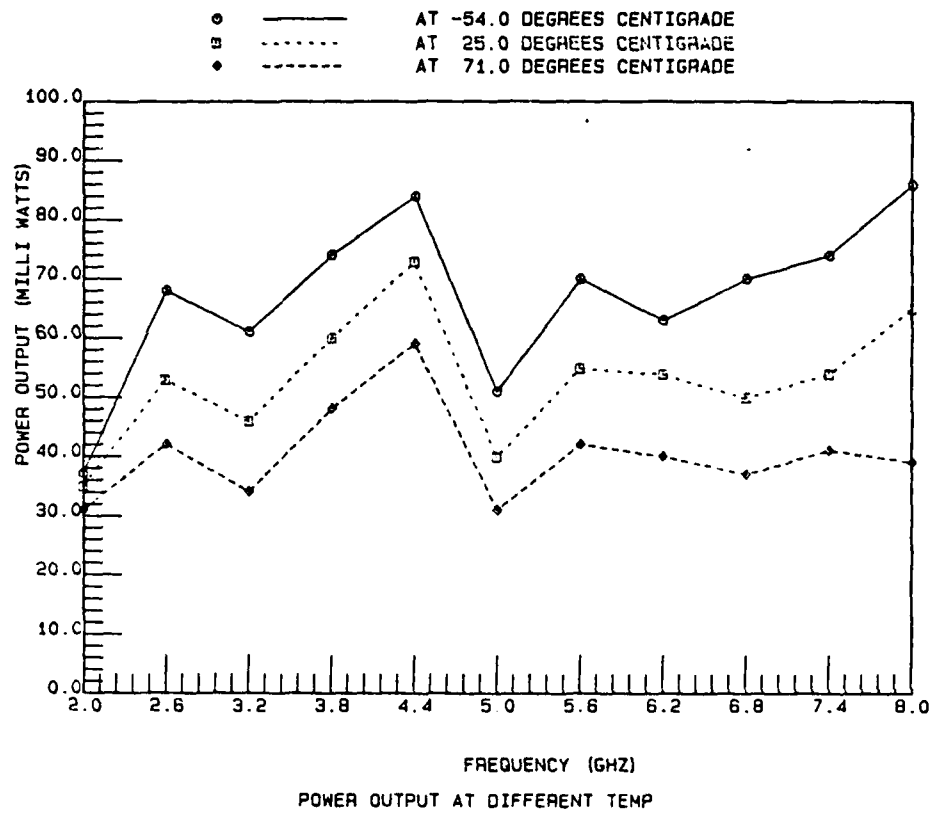
Current: 643 mA; 44 mA

Tuning Voltage (V)	Calculated Frequency (GHz)	Frequency Deviation (MHz) 25° C	Power Output (mW) 25° C
0	2.0	0	35
1	2.6	- .8	53
2	3.2	- .3	46
3	3.8	+1.4	60
4	4.4	+2.1	73
5	5.0	+4.8	40
6	5.6	+7.2	55
7	6.2	+7.1	54
8	6.8	+9.0	50
9	7.4	+9.5	54
10	8.0	- .2	65

Drift: 7.7 MHz (max)

Hysteresis: 8 MHz





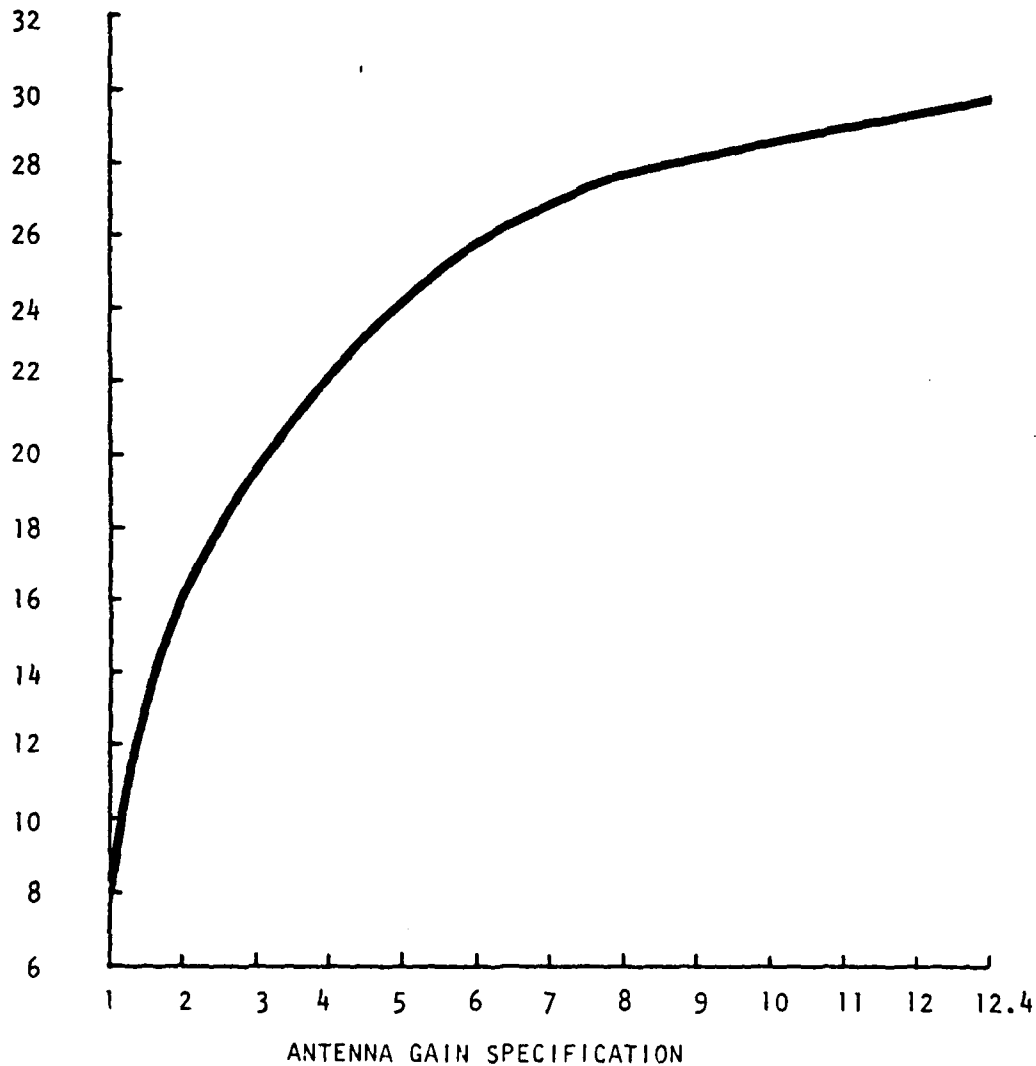
A6 ANTENNAE

PERFORMANCE SPECIFICATIONS

ANTENNA MODEL NUMBER	FREQ RANGE (GHz)	EFFECTIVE DIAMETER in. cm	VSWR (MAX)	GAIN dBi	HOW POLAR- IZED	FRONT TO BACK RATIO MIN dB DN	SQUINT (MAX)	SIDE LOBES MIN. dB DN	3 dB BEAMWIDTH
AR168-AS	1.0 TO 12.4	18 46	3.1**	18 (12 GHz)** 29 (12.4 GHz)	LINEAR	14 dB	1**	10 dB*	30° (1 GHz) 3° (12.4 GHz)

PHYSICAL SPECIFICATIONS

MODEL NUMBER	"A" in.	"B" in.	WEIGHT lb.	"A" cm	"B" cm	WEIGHT kg	CONNECTORS
AR168-AS	20	18	4	51	46	1.81	N FEMALE



PADMASTER
Made in U.S.A.

Parabolic Dish Center Feed 18"

<u>Manufacturer</u>	<u>Cost</u>	<u>Model</u>	<u>CRINC Number</u>
Watkins-Johnson	\$2,675.00	WJ8572-11	1122

This is a dual-ridge linear-polarized-feed antenna.

Frequency (GHz): 8-18.00
Polarization: linear
Beamwidth*: suitable for reflector feed
Type: dual-ridge horn
Output flange: WRD 750; radome cover included

* Antenna patterns and other miscellaneous details are included in the Appendix.

Parabolic Dish Center Feed 12" Antenna

<u>Manufacturer</u>	<u>Cost</u>	<u>Model</u>	<u>CRINC Number</u>
Watkins-Johnson	\$2675.00	WJ8572-12	1123

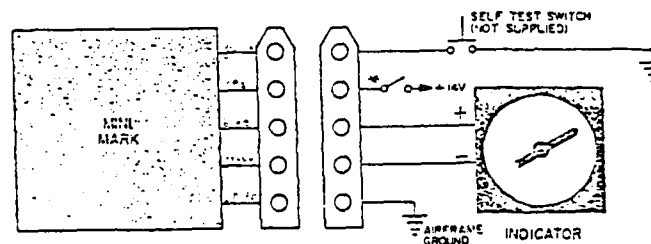
The feed for this antenna is the same as the 18" dish. The only difference is that the diameter of the reflector is 12.0".

A7 RADAR ALTIMETER

<u>Manufacturer</u>	<u>Model</u>	<u>Serial Number</u>
Bonzer	Mini-Mark	M0837

Altitude range: 80 to 1000 (ft)
Output voltage: 80 mV to 1 (V)
Power requirement: + 14 V DC

WIRING DIAGRAM



*In order to comply with FCC transmitter rules, paragraph 87.75 (c) (2), a MINI-MARK "ON-OFF" switch available to the aircraft operator must be provided.

Wiring diagram for radar altimeter.

APPENDIX B
WIRING DIAGRAMS

B1: INVERTER/ACTUATOR MODULE

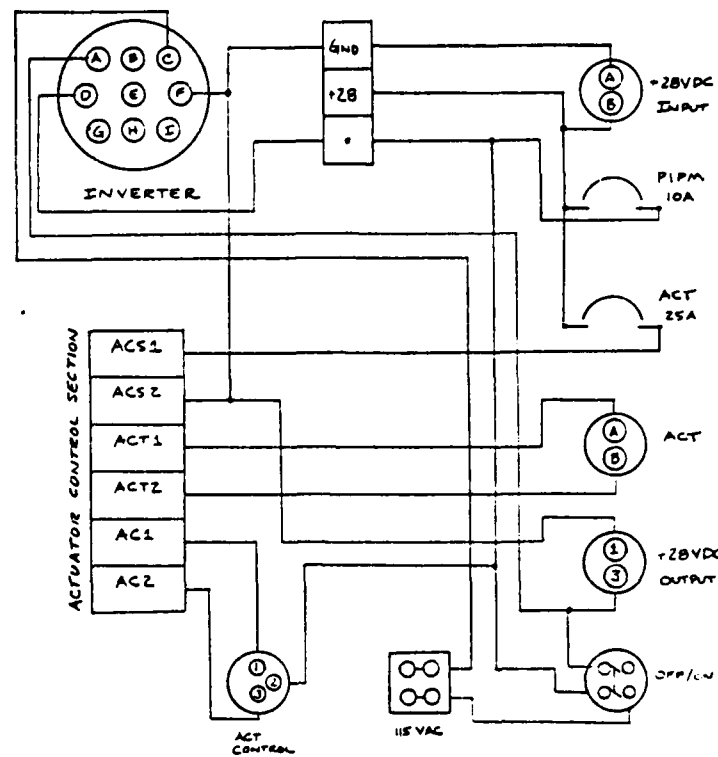


Figure B1.1: Inverter Module

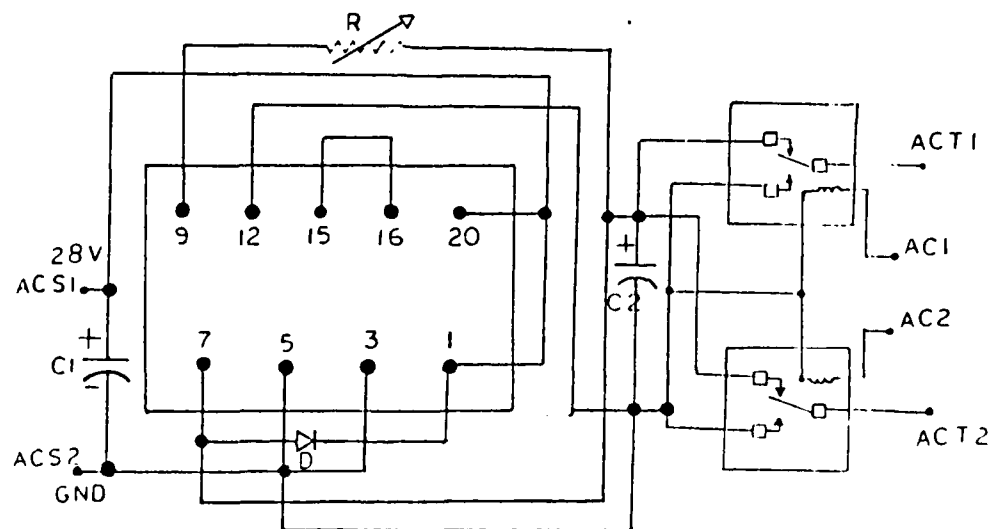


Figure B1.2: Actuator Control Section

B2: DC POWER MODULE

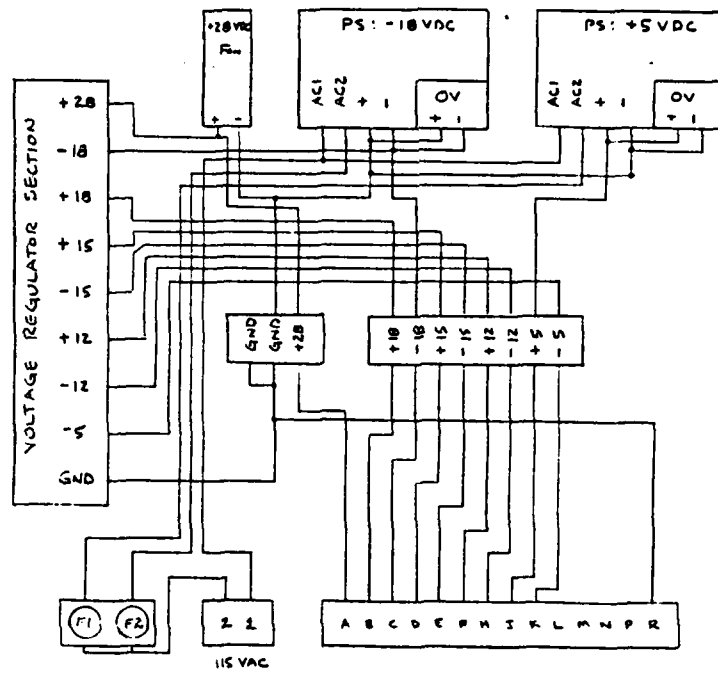


Figure B2.1: Power Supply Module

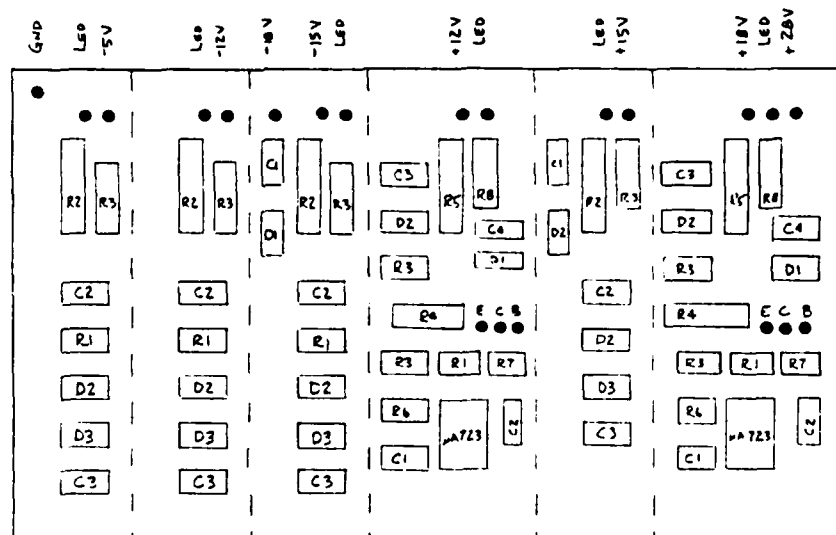


Figure B2.2: Voltage Regulator Board

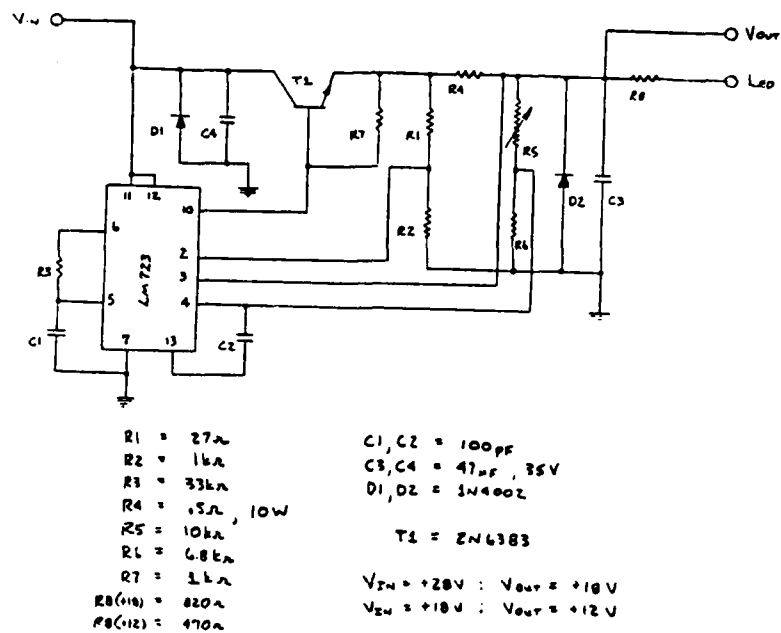
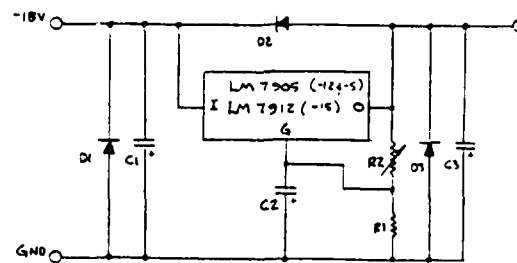
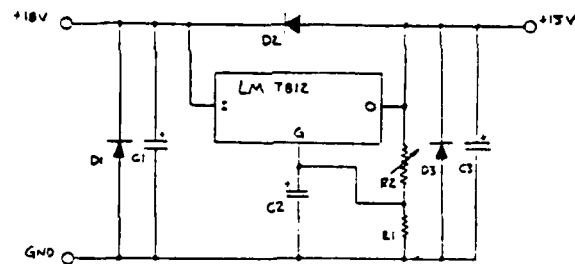


Figure B2.3: +18 V, +12 V Regulators



$C1, C2, C3 = 47\mu F, 35V$
 $D1, D2, D3 = 1N4002$
 $R1 = 750\Omega$
 $R2 = 10k\Omega$
 $R3(+18) = 500\Omega$
 $R3(-15) = 560\Omega$
 $R3(-12) = 470\Omega$
 $R3(-5) = 150\Omega$

Figure B2.4: +15 V, -15, -12, -5 V Regulators

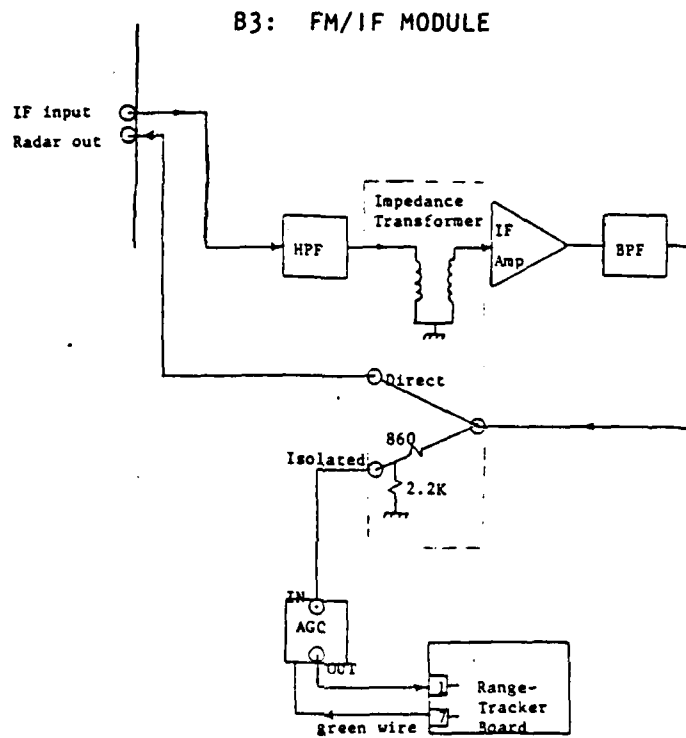


Figure B3.1: FM/IF Module Signal Path

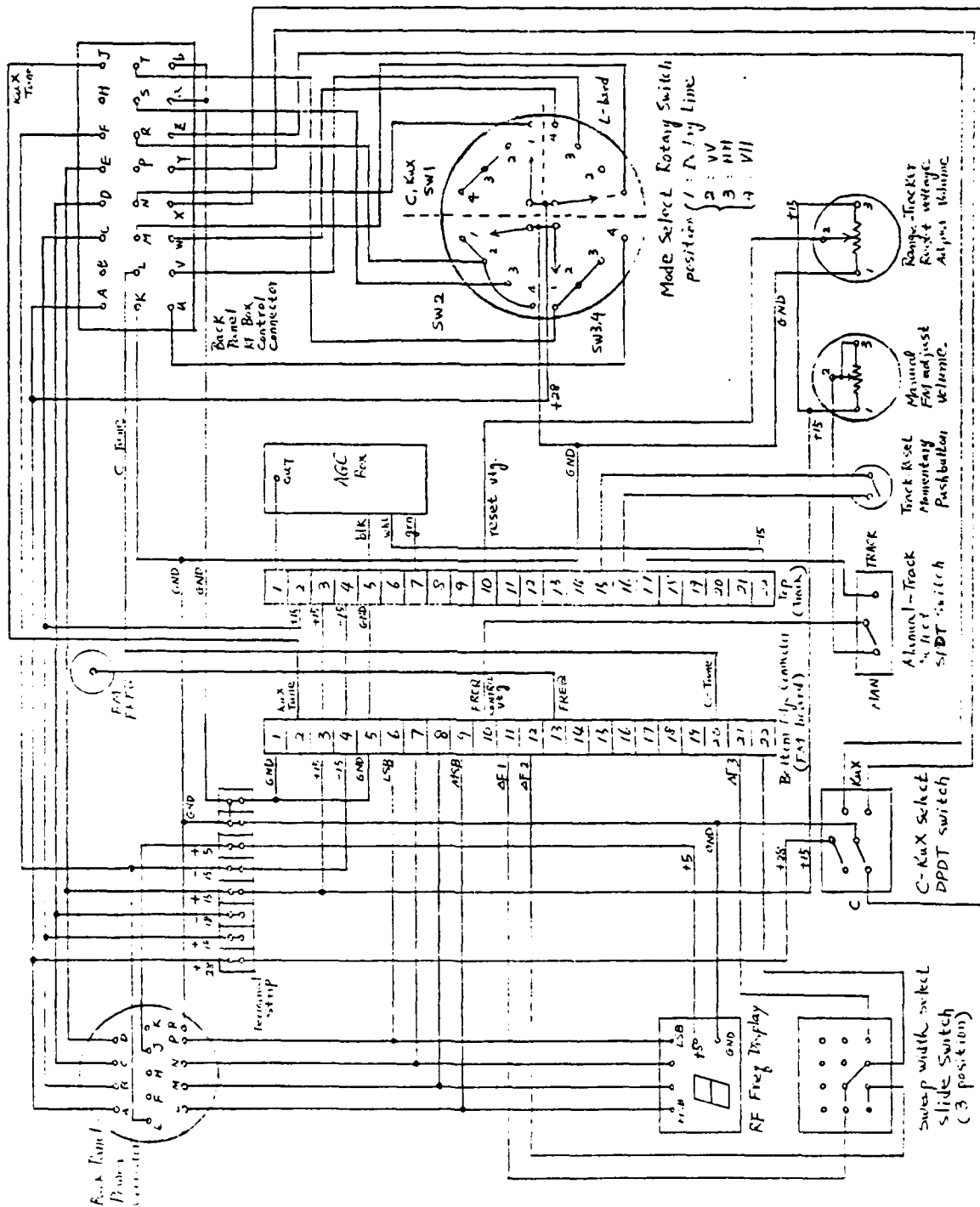


Figure B3.2: FM/IF Module Wiring

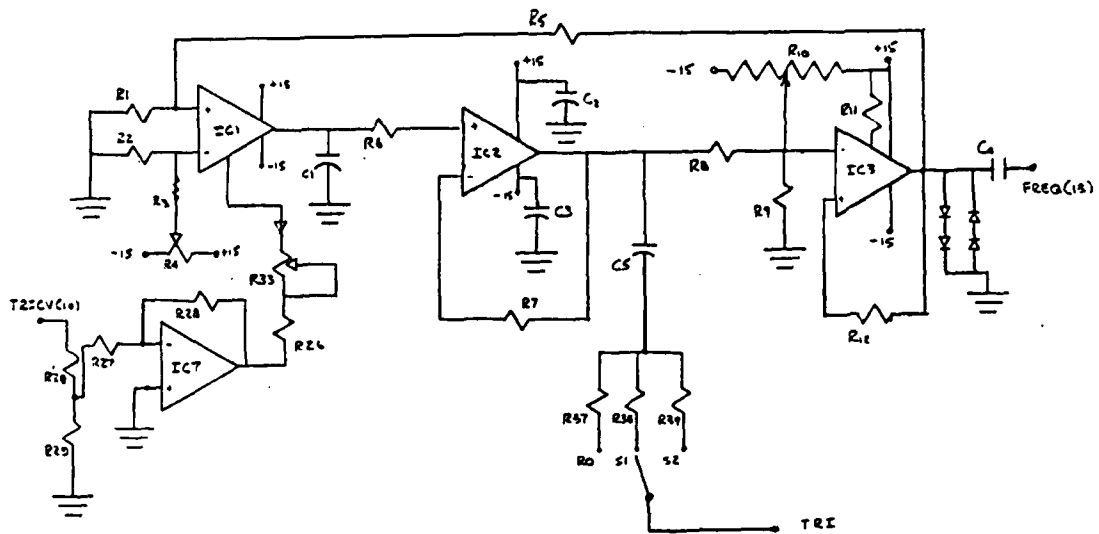


Figure B3.3a: Ku-X-C-Band FM Board, VCO Section
(See component identification on Fig. B3.3c)

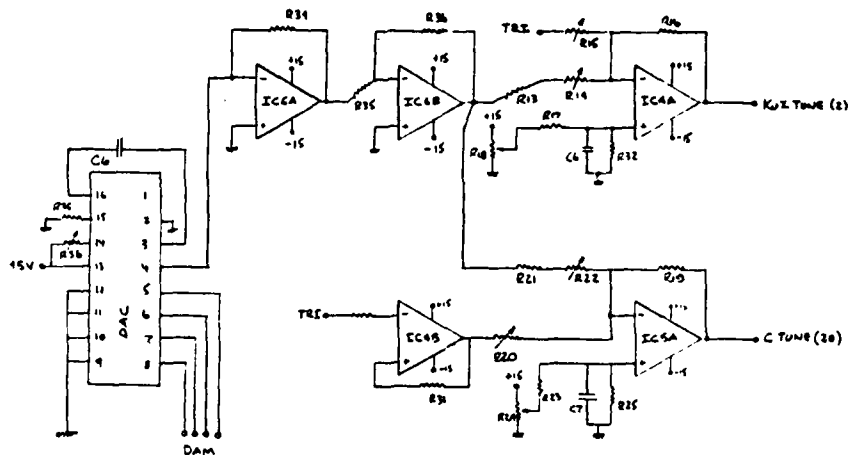


Figure 3.3b: KU-X-C-Band FM Board, Tuning Signal Generator Section
(See component identification on Fig. B3.3c)

Hand-drawn schematic of a ladder network with 10 components. The components are: C35 (0.01 uF), R44 (10 K), R22 (10 K), R23 (10 K), R12 (10 K), R13 (10 K), R14 (10 K), R4 (10 K), R10 (10 K), and R33 (10 K). The components are arranged in a ladder structure with nodes numbered 1 to 10.

[illegible]

Figure 3.4a: L-Band FM Board, Circuit (See component identification on Fig. B3.4b)

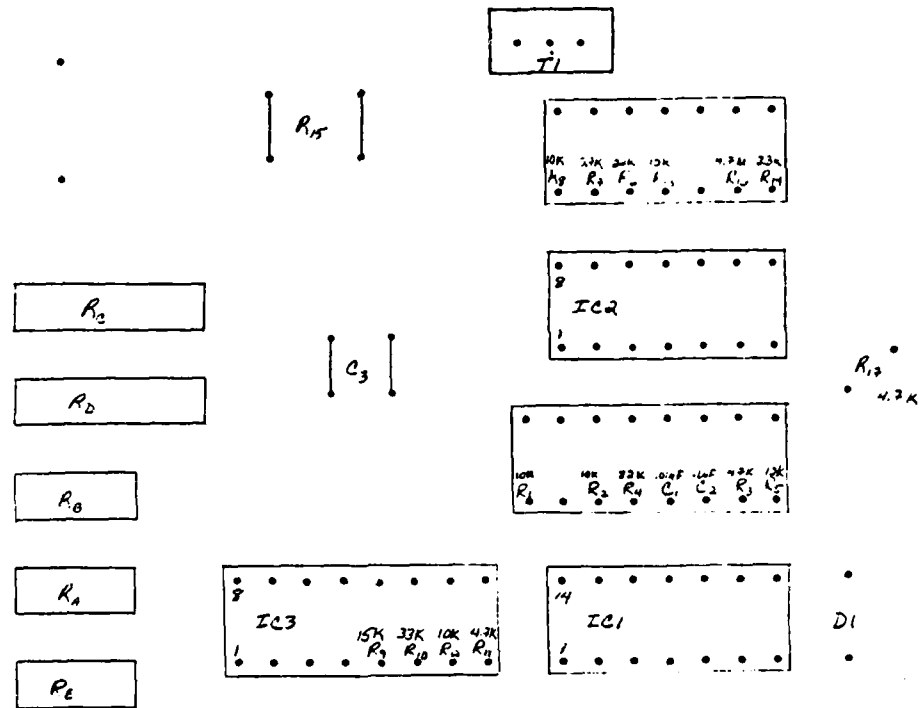


Figure B3.4b: L-Band FM Board, Layout

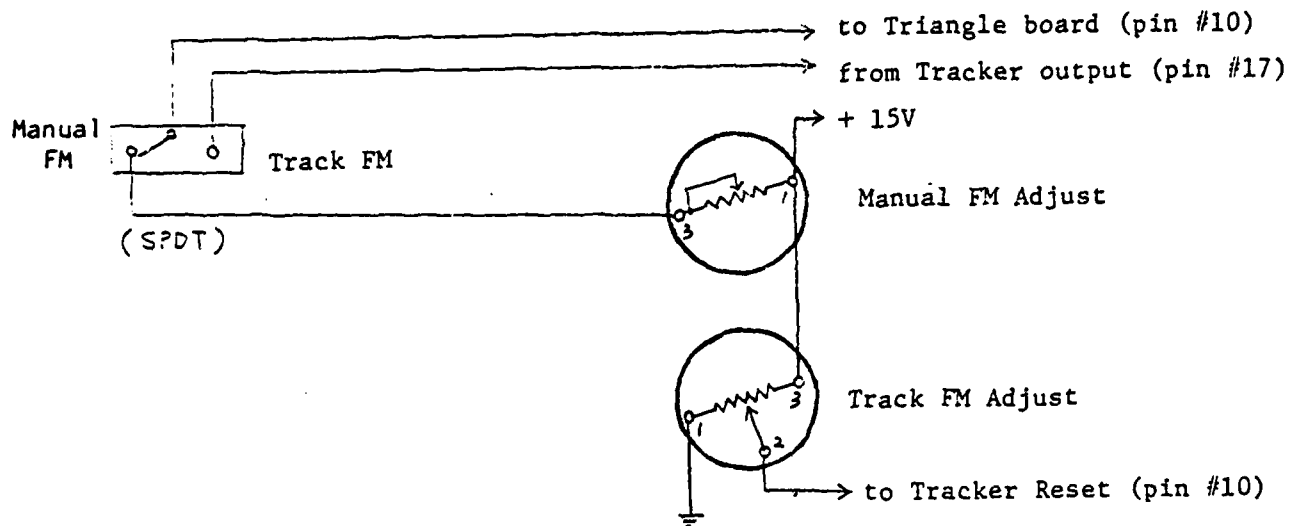


Figure B3.5: Manual-Track FM Control. Controls on front panel of FM/IF module.

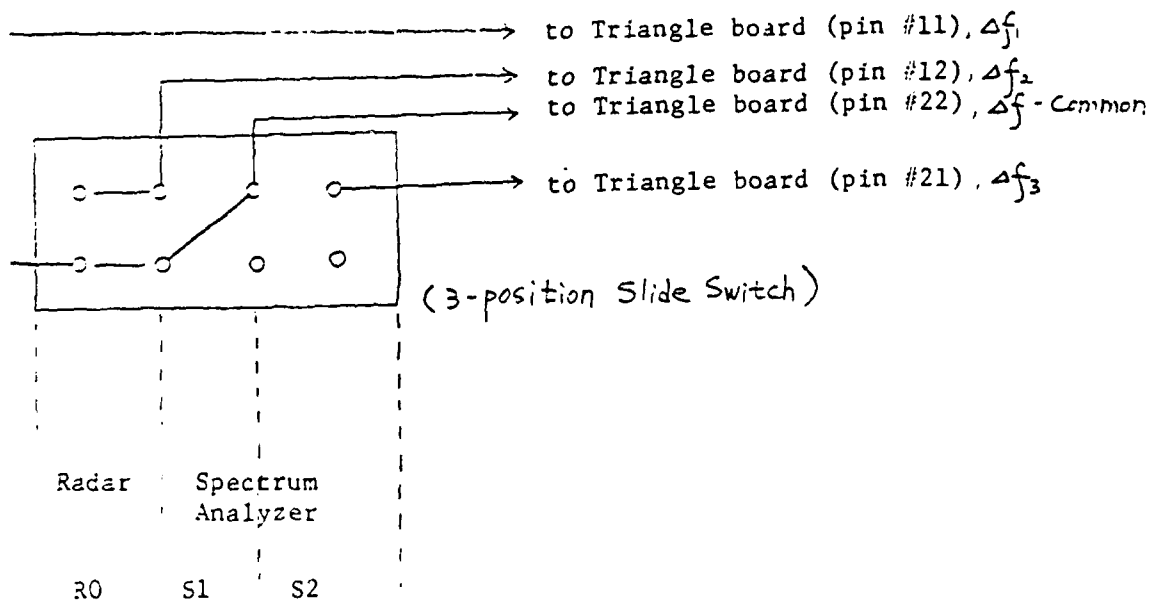


Figure B3.6: RF Sweep Width Control. (Same as above).

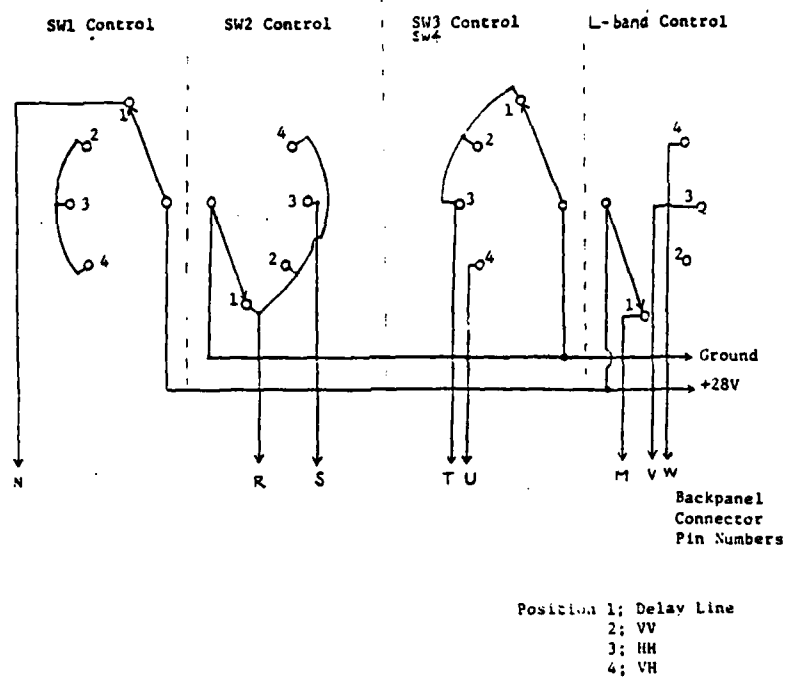


Figure B3.7: Radar Mode Select Rotary Switch

Pin #			
1	Ground	1	Signal input from AGC section
2	Ku-X-Band, Output	2	+18 V
3	15 V	3	+15 V
4	-15 V	4	-15 V
5	Ground	5	GND
6	LSB	6	NC
7	LSB + 1	7	Signal feedback to AGC section
8	MSB - 1	8	NC
9	MSB	9	NC
10	Control voltage	10	Reset voltage from track FM adjust pot.
11	To switch	11	NC
12	To switch	12	NC
13	To frequency counter	13	NC
14	NC	14	NC
15	NC	15	Reset push button
16	NC	16	Reset PUSh button
17	NC	17	Tracker output voltage, to man-track switch
18	NC	18	NC
19	NC	19	Test point, discriminator output
20	C triangle output	20	NC
21	To switch	21	Test point, input to discriminator section
22	Input to OP/amp	22	-15 V to AGC section

Figure B3.8a: Edge Connector Wiring, FM Board

Figure B3.8b: Edge Connector Wiring Tracker Board

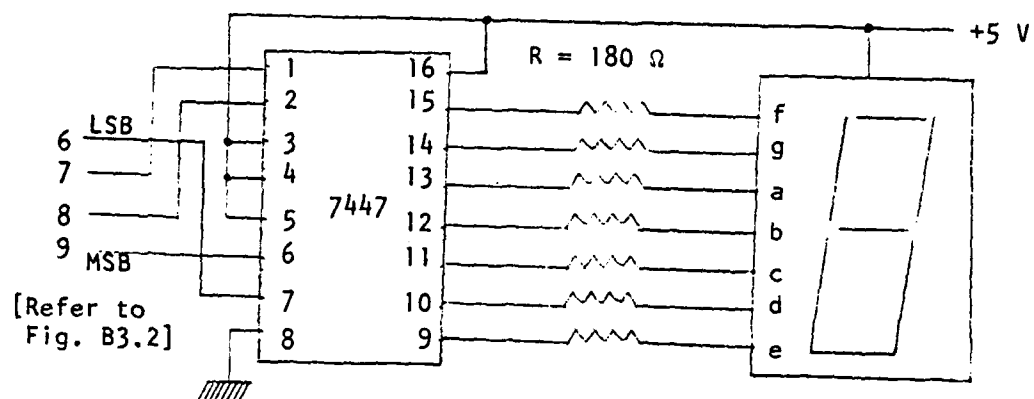


Figure B3.9a: RF Frequency Display Circuit

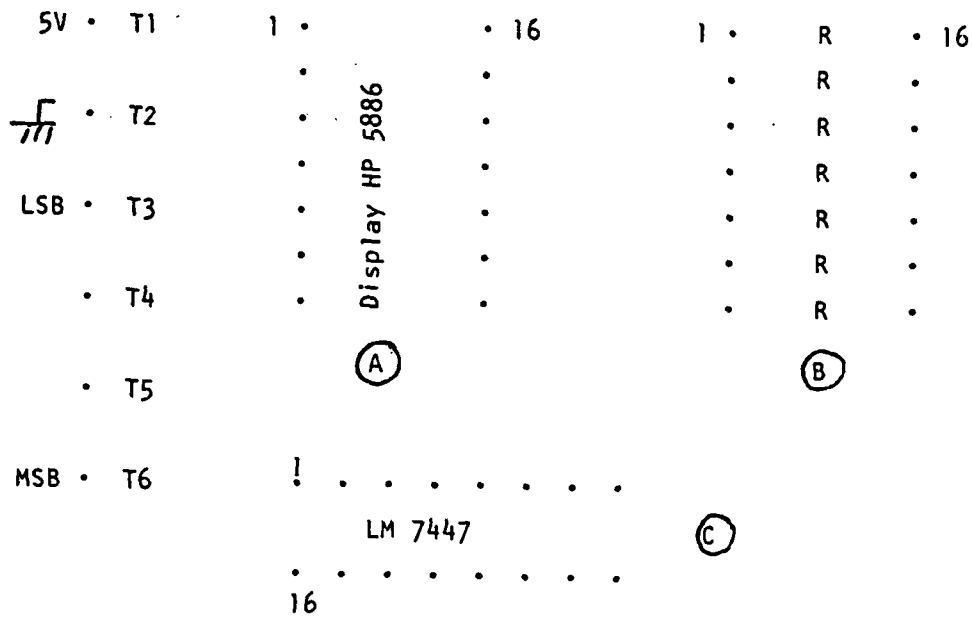
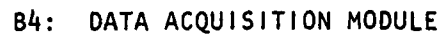


Figure B3.9b: Layout and Display Board

Wiring List:

A1	-	B1
A2	-	B2
A3,A14	-	T1
C3,C4,C5,C16	-	T1
A7	-	B3
A8	-	B5
A11	-	B6

A13	-	B7
B16	-	C15
B14	-	C9
B13	-	C10
B12	-	C11
B11	-	C14
B10	-	C12



Back view of Meter Module front panel

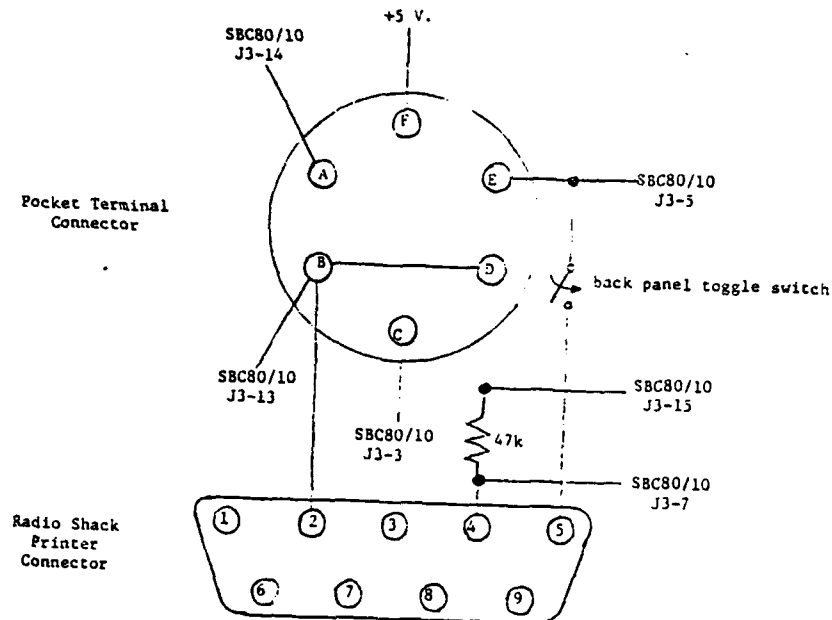


Figure B4.2: Front Panel Connectors

METER MODULE BACK PANEL TOGGLE SWITCH

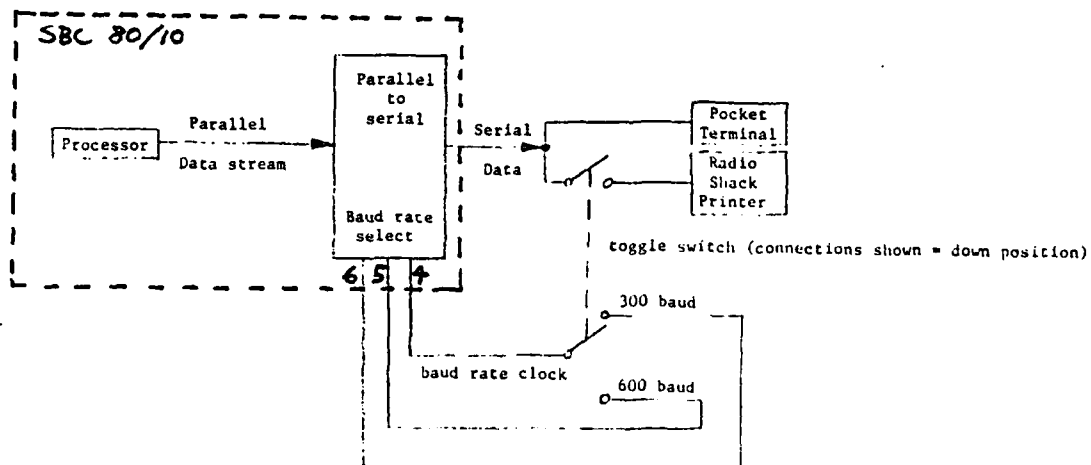


Figure B4.3: Back Panel Toggle Switch

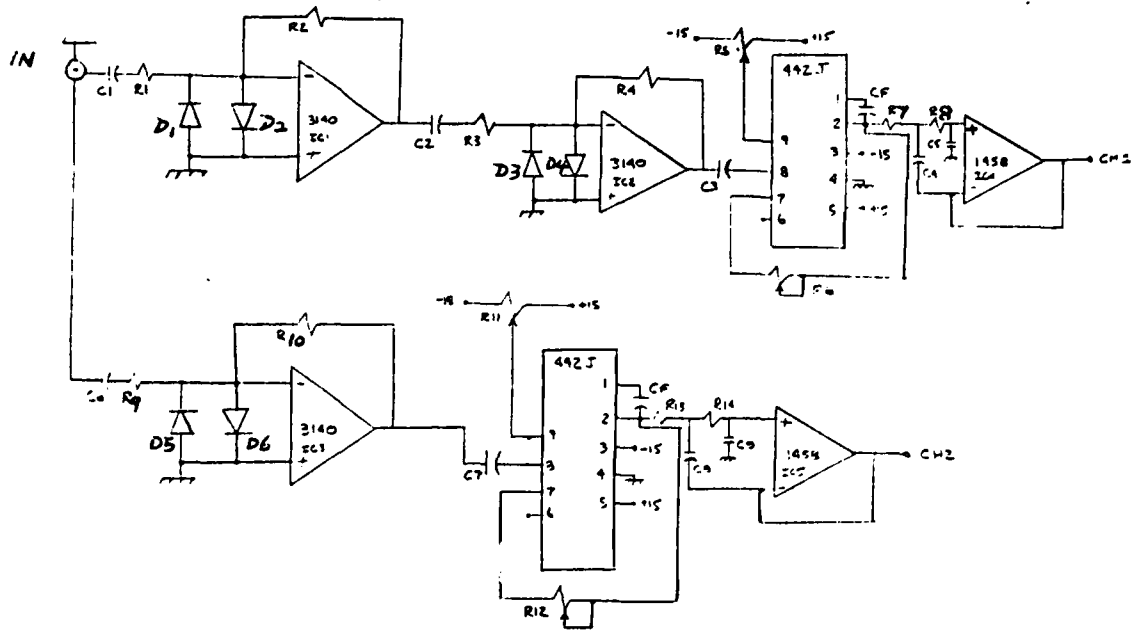
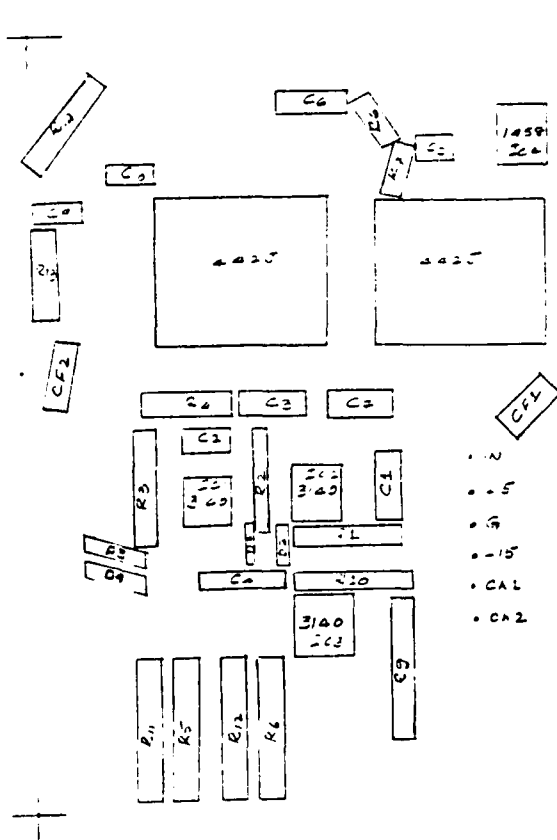


Figure B4.4a: RMS Board, Circuit



Parts List:

- D1, D2, D3, D4, D5, D6 - 1N914
- R5, R11, R12, R6 - 20 k Ω
- R7, R8, R13, R14 - 47 k Ω
- C1, C2, C3, C6, C7 - 10 MF
- R9 - 10 k Ω
- R10 - 33 k Ω
- CF - 1 MF
- C4, C8 - 0.47 MF
- C5, C9 - 0.2 MF

Figure B4.4b: RMS Board, Layout

OSCILLATOR FREQUENCY CONTROL LOGIC

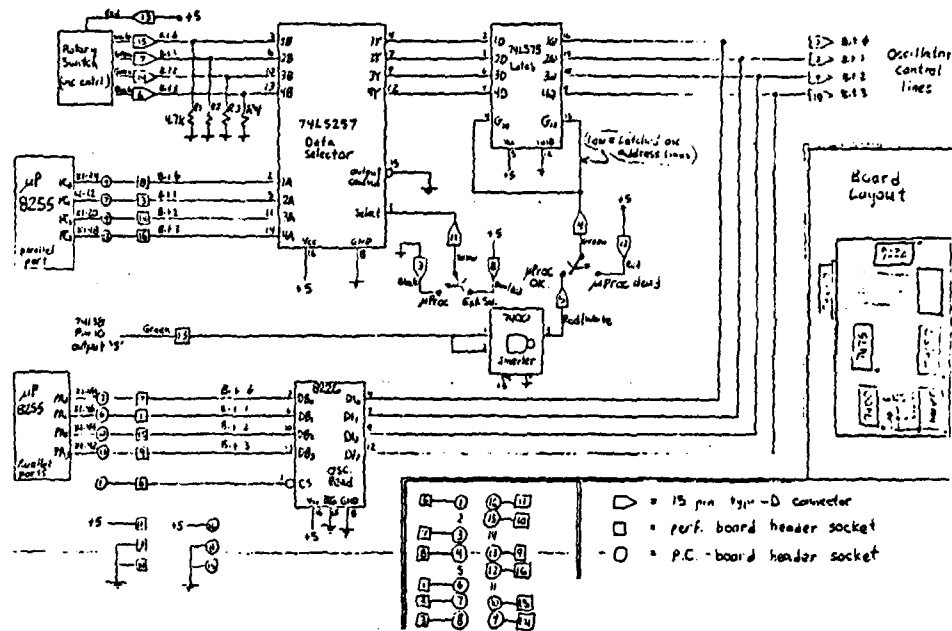


Figure B4.5: Oscillator Frequency Control Circuit

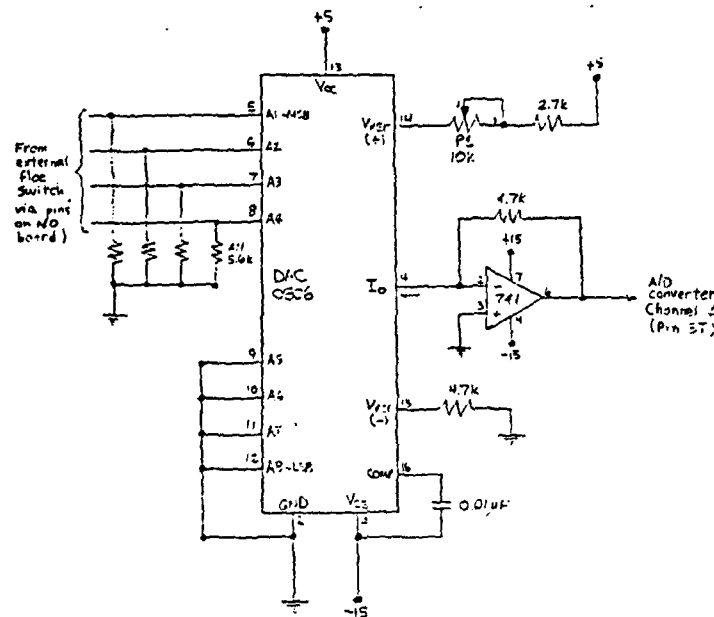
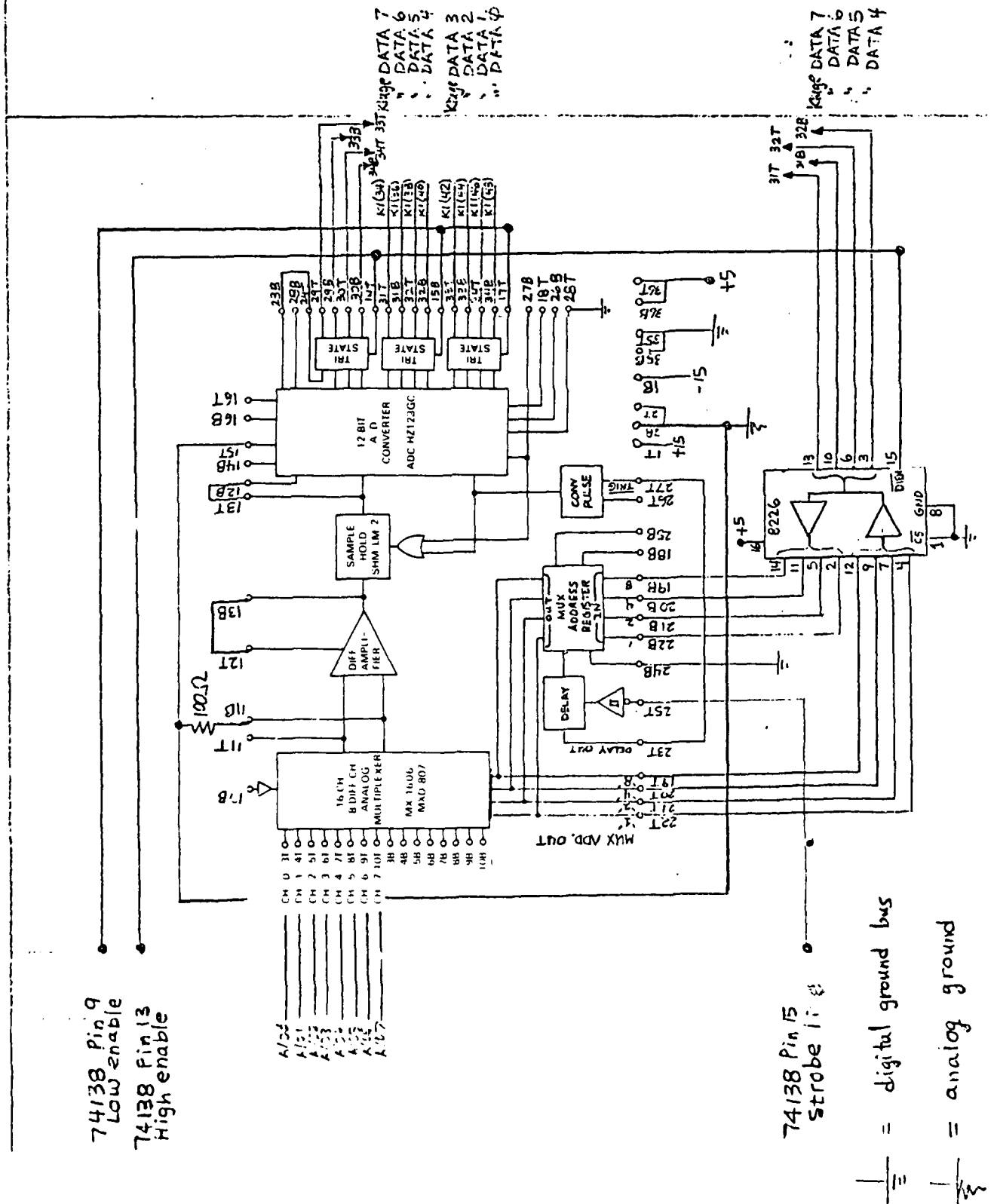


Figure B4.6: Floe Switch D/A Converter

Figure 84.7a: A/D Converter Module



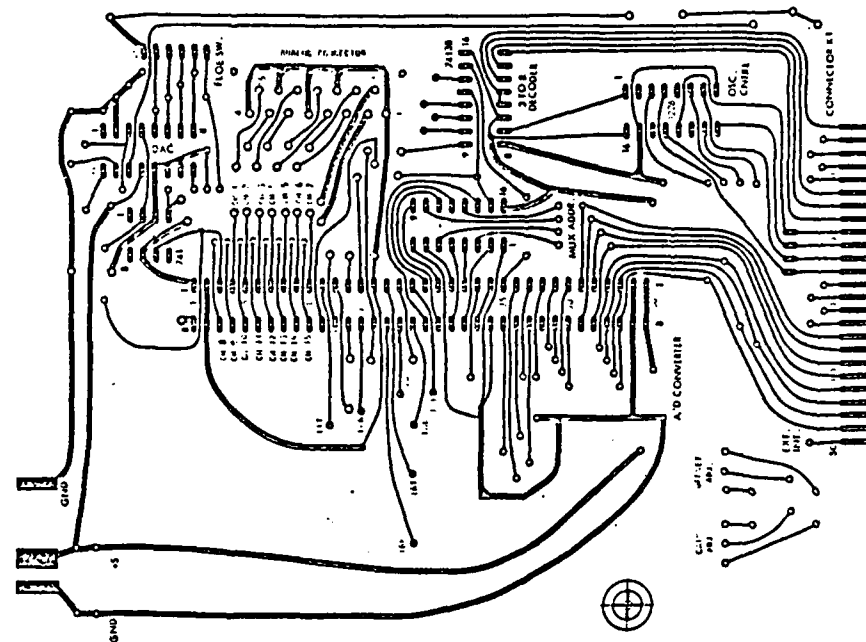


Figure B4.7b: A/D Converter Layout

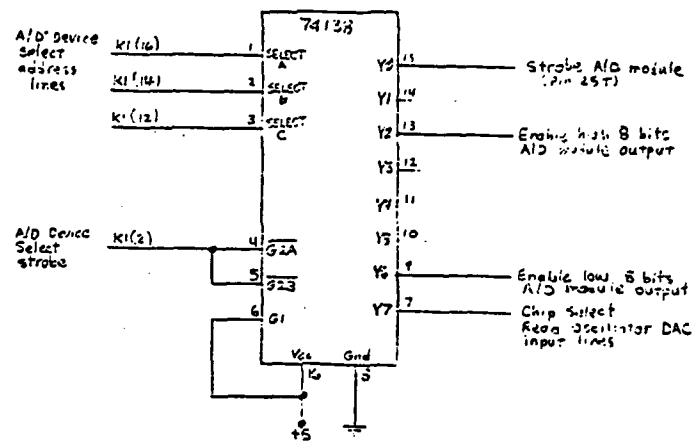


Figure B4.7c: A/D Converter Device Select

Pin #	Signal
2	A/D device select strobe
4	
6	
8	
10	
12	A/D device select address line 'C'
14	" " " " " 'B'
16	" " " " " 'A'
18	Oscillator control bit 3
20	" " " 2
22	" " " 1
24	" " " 0
26	
28	
30	
32	
34	Kluge data bit 7
36	" " " 6
38	" " " 5
40	" " " 4
42	" " " 3
44	" " " 2
46	" " " 1
48	" " " 0
50	

Figure B4.7d: A/D Board Edge Connector 'K1'

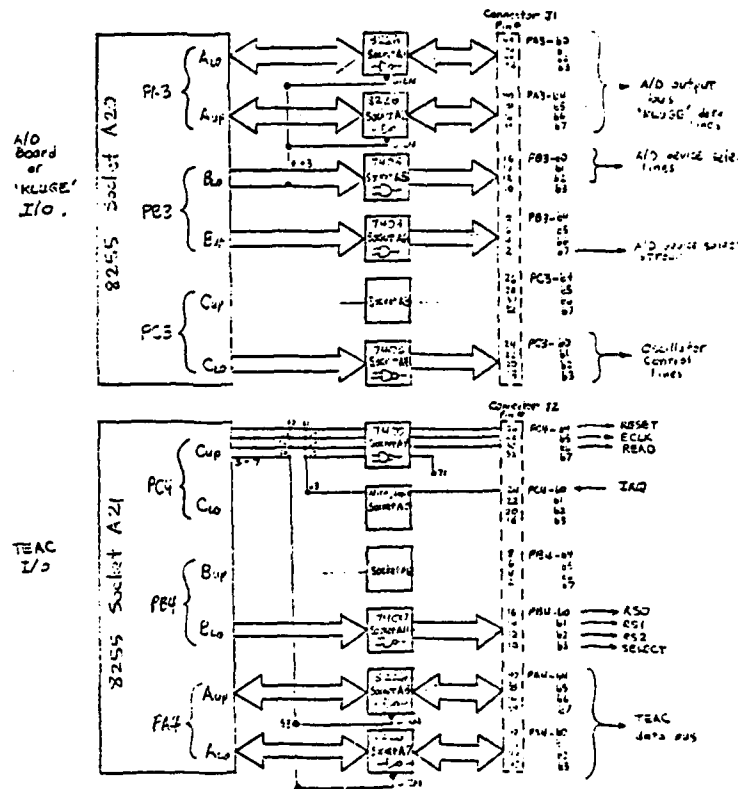
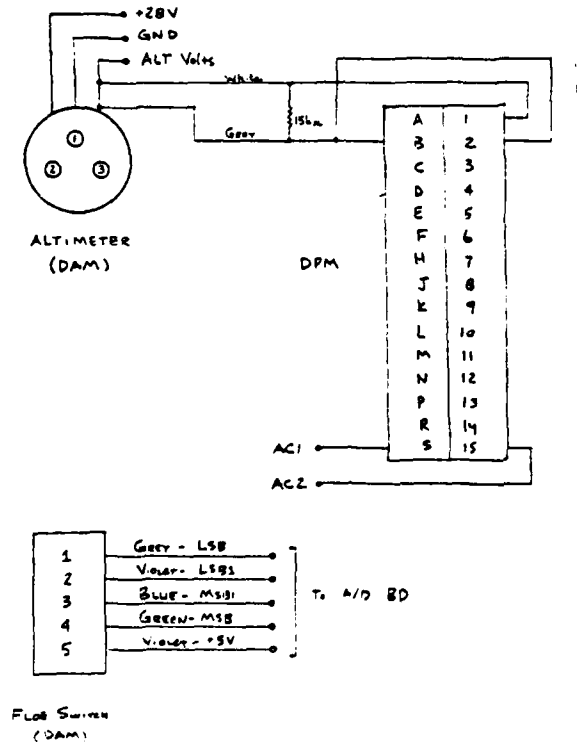


Figure B4.8: SBC104 Parallel Ports



DAM - Data Acquisition Module
DPM - Digital Panel Meter in DAM

Figure B4.9: Panel Meter, Floe Switch Wiring

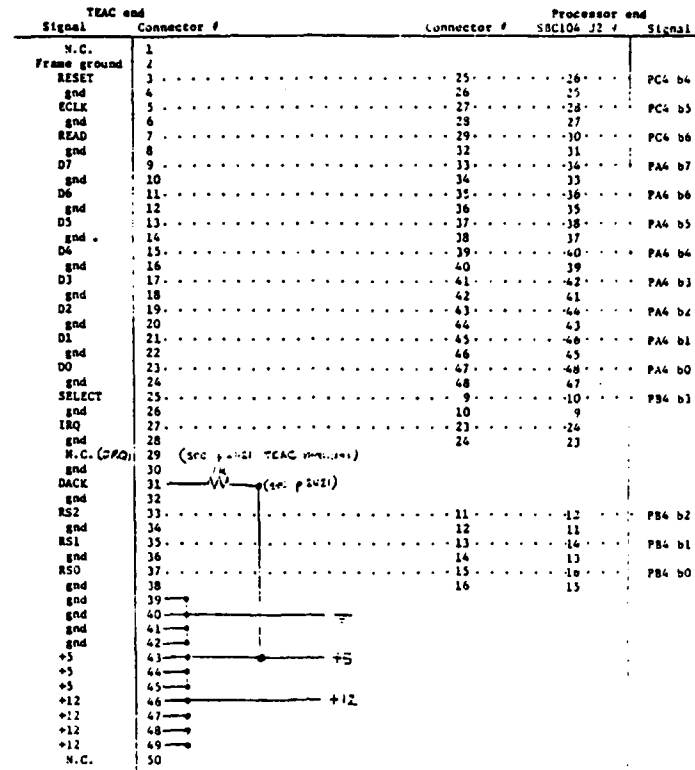


Figure B4.10: TEAC Tape Deck Interface Cable

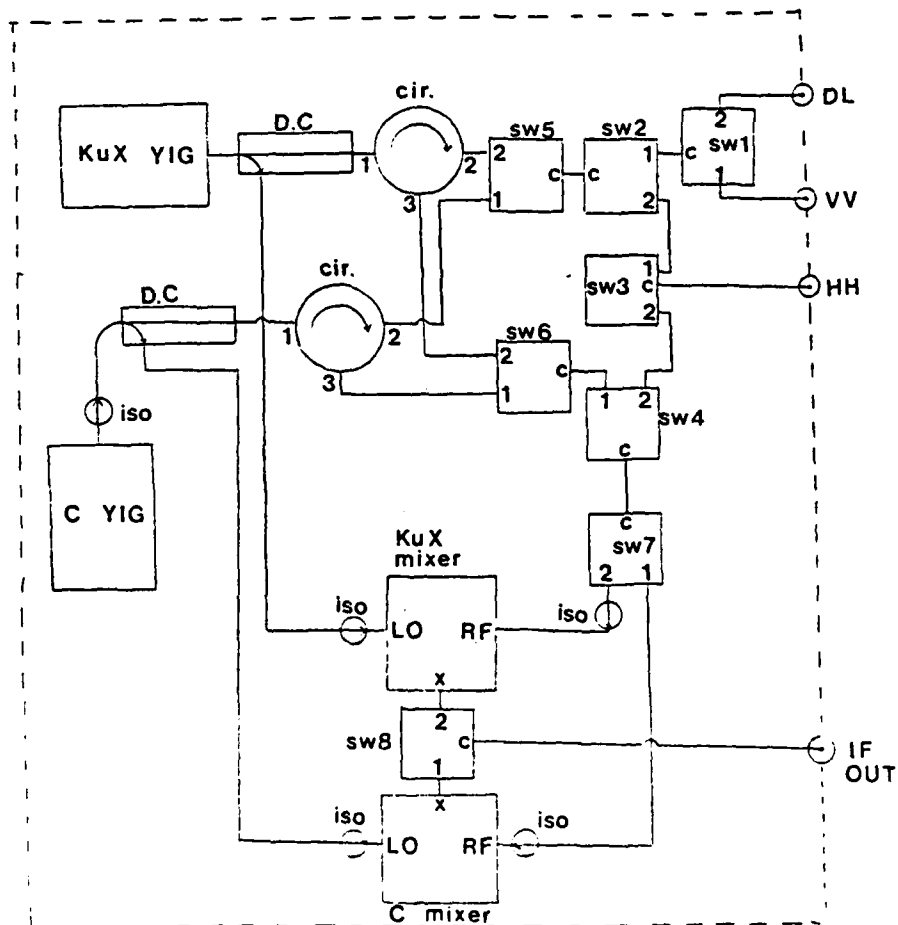
Fluke		SB 8510 -J2	
Signal	connector #	connector #	Signal
3S D8	14	35	P4 B7
3S D4	B	37	B6
3S D2	15	39	B5
3S D1	S	41	B4
4S D8	12	49	B3
4S D4	N	42	B2
4S D2	13	45	B1
4S D1	P	43	B0
5S D8	10	17	P5 B7
5S D4	L	15	B6
5S D2	11	13	B5
5S D1	M	11	B4
LS D8	8	3	B3
LS D4	J	9	B2
LS D2	9	7	B1
LS D1	K	5	B0
Print	2	33	P6 B7
KHe	21	31	B6
DP(L)	F	29	B5
DP(N)	H	27	B4
2SD8	16	19	B3
2SD4	T	21	B2
2SD2	17	23	B1
2SD1	U	25	B0
GND	A	even #'s	GND

Figure B4.11: Fluke Interface Cable

Boonton		SB 80/10 - J1	
Signal	connector #	connector #	Signal
-48m	2	33	P1 B7
MSD 4	4	35	B6
2	A	37	B5
1	1	39	B4
2SD 2	E	47	B3
4	D	45	B2
2	C	41	B1
1	B	43	B0
3SD 3	K	15	P2 B7
4	J	13	B6
2	H	11	B5
1	F	9	B4
LSD 2	P	1	B3
4	N	3	B2
2	M	5	B1
1	L	7	B0
encode complete	W	31	P3 B7
volt mode	3	23	B6
OVER	Z	27	B5
UNDER	Y	21	B4
RANGE 2	U	17	B3
4	T	19	B2
2	S	29	B1
1	R	25	B0
GND	5	Even numbers	GND

* Low voltage ground isolation. Another ground must be provided.

Figure B4.12: Boonton Interface Cable



B5: RF MODULE

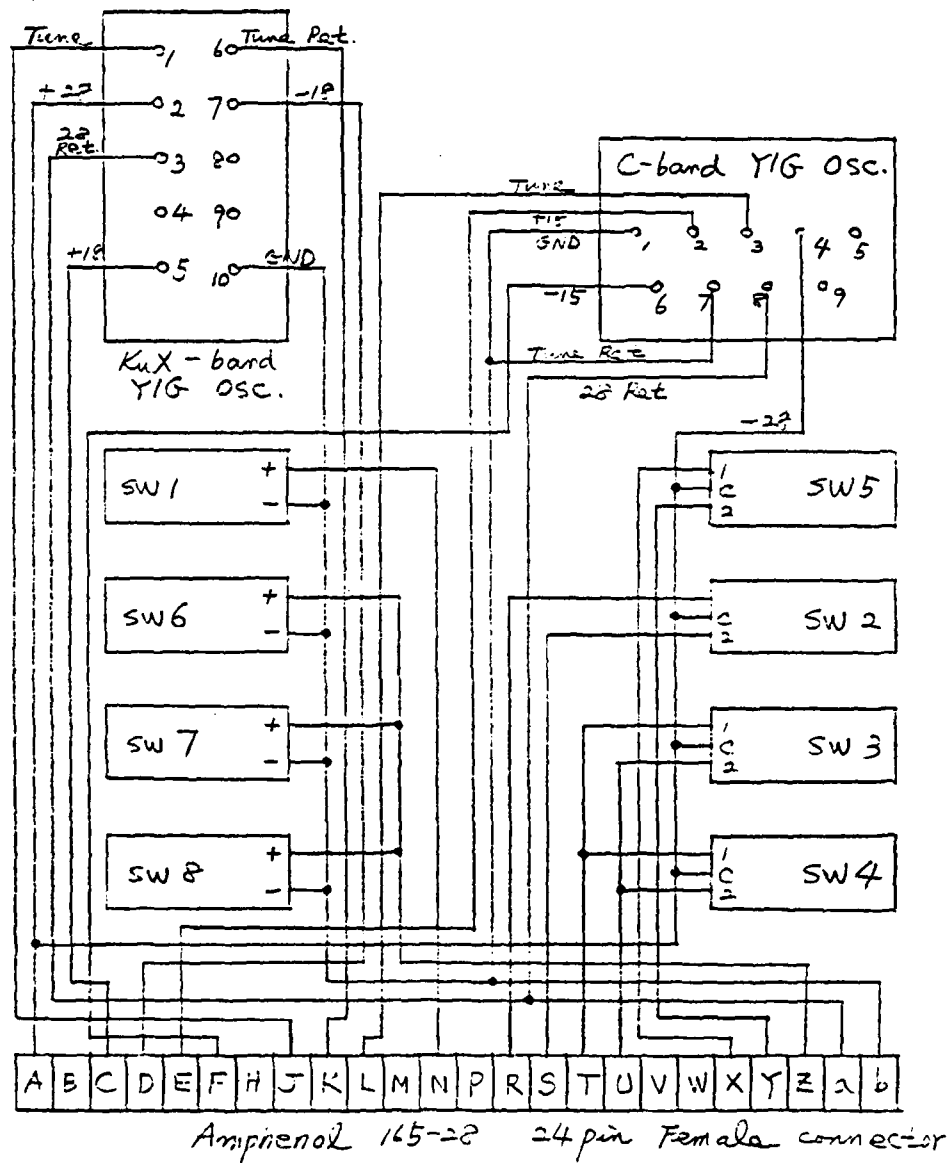


Figure B5.1: RF Module Wiring Diagram

	KuX-band					C-band				
	SW1	SW2	SW3	SW4	SW5,6,7,8	SW1	SW2	SW3	SW4	SW5,6,7,8
DL	2	1	1	1	2	2	1	1	1	1
VV	1	1	1	1	2	1	1	1	1	1
RH	1	2	1	1	2	1	2	1	1	1
VH	1	1	2	2	2	1	1	2	2	1

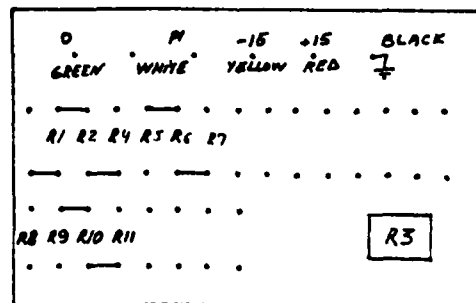
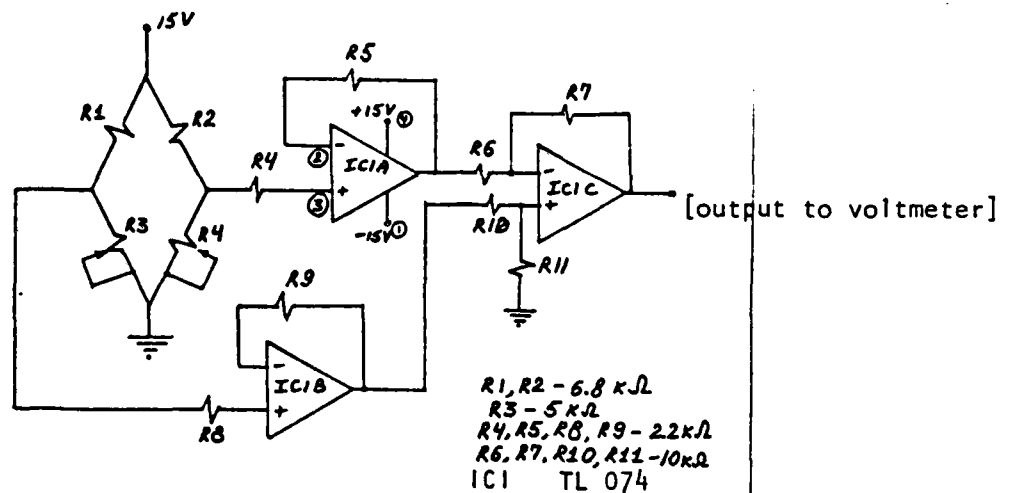
Table B5.1a: Logic Matrix for the Switch Positions

Control Connector Pin	Wiring Color Code	
A	Black	+28 V, Ku-X-YIG(#2), C-YIG(#4), SW5,2,3,4 common
B		open
C	Red	+18 V, Ku-X-YIG(#5)
D	Green	-18 V, Ku-X-YIG(#7)
E	Orange	+15 V, C-YIG(#2, red)
F	Blue	-15 V, C-YIG(#6, green)
H	White/black	open
J	Grey coax	Ku-X-YIG Tune (#1)
K	Coax shield	Ku-X-YIG Tune return (#6)
L	Orange/Black	C-YIG Tune (#3, orange)
M	Blue/Black	L-band mode control SW1 +
N	Black/White	SW1 control-DL port +
P	Red/White	open
R	Green/White	SW2 control 1
S	Blue/White	SW2 control 2
T	Black/Red	SW3,4 control 1
U	White/Red	SW3,4 control 2
V	Orange/Red	L-band mode control SW2 +
W	Blue/Red	L-band mode control SW3,4 +
X	Red/Green	SW5 control 1
Y	Orange/Green	SW5 control 2
Z	Black/White/Red	SW6,7,8 control +
a	White/Black/Red	+28 V return, Ku-X-YIG#3, C-YIG#8
b	Red/Black/White Green/Black/White	Ground to SW1 gnd, SW6,7,8 -, Ku-X-YIG#10, C-YIG#1, #7

Table B5.1b: RF Module Wiring List

Camera Lens	Volts Signal	Requires By Module			Wire Gauge	Color Code
		PS	RM	DAM		
A	+28	x	x	x	18	Red
B	+18	x	x		18	Blue
C	-18	x	x		18	Gray
D	+15	x	x	x	18	Green
E	-15	x	x	x	18	Violet
F	+12	x		x	18	Brown
H	-12	x		x	18	White
J	+5	x	x	x	18	Yellow
K	-5	x		x	18	Orange
L	LSB1		x	x	22	Yellow
M	LSB2		x	x	22	Yellow
N	MSB1		x	x	22	Yellow
P	MSB2		x	x	22	Yellow
R	GND	x	x	x	16	Black

Figure B6: Power Supply Multiconductor Cable



Top View

Figure B7: Angle Encoder (Separate box)

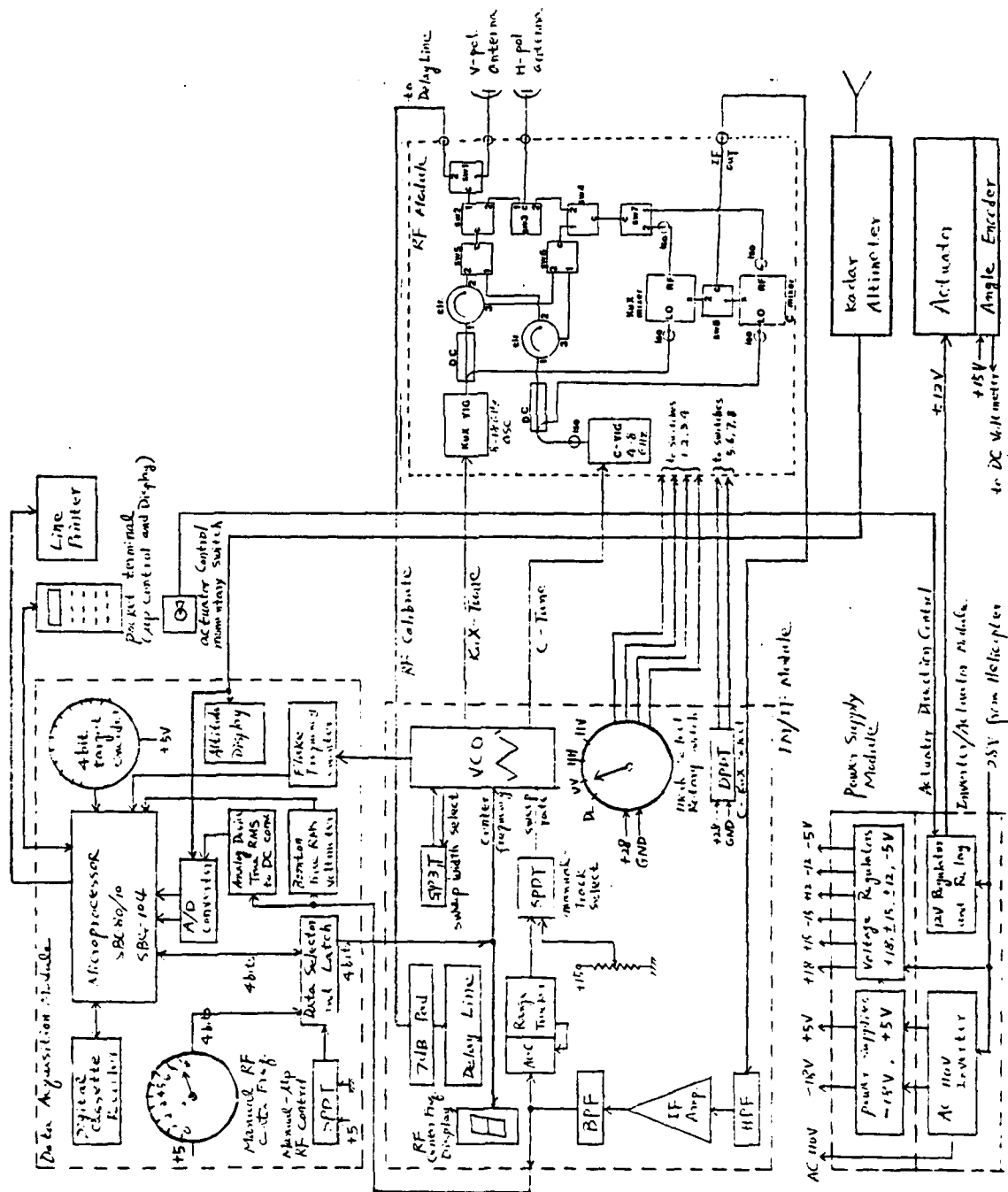


Figure B8: System Block Diagram

TABLE B8
System Control Signal Cables

Cable Name	Description	Connector Description
+28 VDC IN	Aircraft source to INV/ACT Mod.	2pin-Amp
Actuator	Actuator to INV/ACT Mod.	2pin-Amp
Actuator Control	Remote switch to INV/ACT Mod.	3pin-Audio
115 VAC	Source located at INV/ACT Mod. Required by PS, IF/FM, and DA Mods.	AC
DC Power	Links to +28 VDC at INV/ACT Mod. to PS, IF/FM, and DA Mods.	3pin-Audio 14pin-Amp
RF	IF/FM Mod to RF Mod.	28pin-Amp
IF IN	IF/FM Mod. to RF Mod.	BNC
IF OUT	RF Mod. to 50 Ω Term. at DA Mod. (Boonton)	BNC
FM	IF/FM Mod. to DA Mod. (Fluke)	BNC
RMS	At DA Mod. Links RMS to Boonton	BNC
Altimeter	DA Mod. to Altimeter	3pin-Audio

APPENDIX C

TWO-WAY EFFECTIVE BEAMWIDTHS IN DEGREES FOR HELOSCAT SYSTEM

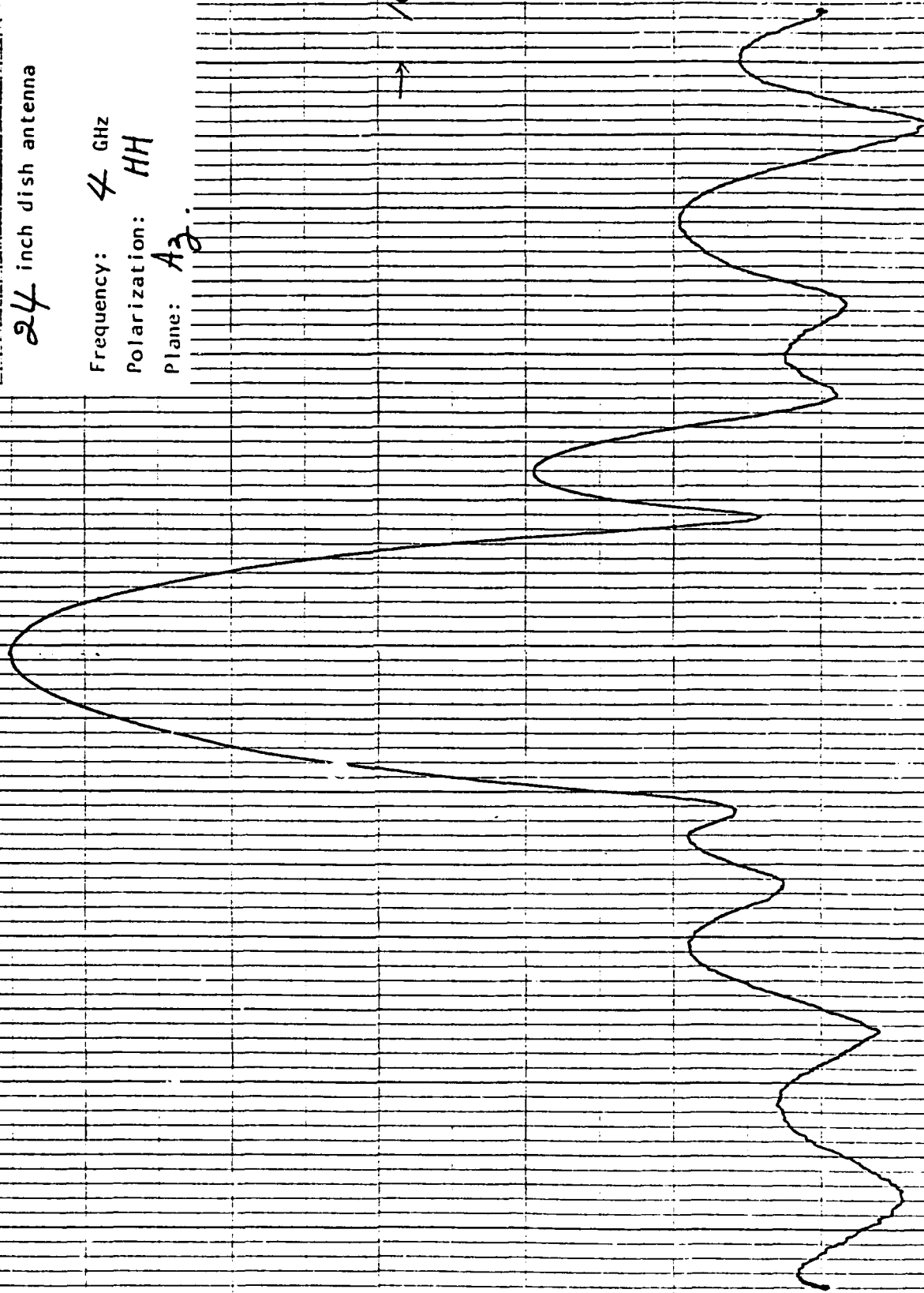
<freq.>	VV-polarization (18" dish)		HH-polarization (24" dish)		VH-polarization	
	β_e	β_a	β_e	β_a	β_e	β_a
1.5 GHz	15.9	14.2	9.1	9.8	11.4	11.5
4.4	8.2	7.4	5.8	6.1	6.8	6.8
4.8	7.6	6.9	5.4	5.8	6.3	6.3
5.2	7.0	6.3	5.1	5.3	5.9	5.9
5.6	6.5	6.0	4.7	5.1	5.4	5.5
6.0	6.2	5.4	4.4	4.7	5.1	5.1
6.4	5.2	5.2	4.2	4.4	4.7	4.9
6.8	5.0	4.9	3.9	4.2	4.4	4.5
7.2	4.9	4.5	3.7	3.9	4.2	4.3
7.6	4.7	4.3	3.5	3.7	4.1	4.0
8.6	3.9	3.7	3.0	3.3	3.5	3.5
9.6	3.7	3.4	2.7	2.9	3.2	3.2
10.6	3.5	3.0	2.5	2.7	2.9	2.9
11.6	3.0	2.8	2.3	2.5	2.6	2.7
12.6	2.9	2.5	2.1	2.4	2.5	2.5
13.6	2.9	2.4	1.9	2.4	2.3	2.5
14.6	2.8	2.4	1.8	2.3	2.1	2.4
15.6	2.7	2.1	1.7	2.3	2.0	2.3
16.6	2.4	1.9	1.6	2.1	1.8	2.0

94" 46, 111, A3

24 inch dish antenna

Frequency: 4 GHz
Polarization: HH
Plane: A3

↑ 5dB ↓ 10°



24", 4G, HA, EL.

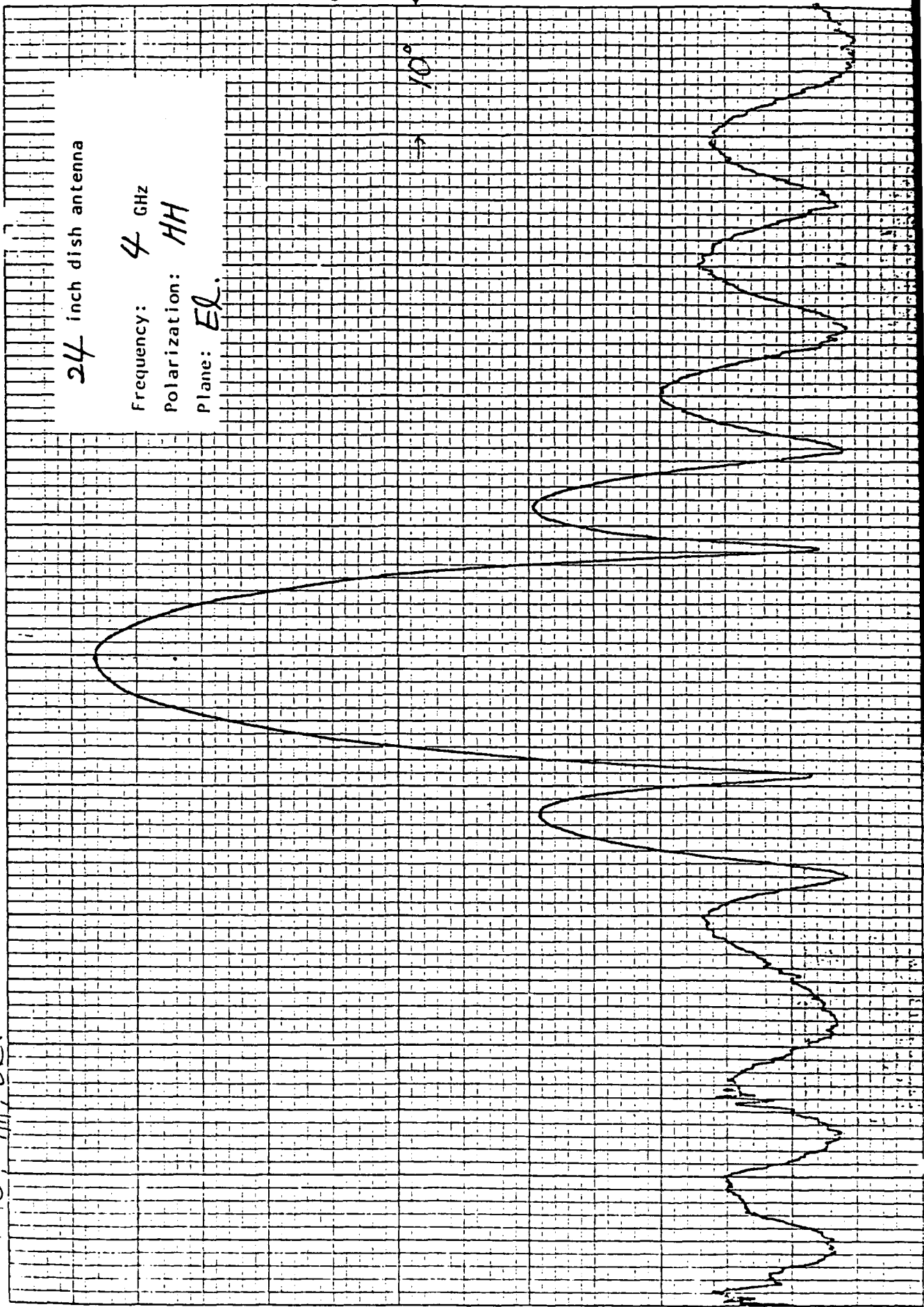
24 inch dish antenna

Frequency: 4 GHz

Polarization: HH

Plane: EL.

5dB 10°



10.8 TO 10.9 GHz, A3

24 inch dish antenna

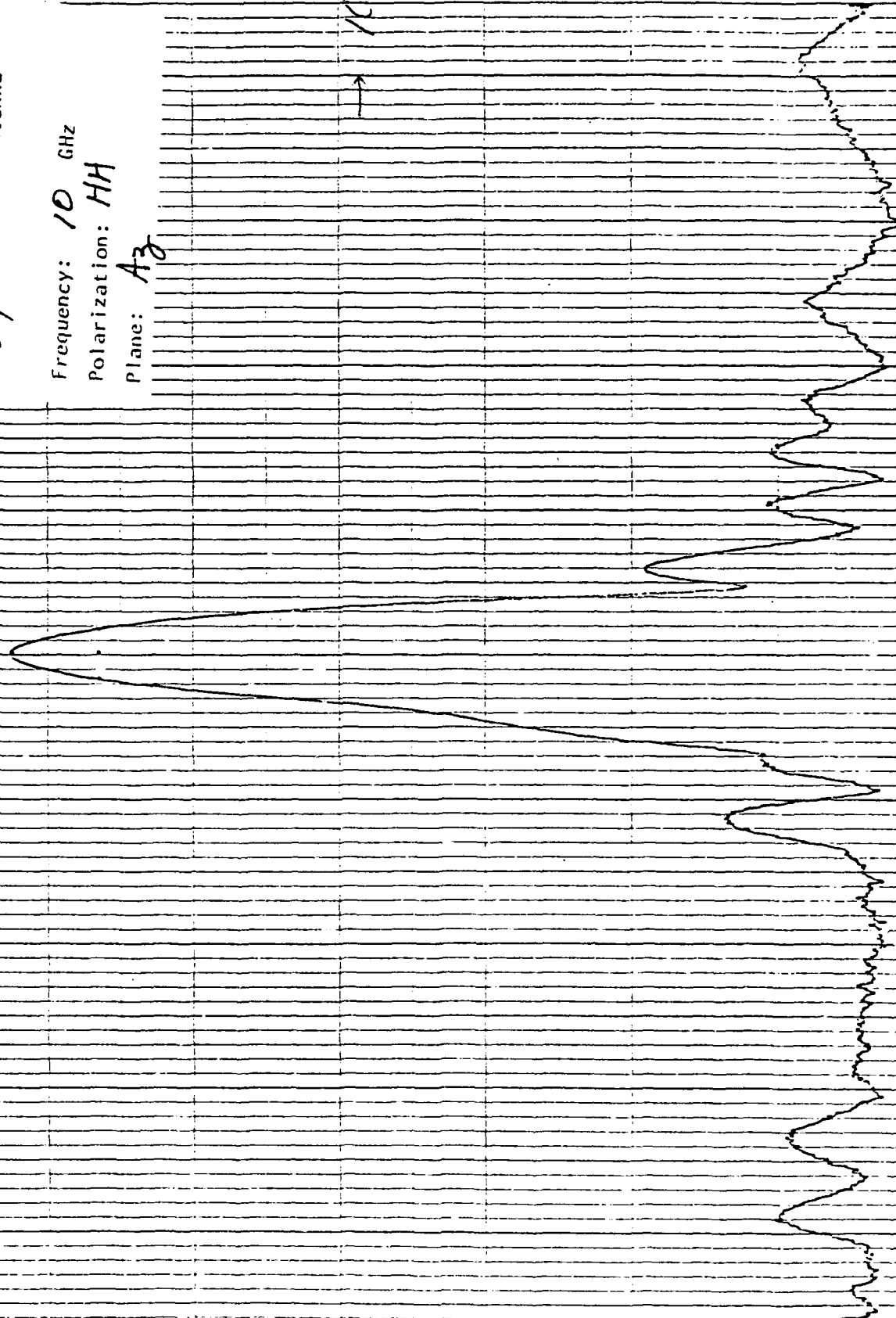
Frequency: 10 GHz

Polarization: HH

Plane: A3

5 dB

10.8



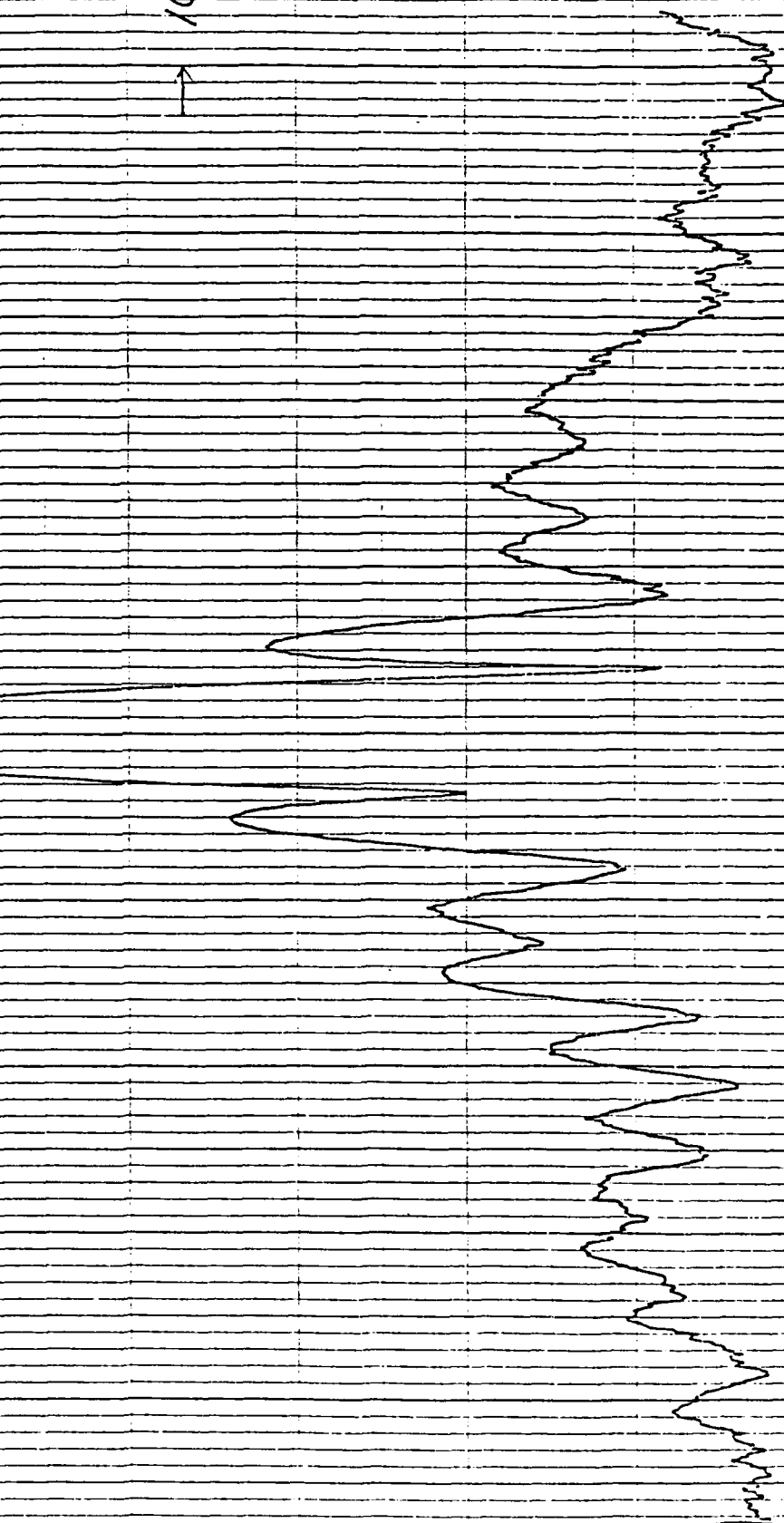
24" 10G, HH, EL

24 inch dish antenna

Frequency: 10 GHz

Polarization: HH

Plane: EL



20"

16.5, 111, A3

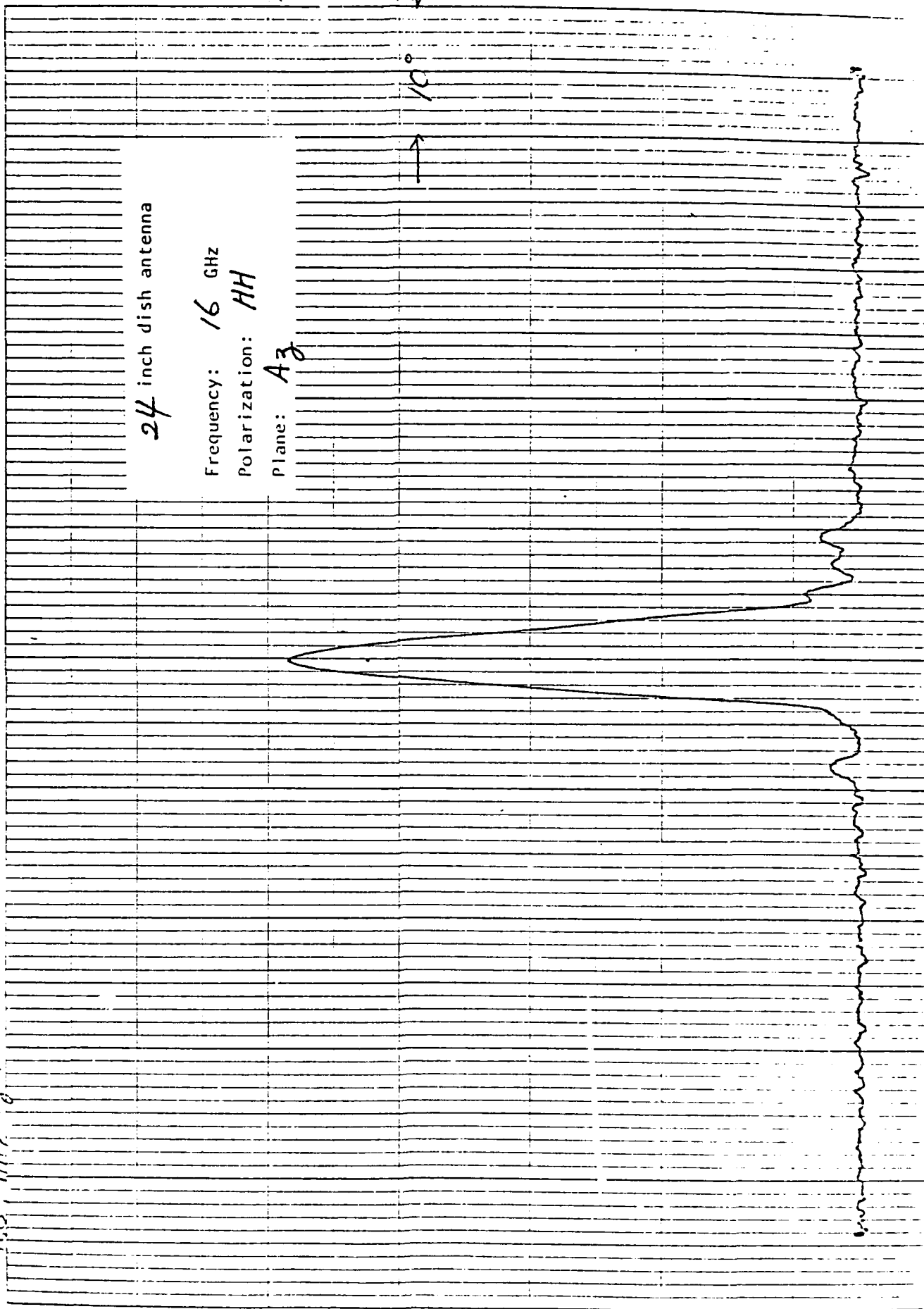
24 inch dish antenna

Frequency: 16 GHz

Polarization: HH

Plane: A3

541
10°



“

1(G, 111, E2

24 inch dish antenna

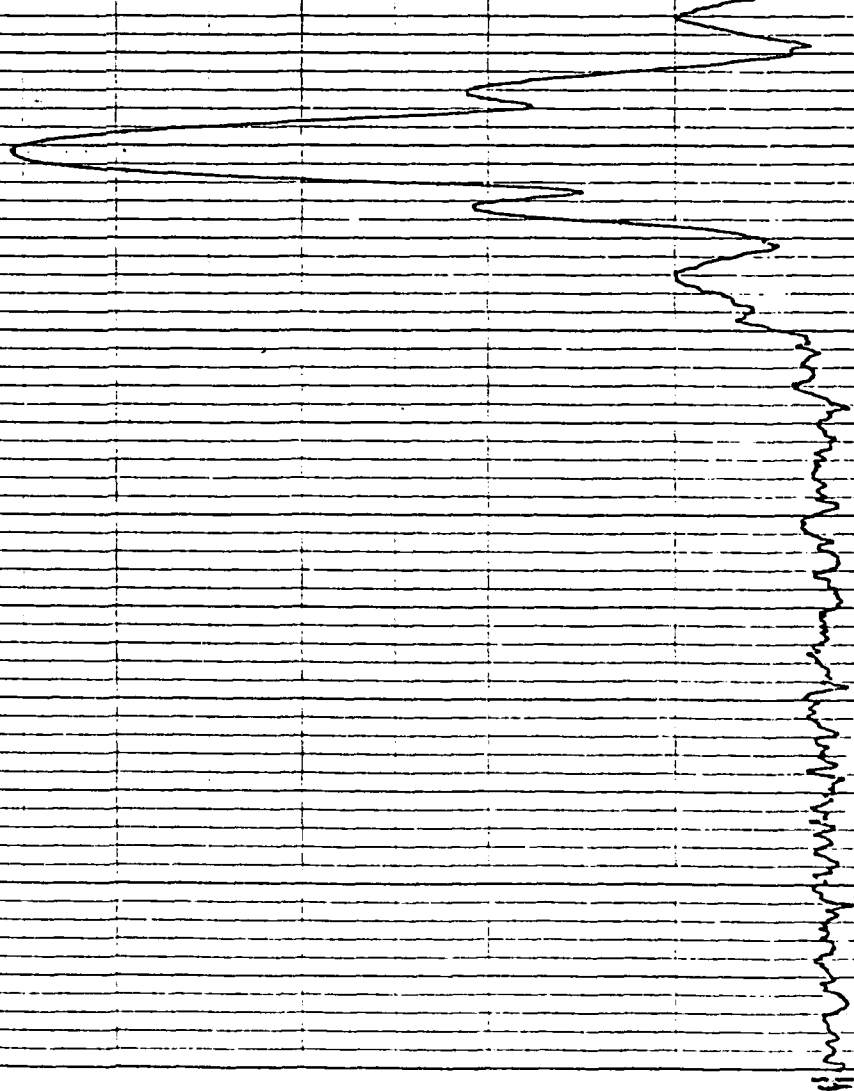
Frequency: 16 GHz

Polarization: HH Plane: $z\bar{z}$.

↓ 5 dB ↓ ↓

81

7



18"

18" 10A IN TO THE PCH-7 x 10 INCHES
18" 10A IN TO THE PCH-7 x 10 INCHES

46 0782

4G, 1V, A3

18 inch dish antenna

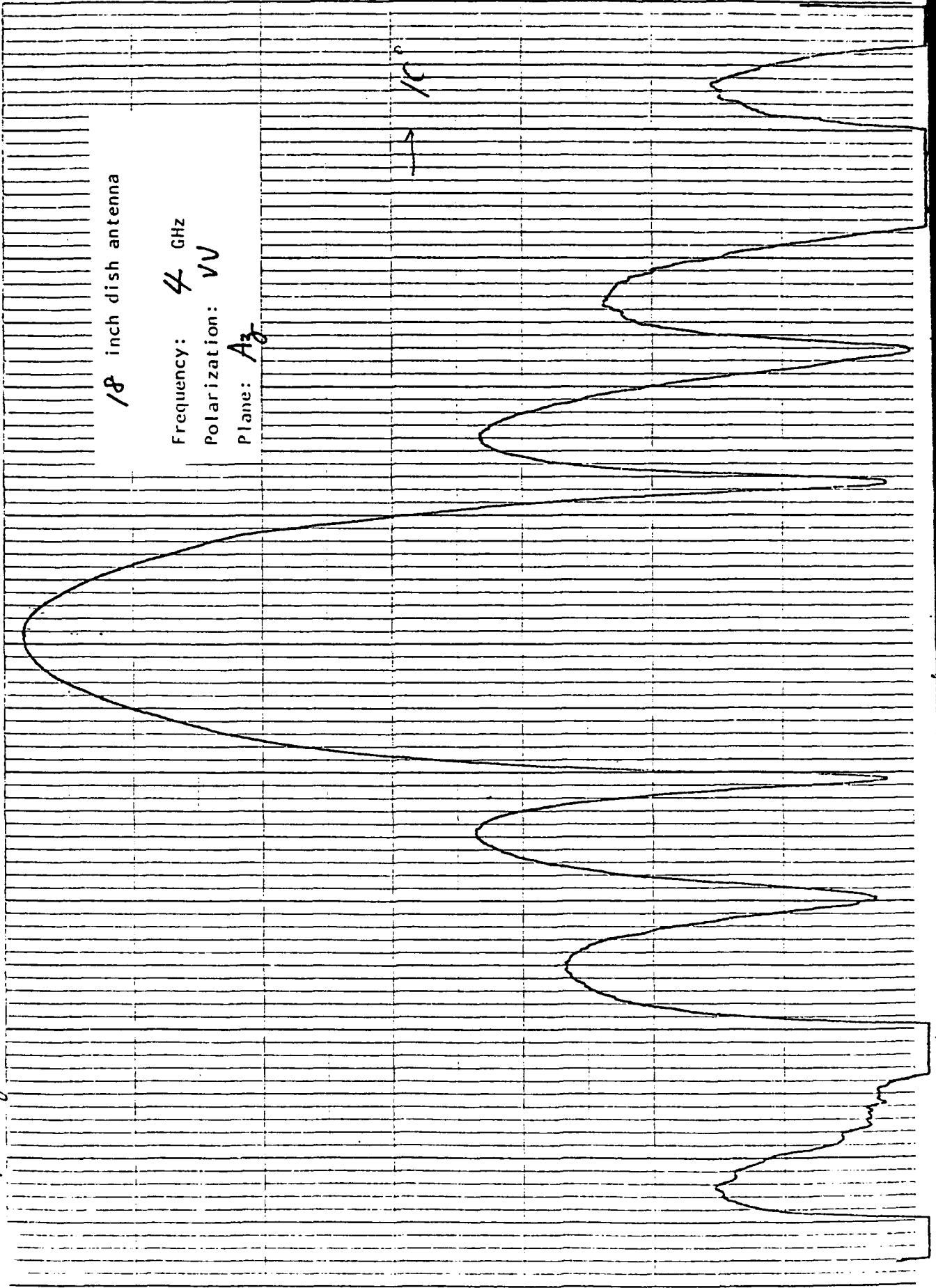
Frequency: 4 GHz

Polarization: VV

Plane: A3

↓ bdf ↓

82



vv, El.

8 inch dish antenna

Frequency: ~~4~~ GHz

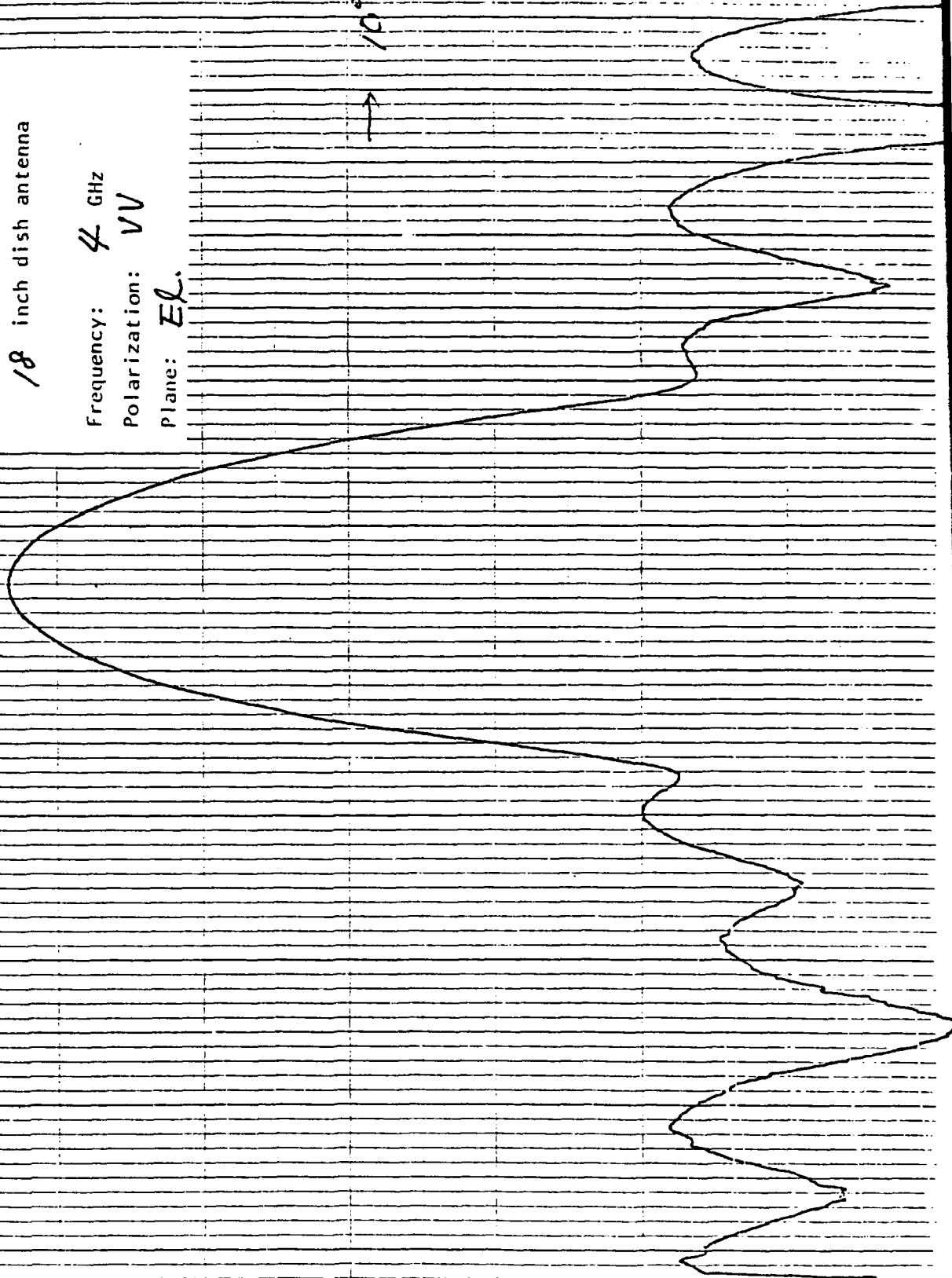
Polarization: VV

Plane: EL.

↓ 545 ↓ ↓

83

21



18"

106, VV, Az

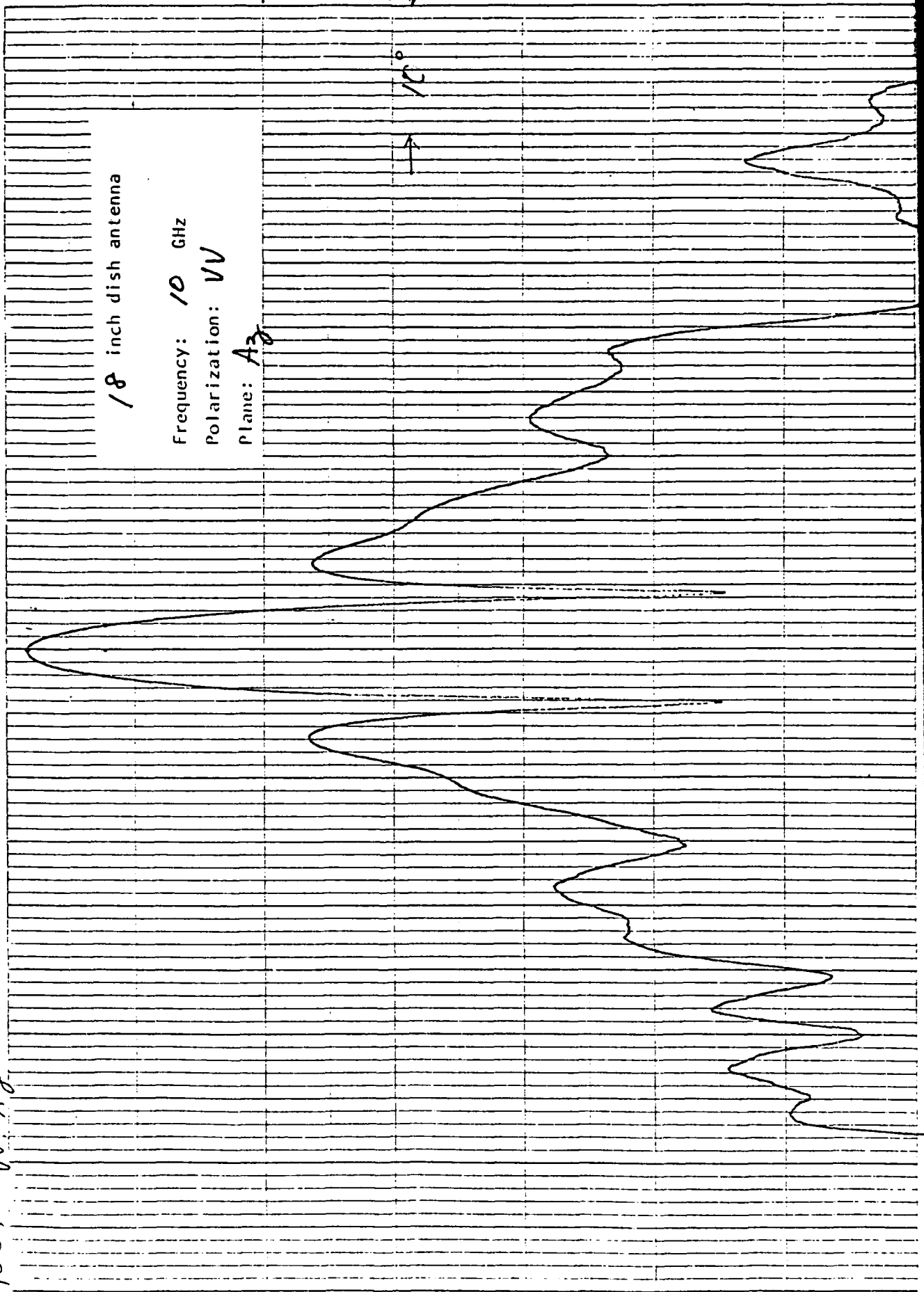
18 inch dish antenna

Frequency: 10 GHz

Polarization: VV

Plane: Az

5dB
10°



18"

106. VV, EL

18 inch dish antenna

Frequency: 10 GHz

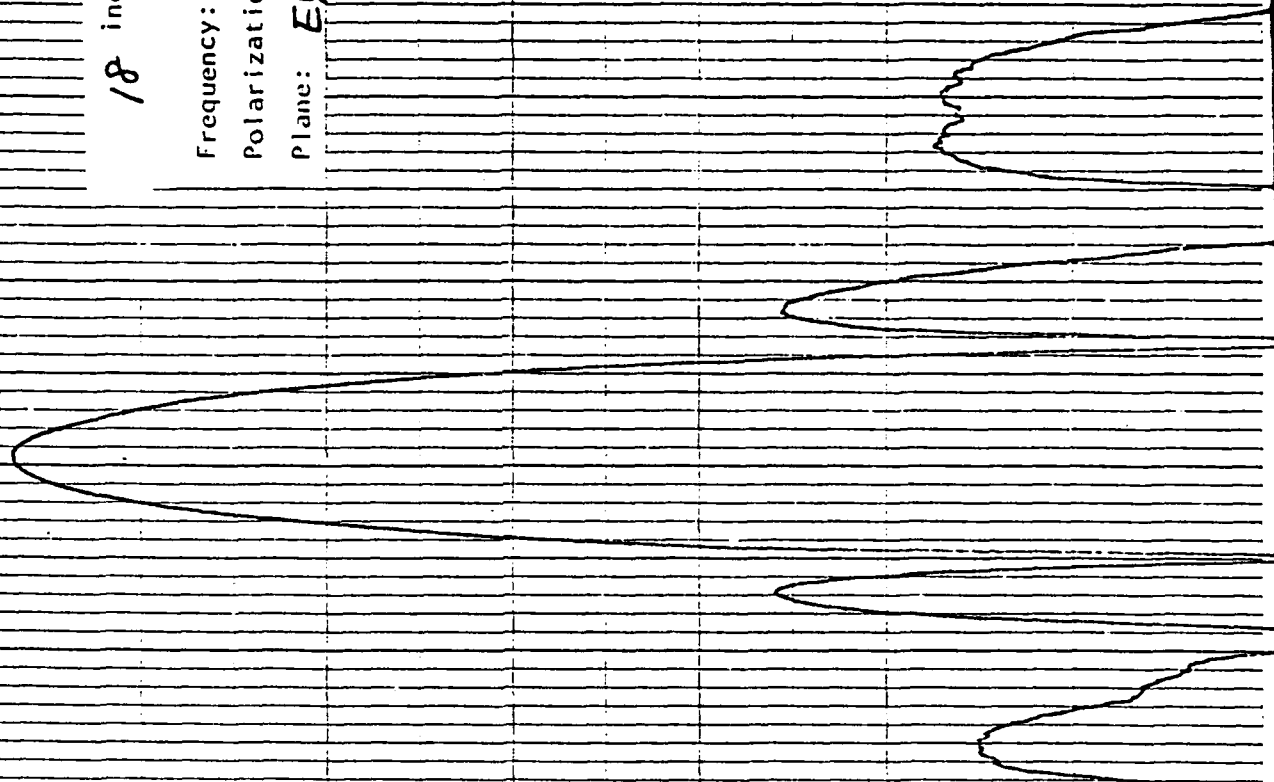
Polarization: VV

Plane: EL

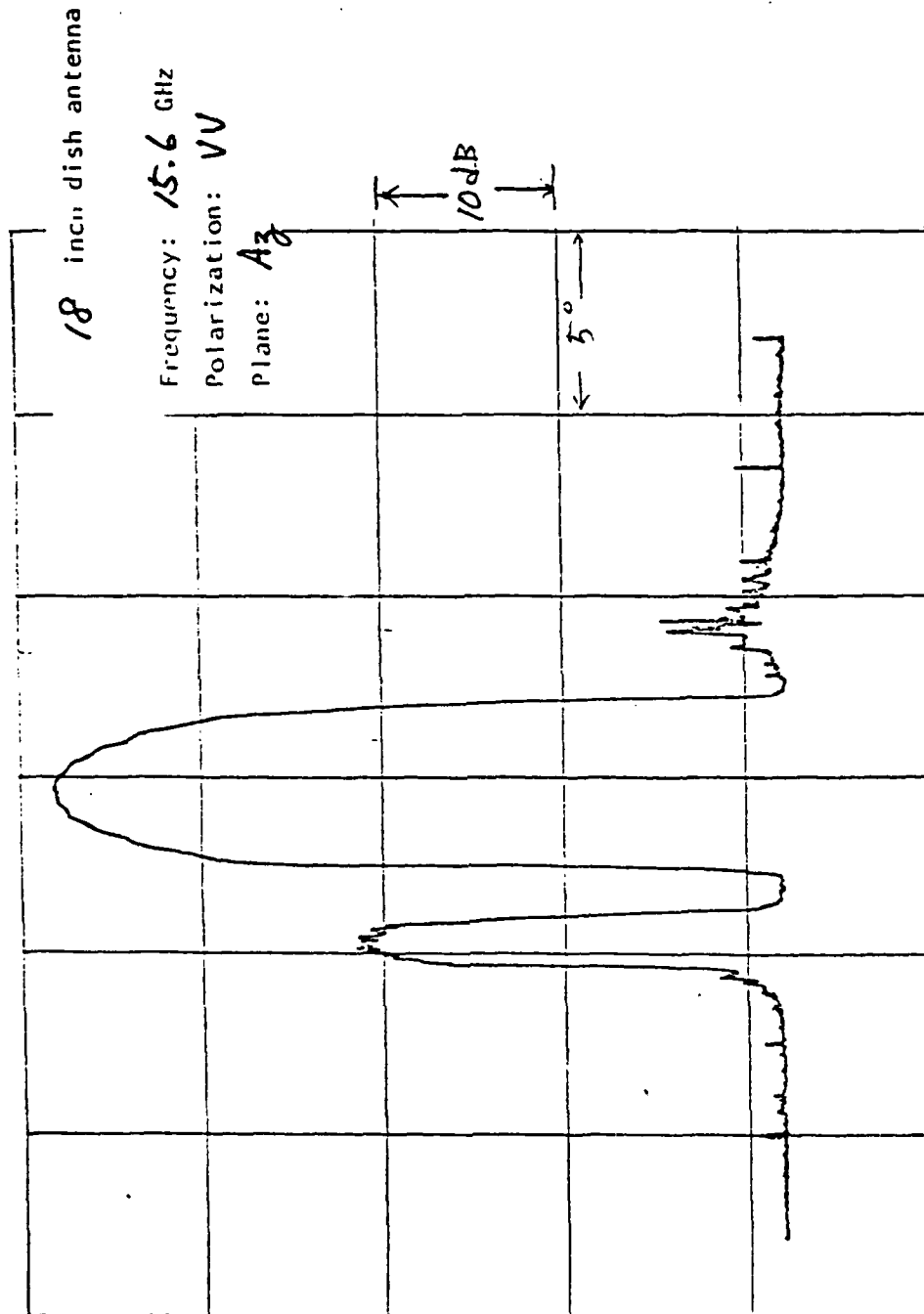
5dB

85

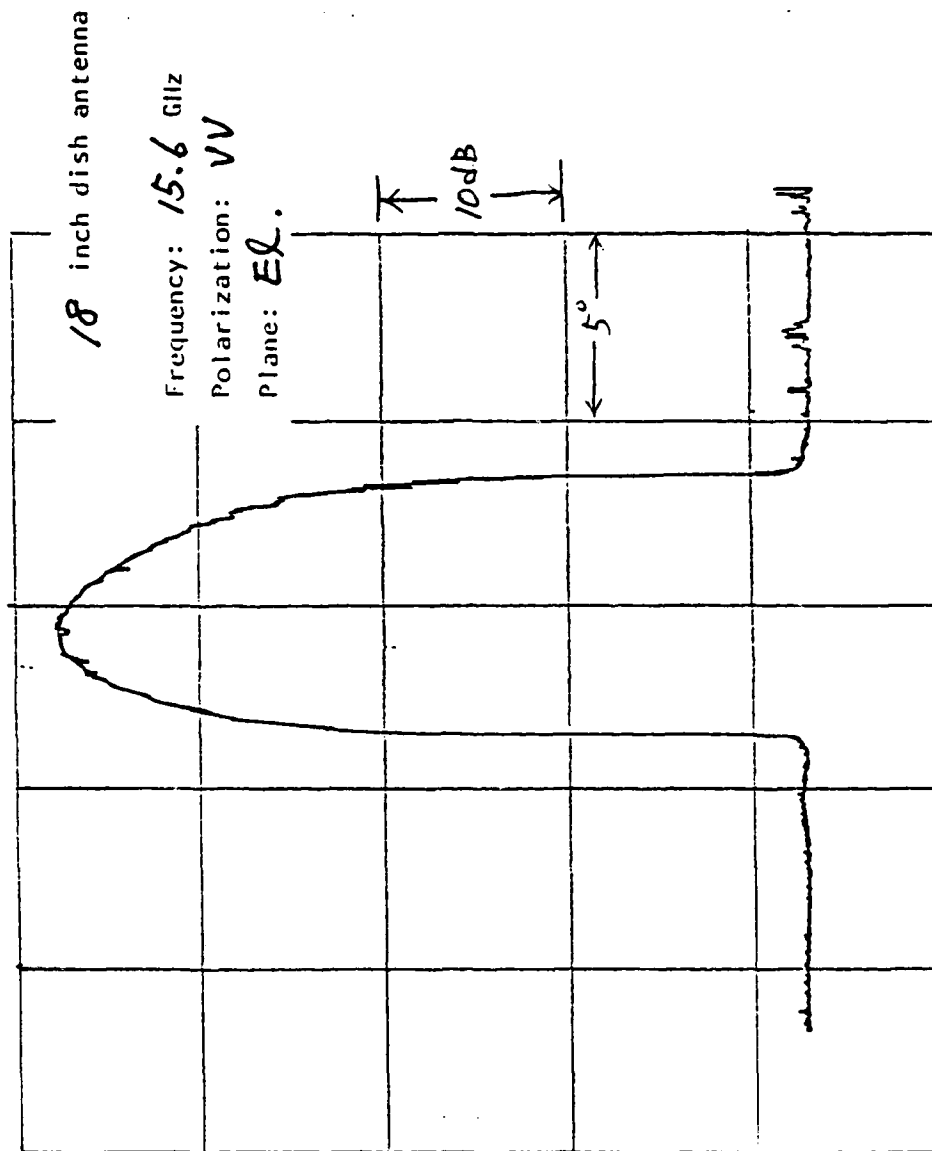
10°



18", 15.66, VV, A₃



15.66, VV, EL.



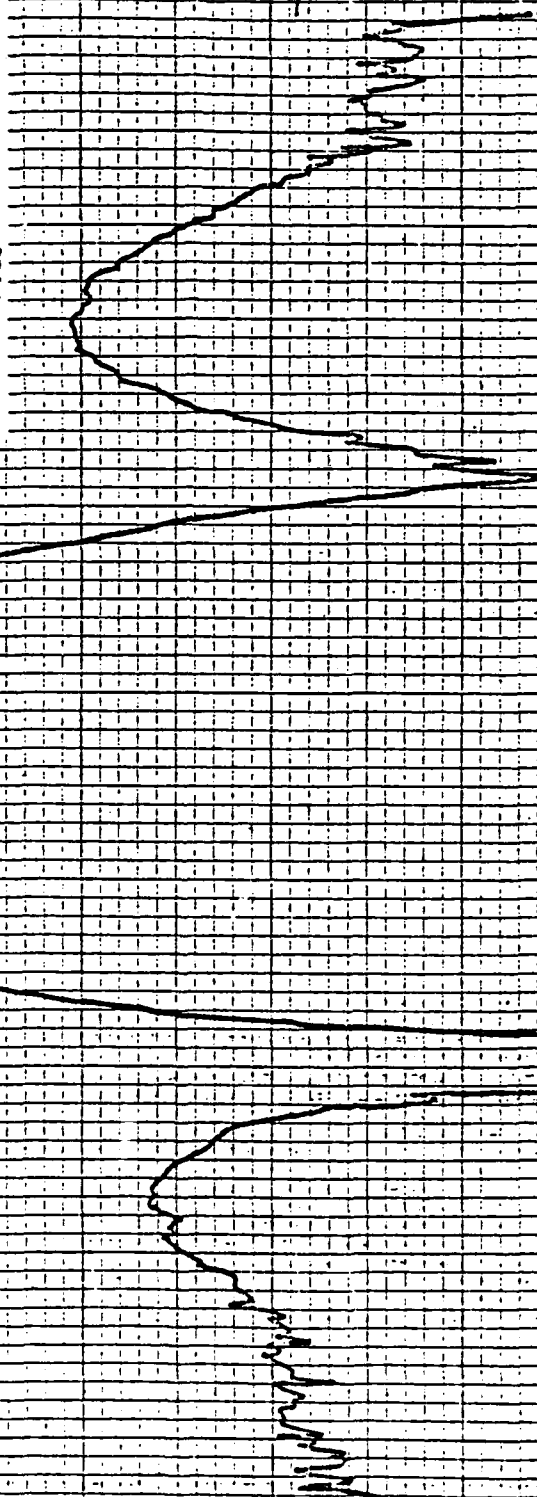
$\frac{1}{2}$ " 46, UU, 13. $\frac{1}{8}$ /inch. 5 db/inch

12 inch dish antenna

Frequency: 9 GHz

Polarization: VV

Plane: AZ



541 不

88

12-10, III, 12

1/2 inch dish antenna

Frequency: 9 GHz

Polarization: HH

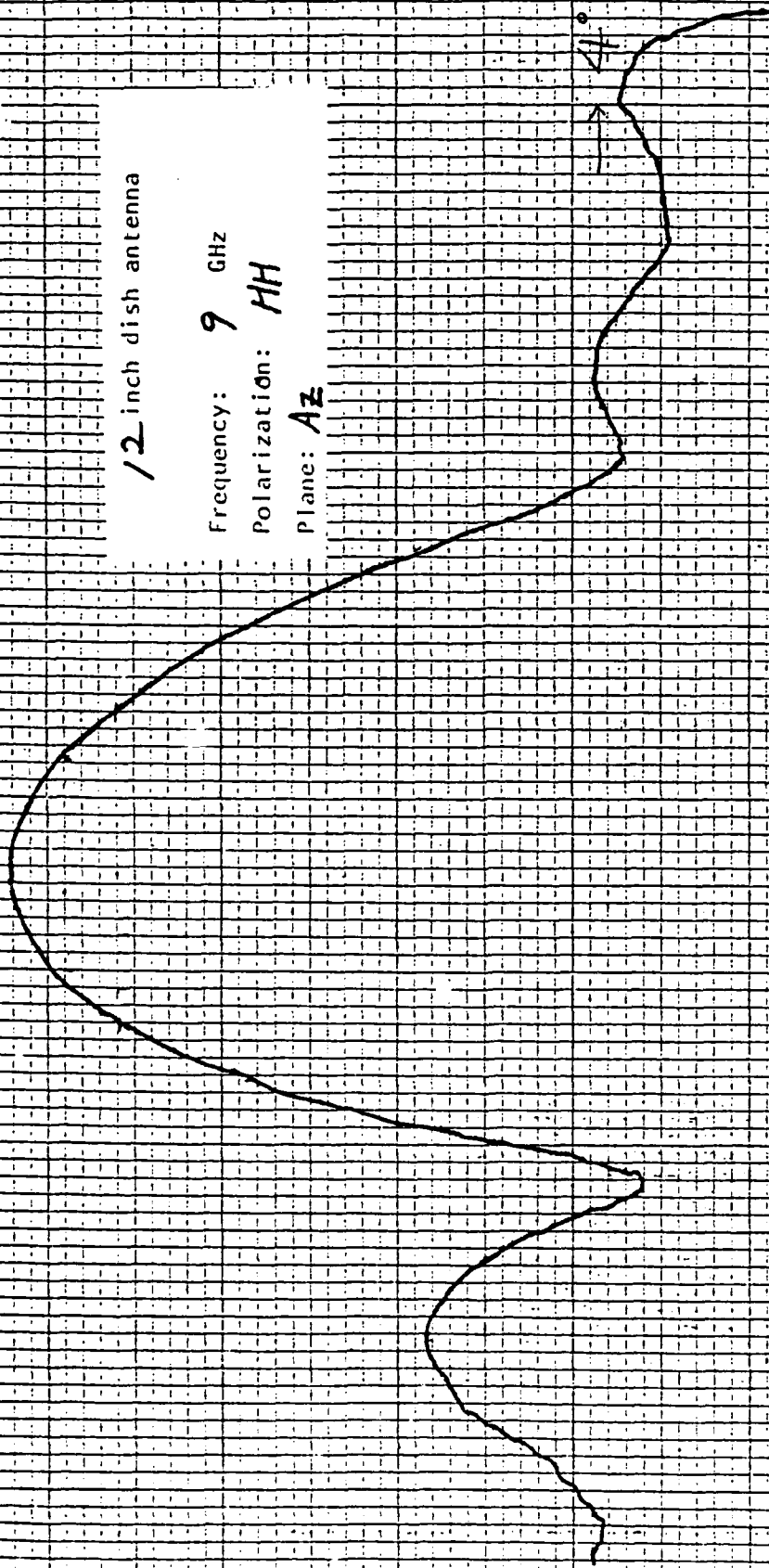
Plane: Az

↓ 50

↑ 50

89

41°



12" 13G, VV, Az

1/2 inch dish antenna

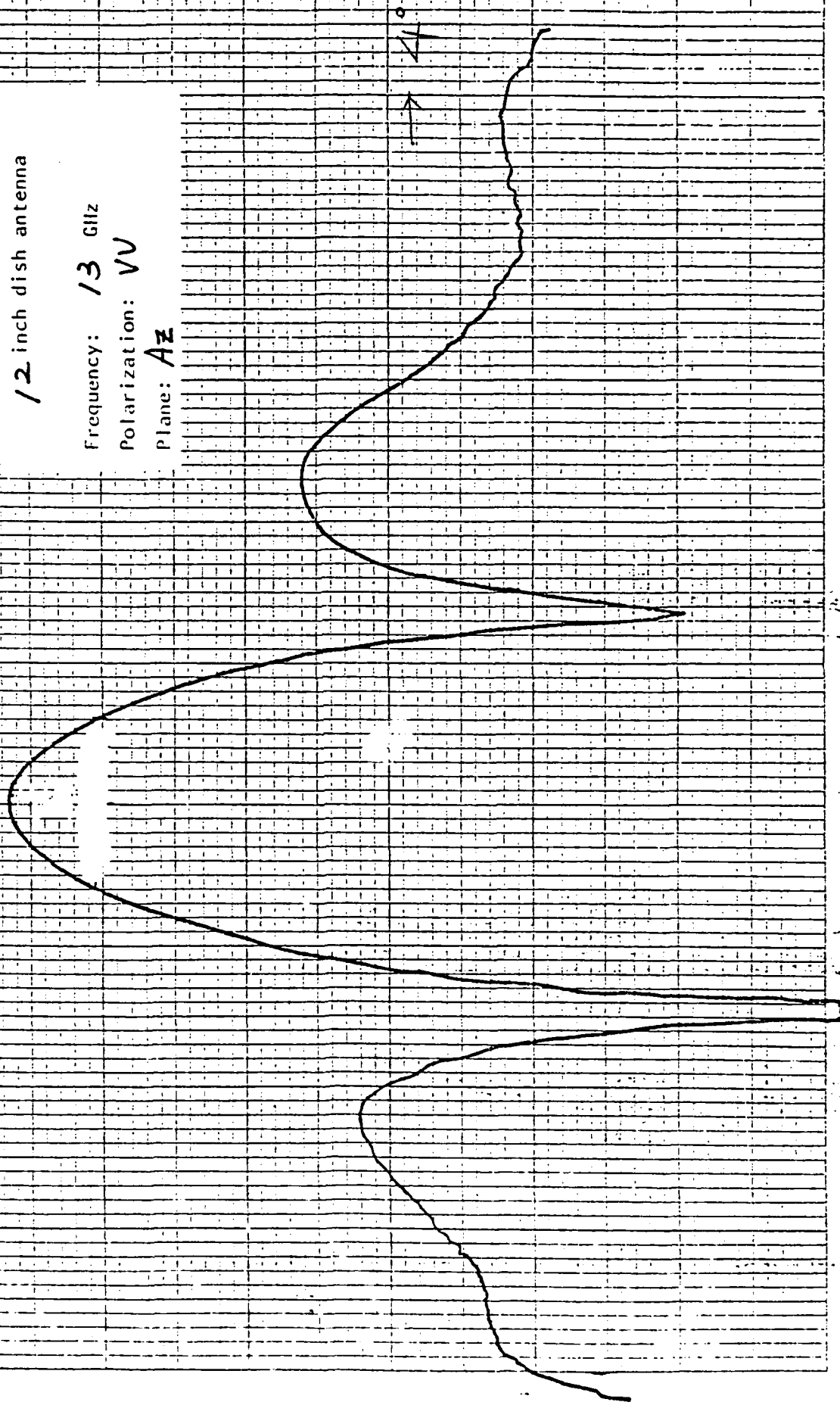
Frequency: 13 GHz

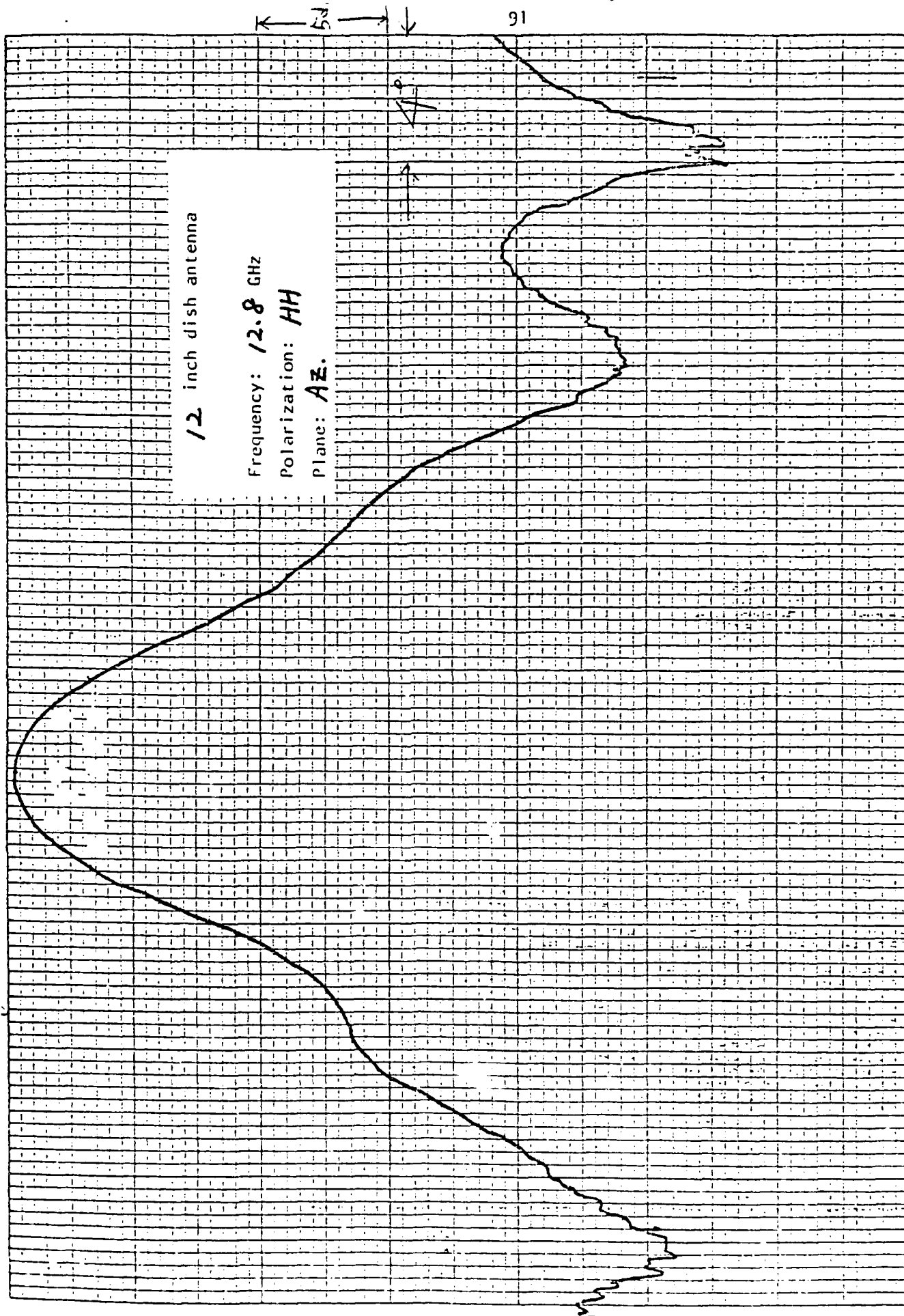
Polarization: VV

Plane: Az

← 0° →

90





AD-A125 796

HELICOPTER-BORNE SCATTEROMETER(U) KANSAS UNIV/CENTER
FOR RESEARCH INC LAWRENCE REMOTE SENSING LAB
R G ONSTOTT ET AL. OCT 82 CRINC/RSL-TR-331-24
N00014-76-C-1105

2/2

UNCLASSIFIED

F/G 17/9

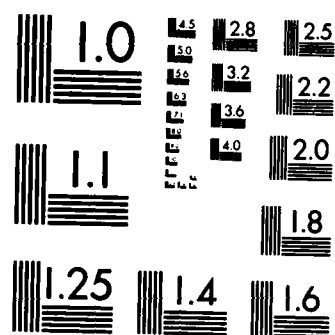
NL

END

FILMED

11

DTIC



12" 116, 117, 118

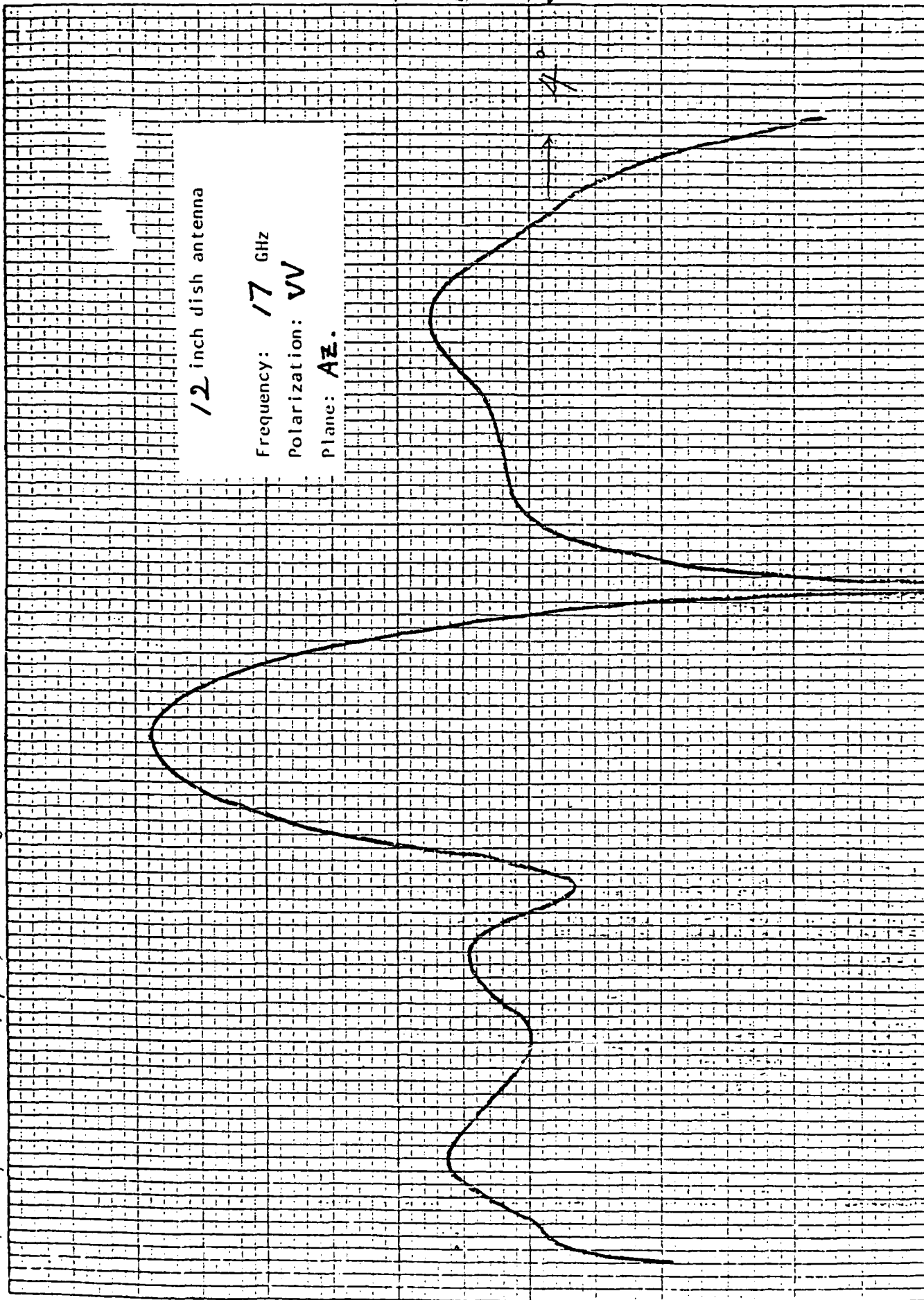
12 inch dish antenna

Frequency: 17 GHz

Polarization: VV

Plane: AZ.

5dl 92



12-1796, MM, A3

12 inch dish antenna

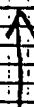
Frequency: 17 GHz

Polarization: HH

Plane: AZ

5d1 93

4°



APPENDIX D FM BOARD CALIBRATION

Calibration procedure for triangle wave generator:

1. Disconnect the power cable to the RF box and then apply power.
 2. Connect a scope between either T₁ or T₂ and ground pins on the board.
 3. Set the frequency of the triangle wave to 600 Hz (using MAN FM) and adjust for symmetry using P2.
 4. Set the frequency at 100 Hz and adjust for low frequency symmetry using P3.
 5. Connect AC voltmeter between either T₁ or T₂ and ground pins and set the amplitude (sweep width) of the triangle wave as listed in table using P4 and P7 for Ku-X- and C-band, respectively.
 6. Connect a DC voltmeter and adjust the DC offset and step size using potentiometers as follows:
 - P5 step size for Ku-X-band
 - P6 DC offset for Ku-X-band
 - P8 step size for C-band
 - P9 DC offset for C-band
- Note:
- P1 maximum frequency of oscillation
 - P10 sets the maximum current into DAC

	Ku-X-Band	C-Band
Triangle wave amplitude	215 mV rms	354 mV rms
DC offset	0.6 V(DC)	4.0 V(DC)
FREQ step voltage	1.0 V(DC)	0.67 V(DC)

APPENDIX E FAST RMS DETECTOR CALIBRATION

Do the following adjustments before mounting the TRMS module in the microprocessor cage. (See Figure B4.4b)

1. Connect DC voltmeter to Channel 1.
2. Apply ± 15 V from the HP power supply before turning on the instruments and wait for 5 minutes.
3. Connect the TRMS input to ground and adjust R₅ to get a minimum reading on the voltmeter, preferably zero.
4. Connect the DC voltmeter to Channel 2 and adjust R₁₁ to get a zero volt indication.
5. Apply 10 mV, 1 kHz sine wave to the input and adjust R₆ so that Channel 1 output is $2130 \text{ mV} \pm 5 \text{ mV}$.
6. Increase the input to 50 mV and adjust the R₁₂ so that Channel 2 output is $165 \pm 3 \text{ mV}$.
7. After above calibration is done, install the module in the cage and connect the output connector to the A/D circuit board.

Do not connect the power supply ground to the signal ground. Connect the ground of signal cable to ground pin on the board marked as G.

APPENDIX F RANGE TRACKER

F.1 System Concept

The range tracker was designed to interface with an FM-CW radar system, to allow the system to follow a rapidly moving target. As a result, the centroid of the return spectrum is kept at the same frequency, which facilitates data analysis, and the distance to the target can be determined in real time. The system block diagram is shown in Figure F.1. The frequency of the IF signal centroid is directly proportional to both the sweep rate and the time delay from the RF oscillator to the RF mixer, i.e., $f_{IF} \propto f_{FM} \cdot T_{\text{delay}}$. If the sweep rate is constantly adjusted so that the IF remains constant, then $f_{FM} \propto \frac{1}{T_{\text{delay}}}$. Thus, the distance to the target can be determined by measuring the frequency (sweep rate) and taking into account the delay associated with the antenna and feed lines. It is the range tracker's job to detect the frequency centroid of the IF signal, and keep it at the desired point by varying the sweep rate.

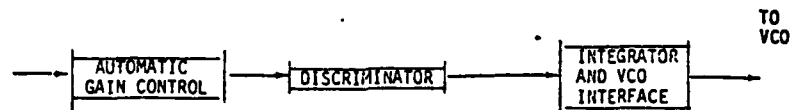


Figure F.1: System Block Diagram

F.2 Operation

The range tracker consists of three basic sections, shown in Figure F.1. The power return varies inversely with the square of the distance (for beam-limited conditions) and the target reflectivities also vary greatly, so that a very wide range of IF voltage can be anticipated. This would adversely affect the discriminator performance, so an automatic-gain-control circuit is provided. It has a 60 dB linear dynamic range, and it provides soft clipping for higher signal levels. The discriminator is a frequency-to-voltage converter, which outputs a positive DC voltage at low frequencies and a negative DC voltage at frequencies above the center frequency. The transfer characteristic for a sine wave input is shown in Figure F.2.

The discriminator voltage is fed to the integrator. When the IF frequency centroid is at its correct value, the discriminator output is zero, the integrator voltage does not change, and the VCO remains at the same frequency. If the IF centroid drifts too high, the discriminator produces a negative voltage, the integrator drifts to a more positive voltage, the VCO frequency is reduced, which lowers the IF centroid to the proper value. The reverse happens if the centroid

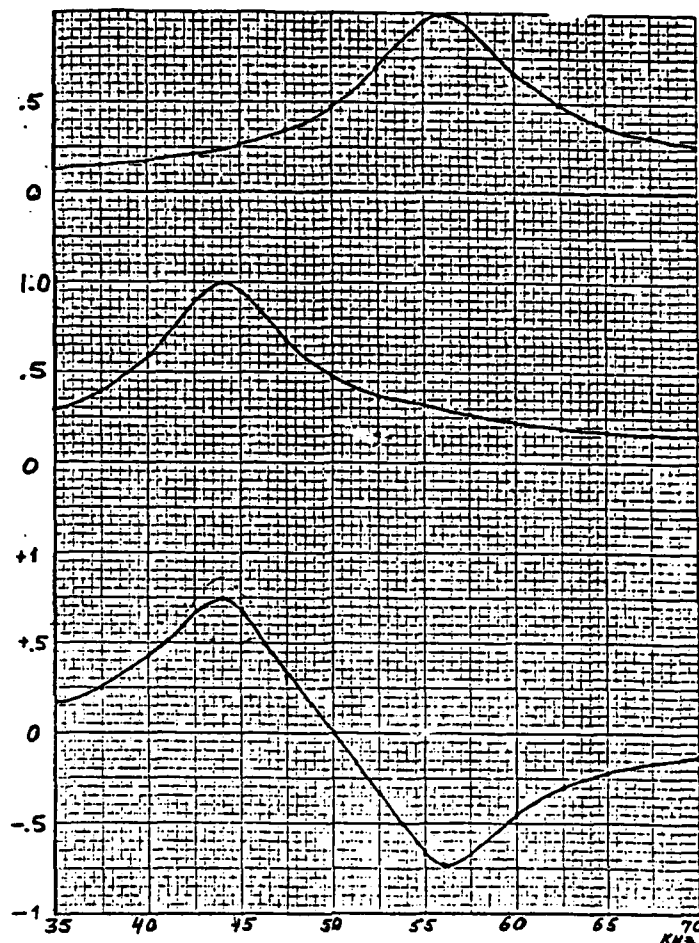


Figure F.2 Discriminator Characteristic

drifts too low. Circuitry is provided so that the integrator can be preset to any desired value by pushing a button. Thus, the distance to the target can be estimated, and then a preset is performed to bring the centroid into the capture range of the system. A linear mapping circuit is provided, which transforms the integrator's output voltage swing into the range required by the VCO.

F.3 Automatic Gain Control

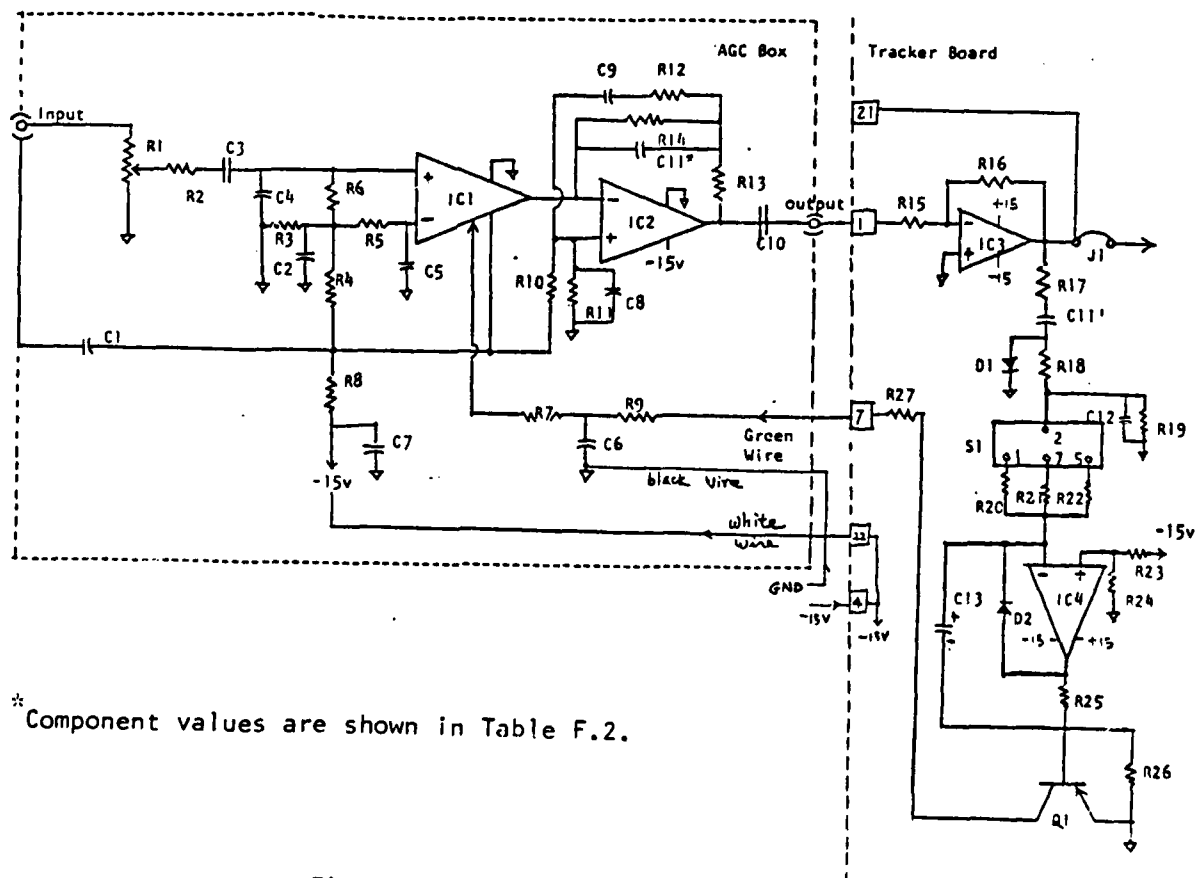
The AGC circuit uses a CA3080 OTA (operational transconductance amplifier) as the variable gain block. This chip has a differential input and a very high output impedance (i.e., current source). The transconductance $(\frac{\Delta I_O}{\Delta V_{IN}})$ is directly proportional to the current flowing into the control terminal, and is given by $g_m(\text{mho}) = 20 I_{\text{CONTROL}}(\mu\text{A})$. It is a two-quadrant multiplier, that is, the transconductance is always positive. The control input has a constant potential of one diode-drop above the V-supply. A 1000:1 gain ratio is easily obtained.

The transfer characteristic of the 3080 is simply that of a transistor differential amplifier, and reasonable linearity can be maintained up to a peak input of 50 mV. Because it deals with extremely small voltages, the gain control stage is enclosed in a metal box.

The full schematic is given in Figure F.3. R_1 attenuates the input signal to a level not to saturate the output. The current source output of IC 1 is converted to a low-impedance voltage source by IC 2. DC is removed by C10. IC 3 provides additional voltage gain. With a sine wave input, IC 3 output is 3.5 V_{pp} . Rectification of the output is provided by C11* and D1 and ripple is filtered by R18 and C12. A reference voltage is provided by R23 and R24, and voltage at inverted input terminal of IC 4 is -0.65 V at steady state. Switch S_1 changes the integrating time constant which determines the AGC range. Overall operation is as follows. If the input signal increases, the voltage at R19 becomes more negative and the integrator (IC 4) output then drifts more positive. The base voltage of Q1 decreases, causing lower current to IC 1.

F.4 Discriminator

The discriminator consists of two second-order bandpass filters and a summer, as shown in Figure F.4. The summer includes a one-pole ripple filter. The frequency response of the two filters, plus the overall frequency-to-DC response, is plotted in Figure F.2.



* Component values are shown in Table F.2.

Figure F.3: AGC Circuit

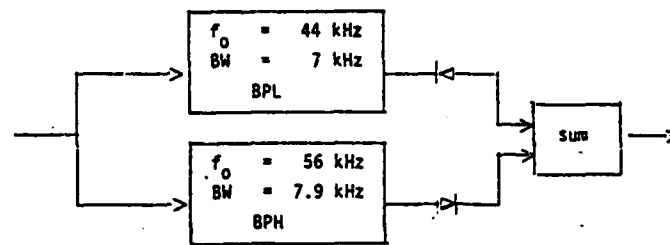


Figure F.4: Discriminator Block Diagram

To adjust the discriminator (see Figure F.5), connect a signal generator to the input (pin 21 when testing outside the system or IF input port at the back panel of the FM/IF module) and a DC voltmeter to the output. Locate the low-frequency peak, and adjust R33 until it is at 44 kHz. Then locate the high-frequency peak, and adjust R30 until it is at 56 kHz. Then adjust R40 for zero output at 50 kHz. The above three steps should be repeated until no further improvement can be obtained. If there is a need for external frequency-to-voltage converter, or a phase-detecting circuit, jumpers J1 and J2 can be removed and then the external circuit can be connected to edge connector pin 19 and pin 21.

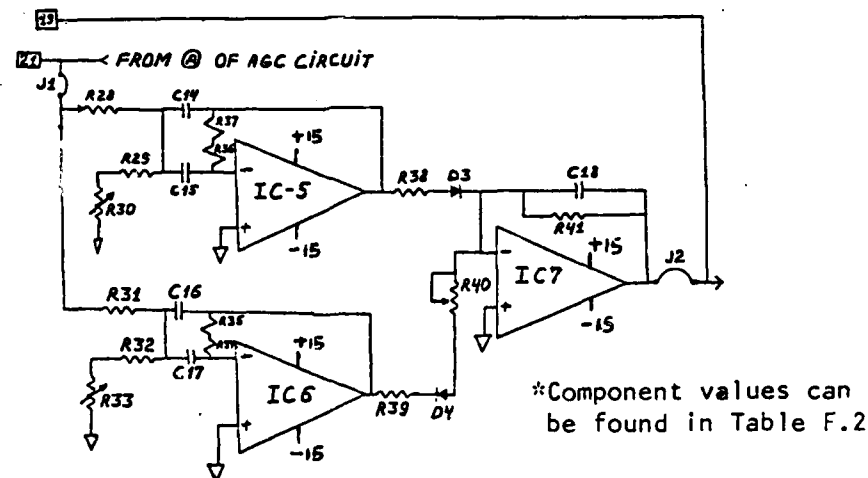


Figure F.5: Discriminator Circuit Diagram

F.5 Integrator, Preset and Mapping

The schematic is given in Figure F.6. The basic integrator is formed by IC9, C19 and the feedback network through the switches S2 and S3. Integrator preset is provided by IC10, which compares the voltage set by an external resistor with the integrator output. When reset push button on the front panel of the control box is depressed, the analog switch (IC12) is 'ON', and the error signal is fed back to the integrator input, and forces the output to the desired value. The output voltage range of the integrator (0 to +13 V) is mapped to the voltage

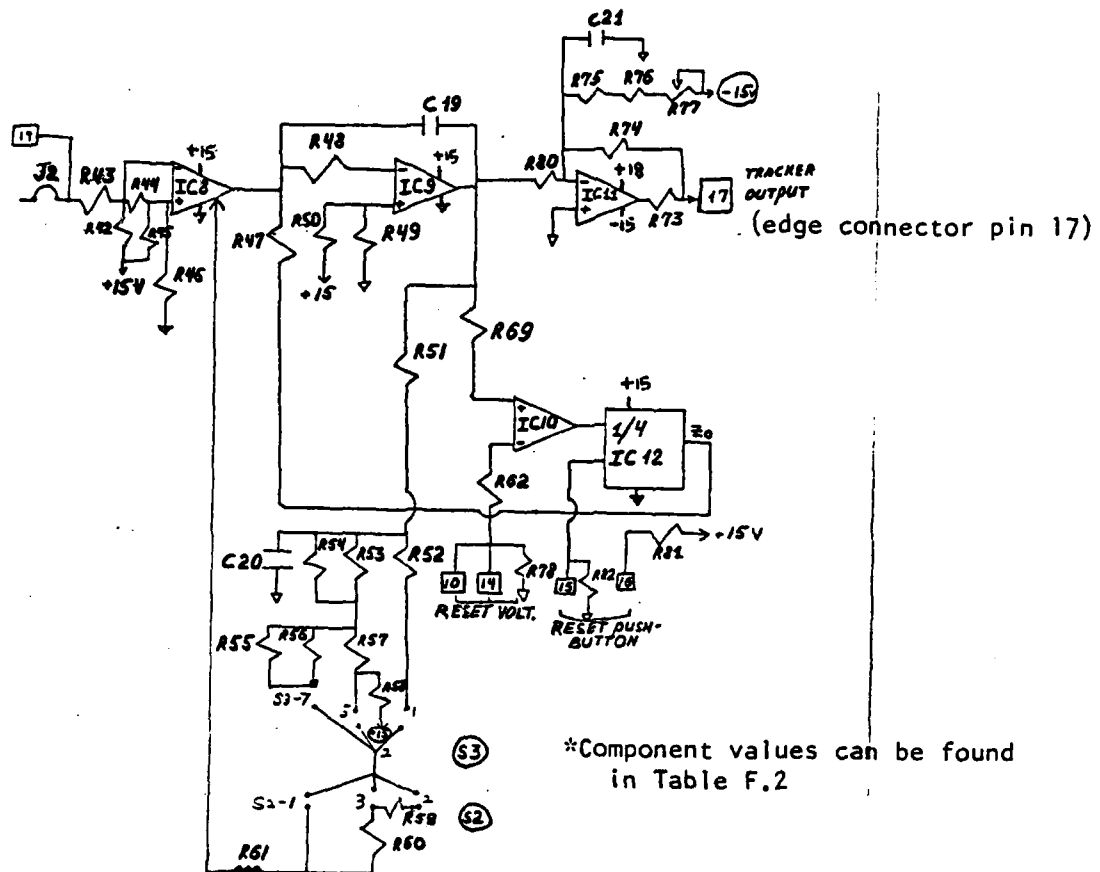


Figure F.6: Integrator and Mapping Circuit

required by the VCO (+5 to +15 V) by IC11. Supply voltage of +18 V is required by IC11 so that it can drive up to +15 volts. R77 is provided to set the low frequency limit (upper voltage limit). Feedback through switch S2, S3 compensates for signal-dependent time constant variation. S2 selects the time constants (1, 3.3, 10.1 sec) and S3 selects minimum to maximum frequency ratio (1/5, 1/10, 1/20). In the system, R77 should be adjusted until the lowest possible PRF forms the selected (by S3) ratio with the highest frequency. If no compensation is desired, the node of C20, R51, R52 can be connected to +15 V.

F.6 Test Procedures

The testing diagram is shown in Figure F.7.

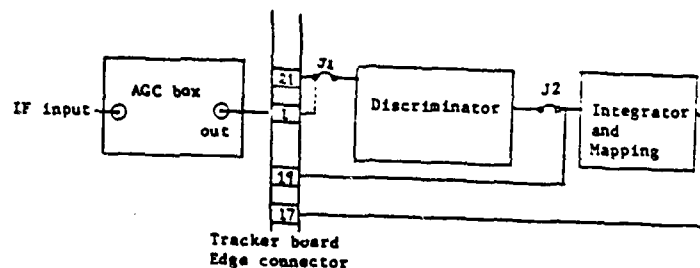


Figure F.7: Testing Diagram

F.6.1 AGC Section

This section, which is partly in a shielded box and partly in the range-tracker board can be tested by applying sine wave (50 kHz) to the IF input terminal of the AGC box and checking the output waveform at pin 21 of the tracker board. When changing the input signal level from 15 mV_{pp} to 5 V_{pp}, the output level should always be 3 V_{pp} at switch S1 upper position. Low level signals distort the output waveform, but it should contain strong input signal frequency component.

F.6.2 Discriminator Section

This section can be tested by applying the sine wave either to the IF input of the AGC box or to pin 19 of the range-tracker board when AGC box is disconnected. When changing the input signal frequency from 30 kHz to 70 kHz, the DC output voltage at pin 19 should have the same characteristics as Figure F.2 with the peak voltages around ± 3 V and 0V at 50 kHz.

F.6.3 Integrator and Mapping Section

This part is strictly a DC section and, therefore, can be tested by applying either DC voltage at pin 19 after removing the jumper wire J2 or sine wave to the IF input of the AGC box. Refer to Figure F.6. Voltage across R61 (current into IC8) should change when changing positions of the switches S2 and S3. And, the output voltage at pin 17 should have the characteristics shown in Figure F.8.

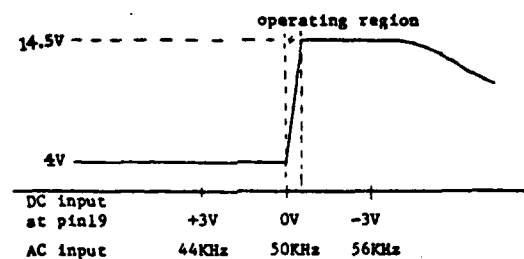
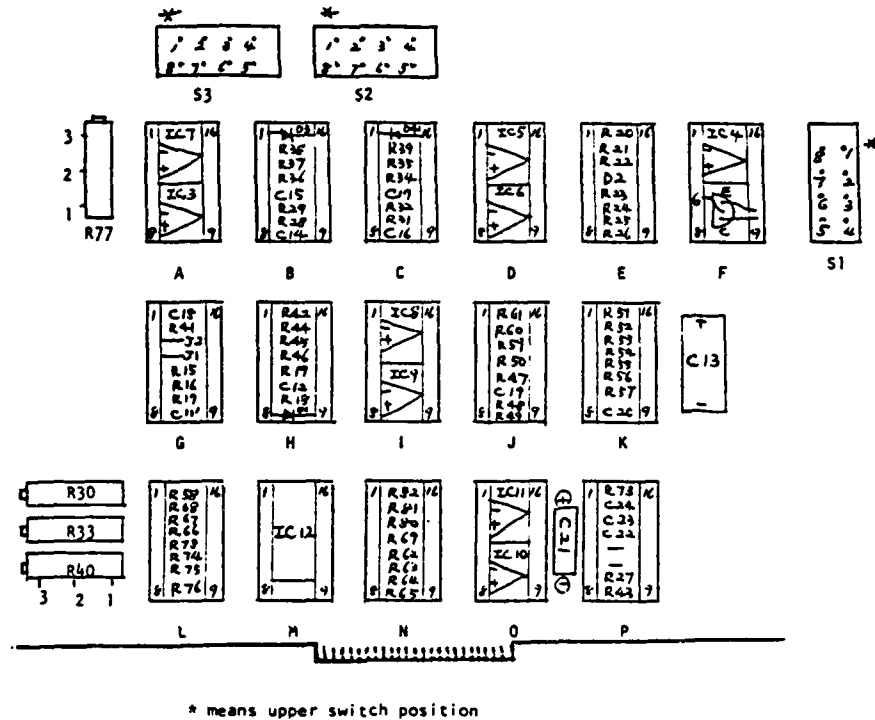


Figure F.8: Output Characteristic of the Range Tracker

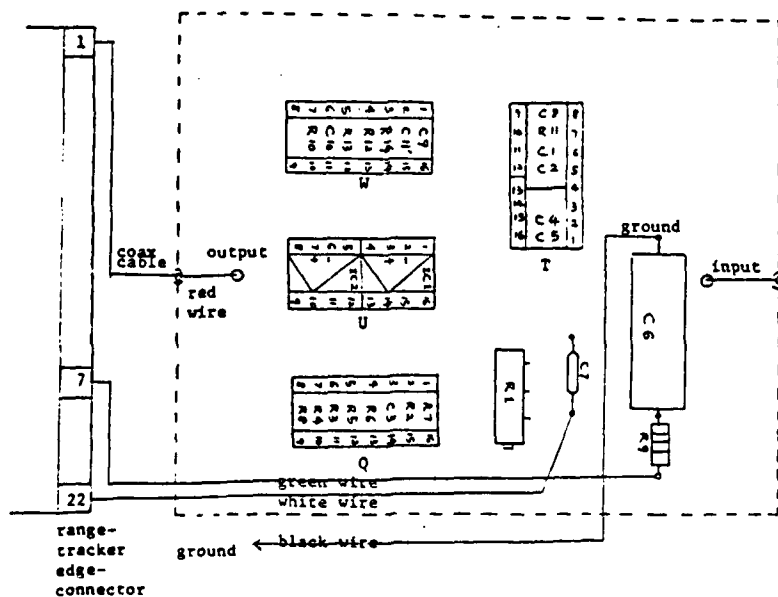
F.6.4 Precautions

The DC output voltage at pin 17 of this tracker board is a very sensitive function of power supply voltages. Therefore, in case of bad power supply fluctuations or in the case where the power supply voltages are adjusted higher than ± 15.5 V and ± 18.5 V (as in the ship experiment where long power lines are required), the maximum DC output voltage may exceed ± 15 V which, in turn, may cause the

failure of the triangle board. Hence, whenever the power supply voltages exceed ± 15.5 V or ± 18.5 V, it is suggested that the maximum output voltage of the tracker board is checked to have around 14.5 VDC at 56 kHz CW input. The voltages higher than 14.5 VDC should be reduced using R77.



Range Tracker Board Layout - Top View



AGC Box Layout - Top View

RANGE TRACKER BOARD WIRING LIST

TABLE F.1

A3-7-Gnd	E4-7-F14	I13-J16	M13-N11
A4-8-(-15v)	E5-F4-(-15v)	J1-2-(S2-1)	M15-N16--- 15
A11-15-(+15v)	E6-8-F11-Gnd	J3-(S2-2)	M16-(+15v)
A2-B16-(R40-1-2)-G1	E9-10-F6-(C13-)	J4-8-17	N1-Gnd
A14-G16	E11-12-F3	J5-6-7	N2-(+15v)
A6-G5	E13-14-15-16-F2-(C13+)	J9-K8-Gnd	N3-4
A10-G11	F15-(+15v)	J12-M2	N7--- 9
B1-2	F10-P10	J14-15-(S2-3)	N8--- 8
B3-4	G1-2	K3-4-5-6-7	N14-02
B5-6-7-8	G14-15-16	K9-13-14-15-16	N15--- 16
B9-14	G5-6	K11-12-(S2-2)	O7-N13
B12-13-02	G7-8	L2-M14--- 13	O8-3-Gnd
B14-15-D14	G10-11-13--- 21	L3-M6--- 12	O10-M1
(R30-2)-Gnd	G12----- 1	L4-M5--- 11	O11-L13-(+15v)
(R33-2)-Gnd	G9-H8	L13-14-15-16	O4-(-15v)
B11-(R30-1)	G3-P8--- 19	L5-Gnd	O15-(+18v)
C1-2	G4-C10-B10	L6-7-02	P2-3-4--- 5-GND
C3-4	H1-2-P9-12	L8-(R77-1)	P13----- 2 +18
C5-6-7-8	H3-16-(+15v)	(R77-2-3)-(-15v)	P14----- 3 +15
C14-15-D10	H4-5-6-9-Gnd	L9-10-(C21-)	P15--- 4-22 ---15
C12-13-06	H7-8	(C21+)-Gnd	P7----- 7
C9-14	H13-14-15-13	L11-014--- 17	
C11-(R33-1)	I4-8-Gnd	L12-N5--- 14--- 10	
C16-(R40-3)	I6-J10	M3-11-12-N12-06	
D4-8-(-15v)	I10-K1-J11-N4	M7-Gnd	
D3-7-Gnd	I11-15-J13-(+15v)	M4-N9	
D11-15-(+15v)	I14-J5	M10-N10	
E1-H10-11-12			

TABLE F.2

TRACKER BOARD PARTS LIST

R15 6.8K	R46 12K
R16 150K	R47 4.7K
R17 3.3K	R48 12K
R18 33K	R49 12K
R19 33K	R50 12K
R20 100K*	R51 12K*
R21 390K*	R52 12K*
R22 1.5M*	R53 12K*
R23 150K	R54 12K*
R24 6.8K	R55 15K*
R25 150K	R56 15K*
R26 150K	R57 12K*
R27 4.7K	R58 120K*
R28 33K*	R59 270K*
R29 390(33)	R60 82K*
✓R30 500(69)	R61 12K*
R31 33K*	R62 1.5M
R32 680(100)	R63 12K
✓R33 500(78)	R64 12K
R34 68K*(82K)	R65 12K
R35 68K*(330K)	R66 12K
R36 120K*(150K)	R67 12K
R37 --- (220K)	R68 12K
R38 15K	R69 12K
R39 12K(15K)	✓R70 5K
✓R40 10K(9.47K)	✓R71 5K
R41 120K	✓R72 5K
R42 12K	R73 680(removed)
R43 12K	R74 33K*(27K)
R44 100	R75 18K(12K)
R45 12K	R76 12K

✓R77 10K	C11 .1*
R78 12K	C12 .1
R79 ---	C13 1.0
R80 47K(39K)	C14 330p*
R81 12K	C15 330p*
R82 120K	C16 330p*
	C17 330p*
	C18 .01
	C19 .22
	C20 .01
	C21 10
	C22 .1
	C23 .1(removed)
	C24 .1
Q1 2N3906	
D1-4 Ge Diodes	
IC3-7 CA3140	
IC8 CA3080	
IC9-11 CA3140	
IC12 CD4066	
(MC14066)	

AGC BOX

✓R1 10K	IC1 CA3080
R2 6.8K	IC2 CA3140
R3 12K	
R4 12K	
R5 1.0K*	
R6 1.0K*	
R7 1.5K	
R8 1.0K	
R9 1.5K	
R10 12K	
R11 12K	
R12 4.7K	
R13 47K	
R14 47K	
C1 .1	
C2 .01	
C3 .01	
C4 330p	
C5 .01	
C6-9 .1	
C10 .01	
C11* 22p	

AGC BOX WIRING LIST

Input-(R1-3)	W2-3-4-5
Green-(R9)	W6-Output
(-15v)-Black-(c7)	W7-U7
T1-2-3-4-5-6-7-8-(C6)-Gnd	W10-U8
T9-10-U7-W1	W11-12-U10
T11-Q7-8-U4-W10	W13-16
T12-Q3	W14-15-U6
T13-14-Q6-U15-U11-Gnd	Q9-(-15v)
T15-U3-Q3-4	Q10-11-12-13
T16-U2-Q5	Q14-15
U13-Q1	(R1-2)-Q2
U14-U6	(R1-1)-Q1
	(R9)-(C6)-Q16

✓ means variable resistors

* means 5% tolerance recommended

() indicates new discriminator design values

APPENDIX G ELECTRICAL LOAD ANALYSIS

- I. Aircraft Source Voltage Required = +28 VDC
Maximum Current Required = 30.5 A
- II. Electronics Package Current Required = 8.5 A continuous
Actuator Current Req. under Stall = 22.0 A
Actuator Current Req. under Load = 10.0 A
- III. Detailed Analysis:
Power Supplies:

Voltage	Current Supplied-A-	Max Current Capability-A-
+18	2.77	5.0
+15	.90	2.2
+12	1.40 - 2.20	2.2
+ 5	5.77	9.0
-18	.73	2.3
-15	.42	2.2
-12	.25	2.2
- 5	.10	2.2

Devices:

Instrument/Device	Supply		Current load(mA/device)	Power	# devices
	AC(Volts)	DC(Volts)			
1 IF amplifier	115	---	---	10	1
2 T.R.M.S. meter	115	---	---	4	1
3 Frequency counter	115	---	---	7	1
4 Altimeter	---	28	600	--	1
5 HP switches	---	28	120	--	2
6 Transco switches	---	28	120	--	5
7 Fans	---	28	220	--	2
8 X -KU band oscillator	---	28	180	--	1
	---	18	500	--	1
	---	-18	100	--	
9 Microprocessor	---	12	400	--	1
	---	-12	250	--	
	---	5	5000	--	
	---	- 5	10	--	
10 A/D convertor	---	15	150	--	1
and associated circuits	---	-15	150	--	
11 Recorder	---	12	1000 (average)	--	1
	---	5	700 (average)	--	
12 C-band oscillator	---	+15	650	--	1
	---	-15	100	--	
	---	28	50	--	
13 FM generator	---	15	50	--	1
and range tracker	---	-15	50	--	
	---	18	20	--	
	---	5	10	--	
14 Pin diode switch	---	-15	65	--	1
	---	5	50	--	1
15 Actuator control	---	28	10,000 (average)	--	1
			22,000 (peak)	--	

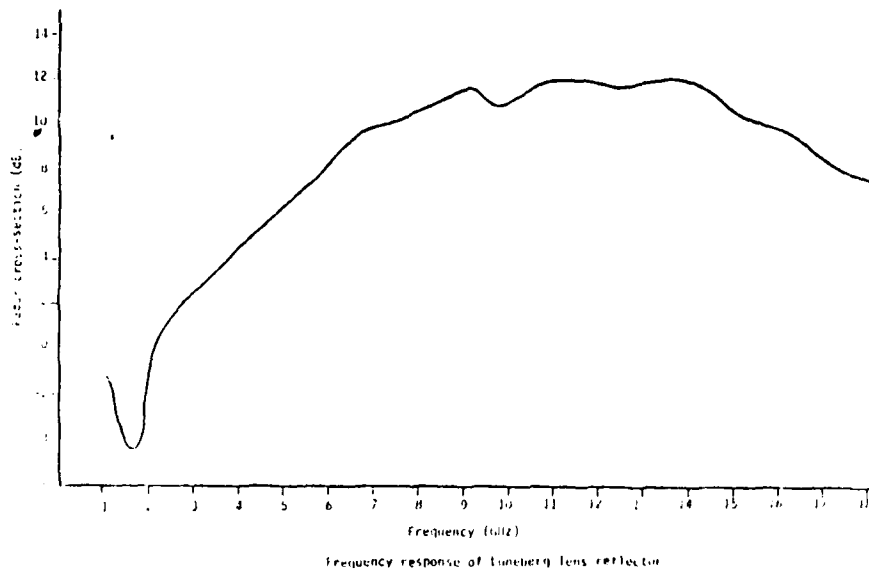
APPENDIX H HELOSCAT SYSTEM WEIGHTS

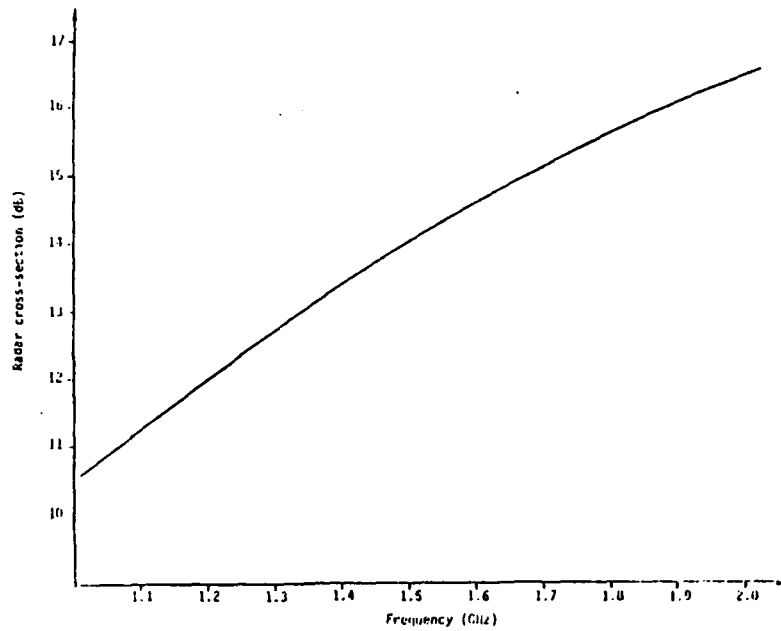
Data Acquisition Module	= 30	13.6
Power and IF Processing Module	= 67.5	30.6
RF Module	= 8.5	3.9
HELOSCAT Structure	= 49.0	22.3
24" Dish Antenna	= 14.0	6.4
18" Dish Antenna	= 9.0	4.1
Radar Altimeter and Mount	= 8.0	3.6
TOTAL WEIGHT	= 181.0 lbs.	82.3 kg

APPENDIX I STANDARD RADAR TARGETS

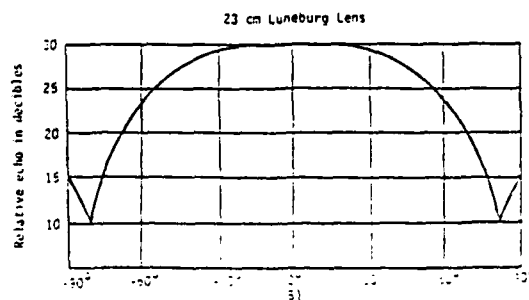
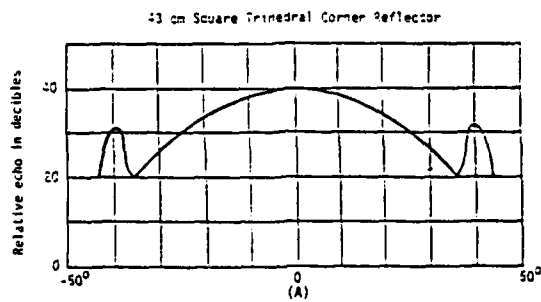
Luneberg Lens Cross-Section (#328)

Frequency (GHz)	Cross-Section (dB rel. to 1 m ²)
1.5	- 4.5
4.4	5.3
4.8	6.1
5.2	6.7
5.6	7.4
6.0	8.4
6.4	8.8
6.8	9.7
7.2	9.8
7.6	10.2
8.6	11.2
9.6	10.8
10.6	11.6
11.6	11.8
12.6	11.6
13.6	11.9
14.6	11.0
15.6	9.9
16.6	8.9





Theoretical 1-2 GHz radar cross-section response of 43 cm square trihedral corner reflector



Angular response of standard targets

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permit fully legible reproduction

APPENDIX J

HELOSCAT System Footprint Sizes
and
Independent Samples

ANTENNA HEIGHT= 15.2 METERS(50. FEET)

ANTENNA HEIGHT= 15.2 METERS(50. FEET)

POLARIZATION= VV (18 INCH DISH)

POLARIZATION= HH (24 INCH DISH)

INCIDENCE ANGLE= 10 DEGREES

INCIDENCE ANGLE= 10 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	4.33	3.35	13.27	4
4.4 GHZ	2.26	2.01	3.56	2
4.8 GHZ	2.07	1.86	3.02	2
5.2 GHZ	1.92	1.70	2.57	2
5.6 GHZ	1.79	1.61	2.27	2
6.0 GHZ	1.70	1.46	1.95	1
6.4 GHZ	1.42	1.40	1.56	1
6.8 GHZ	1.36	1.31	1.40	1
7.2 GHZ	1.33	1.22	1.37	1
7.6 GHZ	1.30	1.15	1.18	1
8.0 GHZ	1.03	1.00	0.95	1
9.6 GHZ	1.02	0.91	0.73	1
10.6 GHZ	0.96	0.82	0.62	1
11.6 GHZ	0.83	0.76	0.50	1
12.6 GHZ	0.80	0.67	0.42	1
13.6 GHZ	0.80	0.64	0.40	1
14.6 GHZ	0.77	0.64	0.39	1
15.6 GHZ	0.74	0.53	0.34	1
16.6 GHZ	0.65	0.52	0.26	1

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	2.51	2.65	5.22	2
4.4 GHZ	1.53	1.64	2.03	1
4.8 GHZ	1.43	1.55	1.81	1
5.2 GHZ	1.53	1.43	1.56	1
5.6 GHZ	1.50	1.37	1.40	1
6.0 GHZ	1.20	1.29	1.21	1
6.4 GHZ	1.14	1.19	1.07	1
6.8 GHZ	1.03	1.13	0.96	1
7.2 GHZ	1.02	1.06	0.95	1
7.6 GHZ	0.96	1.00	0.75	1
8.0 GHZ	0.83	0.89	0.59	1
9.6 GHZ	0.74	0.79	0.46	1
10.6 GHZ	0.63	0.73	0.39	1
11.6 GHZ	0.62	0.67	0.32	1
12.6 GHZ	0.59	0.64	0.29	1
13.6 GHZ	0.52	0.64	0.26	0
14.6 GHZ	0.49	0.61	0.24	0
15.6 GHZ	0.46	0.61	0.22	0
16.6 GHZ	0.43	0.58	0.20	0

INCIDENCE ANGLE= 20 DEGREES

INCIDENCE ANGLE= 20 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	4.83	4.04	15.31	3
4.4 GHZ	2.43	2.11	4.11	4
4.8 GHZ	2.23	1.95	3.49	4
5.2 GHZ	2.11	1.79	2.96	4
5.6 GHZ	1.97	1.69	2.62	3
6.0 GHZ	1.37	1.53	2.25	1
6.4 GHZ	1.56	1.47	1.80	3
6.8 GHZ	1.49	1.37	1.61	3
7.2 GHZ	1.46	1.28	1.46	2
7.6 GHZ	1.43	1.21	1.36	2
8.0 GHZ	1.19	1.05	0.98	2
9.6 GHZ	1.12	0.96	0.84	2
10.6 GHZ	1.05	0.86	0.71	2
11.6 GHZ	0.92	0.80	0.57	2
12.6 GHZ	0.83	0.70	0.49	2
13.6 GHZ	0.88	0.67	0.46	2
14.6 GHZ	0.85	0.67	0.45	1
15.6 GHZ	0.81	0.61	0.37	1
16.6 GHZ	0.71	0.54	0.30	1

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	2.76	2.73	6.02	5
4.4 GHZ	1.73	1.72	2.34	3
4.8 GHZ	1.63	1.63	2.08	3
5.2 GHZ	1.53	1.50	1.80	3
5.6 GHZ	1.43	1.44	1.61	2
6.0 GHZ	1.32	1.34	1.39	2
6.4 GHZ	1.26	1.24	1.23	2
6.8 GHZ	1.19	1.18	1.10	2
7.2 GHZ	1.12	1.12	0.93	2
7.6 GHZ	1.05	1.05	0.97	2
8.0 GHZ	0.92	0.92	0.66	2
9.6 GHZ	0.81	0.83	0.53	1
10.6 GHZ	0.75	0.76	0.45	1
11.6 GHZ	0.63	0.70	0.37	1
12.6 GHZ	0.64	0.67	0.34	1
13.6 GHZ	0.58	0.67	0.30	1
14.6 GHZ	0.54	0.64	0.27	1
15.6 GHZ	0.51	0.64	0.25	1
16.6 GHZ	0.47	0.61	0.23	1

INCIDENCE ANGLE= 30 DEGREES

INCIDENCE ANGLE= 30 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	5.70	4.73	19.69	14
4.4 GHZ	2.92	2.29	5.25	7
4.8 GHZ	2.63	2.11	4.45	7
5.2 GHZ	2.43	1.94	3.79	6
5.6 GHZ	2.32	1.84	3.75	6
6.0 GHZ	2.20	1.66	2.37	6
6.4 GHZ	1.84	1.57	2.70	5
6.8 GHZ	1.75	1.40	2.05	4
7.2 GHZ	1.72	1.73	1.37	4
7.6 GHZ	1.68	1.71	1.73	4
8.0 GHZ	1.40	1.14	1.25	3
9.6 GHZ	1.32	1.04	1.07	3
10.6 GHZ	1.24	0.93	0.91	3
11.6 GHZ	1.03	0.86	0.73	3
12.6 GHZ	1.04	0.76	0.62	3
13.6 GHZ	1.04	0.73	0.59	3
14.6 GHZ	1.00	0.77	0.57	2
15.6 GHZ	0.96	0.66	0.49	2
16.6 GHZ	0.84	0.59	0.39	2

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	3.25	3.02	7.70	8
4.4 GHZ	2.04	1.37	3.00	5
4.8 GHZ	1.92	1.77	2.66	5
5.2 GHZ	1.30	1.63	2.30	5
5.6 GHZ	1.63	1.56	2.05	4
6.0 GHZ	1.56	1.45	1.79	4
6.4 GHZ	1.49	1.35	1.57	4
6.8 GHZ	1.40	1.29	1.41	3
7.2 GHZ	1.32	1.21	1.25	3
7.6 GHZ	1.24	1.14	1.11	3
8.0 GHZ	1.03	1.00	0.85	3
9.6 GHZ	0.96	0.90	0.68	2
10.6 GHZ	0.88	0.83	0.75	2
11.6 GHZ	0.80	0.76	0.48	2
12.6 GHZ	0.76	0.73	0.43	2
13.6 GHZ	0.63	0.73	0.39	2
14.6 GHZ	0.64	0.69	0.35	2
15.6 GHZ	0.60	0.69	0.33	1
16.6 GHZ	0.56	0.66	0.29	1

INCIDENCE ANGLE= 40 DEGREES

INCIDENCE ANGLE= 40 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	7.34	4.99	28.75	24
4.4 GHZ	3.75	2.59	7.61	12
4.8 GHZ	3.43	2.39	6.45	11
5.2 GHZ	3.18	2.19	5.47	10
5.6 GHZ	2.97	2.03	4.84	10
6.0 GHZ	2.62	1.33	4.16	3
6.4 GHZ	2.55	1.30	3.33	3
6.8 GHZ	2.25	1.03	2.97	7
7.2 GHZ	2.22	1.57	2.70	7
7.6 GHZ	2.15	1.40	2.51	7
8.0 GHZ	1.73	1.23	1.31	6
9.6 GHZ	1.67	1.17	1.55	5
10.6 GHZ	1.53	1.00	1.31	5
11.6 GHZ	1.58	0.98	1.06	4
12.6 GHZ	1.37	0.86	0.70	4
13.6 GHZ	1.33	0.70	0.35	4
14.6 GHZ	1.23	0.82	0.82	4
15.6 GHZ	1.23	0.71	0.72	4
16.6 GHZ	1.07	0.60	0.39	5

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	4.16	3.42	11.17	13
4.4 GHZ	2.61	2.11	4.33	3
4.8 GHZ	2.45	2.00	3.85	3
5.2 GHZ	2.30	1.34	3.32	7
5.6 GHZ	2.15	1.76	2.37	7
6.0 GHZ	1.99	1.64	2.57	6
6.4 GHZ	1.39	1.53	2.27	6
6.8 GHZ	1.77	1.45	2.03	6
7.2 GHZ	1.67	1.27	1.31	5
7.6 GHZ	1.58	1.20	1.61	5
8.0 GHZ	1.53	1.13	1.23	4
9.6 GHZ	1.23	1.02	0.78	4
10.6 GHZ	1.12	0.84	0.83	4
11.6 GHZ	1.02	0.86	0.60	3
12.6 GHZ	0.97	0.82	0.63	3
13.6 GHZ	0.87	0.82	0.56	3
14.6 GHZ	0.82	0.79	0.50	3
15.6 GHZ	0.77	0.79	0.47	2
16.6 GHZ	0.71	0.71	0.42	2

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INCIDENCE ANGLE= 50 DEGREES

FREQUENCY	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	6.90	5.98	44.50	34
4.4 GHZ	5.94	5.09	12.96	21
4.3 GHZ	4.89	2.85	10.97	19
5.2 GHZ	4.52	2.62	9.50	17
5.6 GHZ	4.25	2.48	8.25	16
6.0 GHZ	4.01	2.24	7.06	15
6.4 GHZ	3.75	2.15	5.44	13
6.3 GHZ	3.20	2.01	5.04	12
7.2 GHZ	3.17	1.57	4.59	12
7.6 GHZ	2.05	1.77	4.25	12
8.6 GHZ	2.54	1.54	3.07	10
9.6 GHZ	2.40	1.40	2.67	9
10.6 GHZ	2.25	1.26	2.27	9
11.6 GHZ	1.96	1.17	1.79	8
12.6 GHZ	1.89	1.03	1.52	7
13.6 GHZ	1.33	0.93	1.45	7
14.6 GHZ	1.81	0.98	1.39	7
15.6 GHZ	1.74	0.89	1.21	7
16.6 GHZ	1.52	0.79	0.95	6

INCIDENCE ANGLE= 60 DEGREES

FREQUENCY	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	10.47	7.32	73.12	45
4.4 GHZ	3.90	3.99	27.83	39
4.3 GHZ	9.14	3.68	23.55	35
5.2 GHZ	7.52	3.38	19.94	33
5.6 GHZ	7.02	3.19	17.61	30
6.0 GHZ	6.65	2.89	15.10	29
6.4 GHZ	5.55	2.77	12.05	24
6.3 GHZ	5.50	2.58	10.76	23
7.2 GHZ	5.13	2.40	9.73	22
7.6 GHZ	5.06	2.29	9.07	22
8.6 GHZ	4.21	1.93	6.55	18
9.6 GHZ	3.97	1.90	5.61	17
10.6 GHZ	3.72	1.62	4.74	16
11.6 GHZ	3.24	1.50	3.82	14
12.6 GHZ	3.12	1.32	3.23	14
13.6 GHZ	3.12	1.26	3.09	14
14.6 GHZ	3.00	1.26	2.97	14
15.6 GHZ	2.99	1.14	2.53	12
16.6 GHZ	2.52	1.02	2.02	11

INCIDENCE ANGLE= 70 DEGREES

FREQUENCY	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	13.65	12.01	148.70	64
4.4 GHZ	13.65	5.90	70.82	64
4.3 GHZ	13.65	5.44	63.79	64
5.2 GHZ	13.56	4.98	56.85	64
5.6 GHZ	13.18	4.70	51.72	62
6.0 GHZ	12.89	4.25	45.42	61
6.4 GHZ	11.97	4.06	39.18	56
6.3 GHZ	11.45	3.79	34.07	54
7.2 GHZ	11.17	3.55	30.34	53
7.6 GHZ	10.90	3.35	28.63	51
8.6 GHZ	9.04	2.90	20.62	45
9.6 GHZ	8.52	2.64	17.65	40
10.6 GHZ	7.99	2.37	14.90	33
11.6 GHZ	6.95	2.20	11.93	33
12.6 GHZ	6.69	1.93	10.15	31
13.6 GHZ	6.69	1.84	9.69	31
14.6 GHZ	6.45	1.84	9.31	30
15.6 GHZ	6.17	1.67	8.03	29
16.6 GHZ	5.39	1.49	6.32	25

INCIDENCE ANGLE= 80 DEGREES

FREQUENCY	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	24.85	35.93	536.43	122
4.4 GHZ	24.35	12.49	276.31	122
4.3 GHZ	24.35	11.56	254.35	122
5.2 GHZ	24.35	10.31	232.34	122
5.6 GHZ	24.35	9.07	219.52	122
6.0 GHZ	24.35	3.71	133.04	122
6.4 GHZ	24.35	3.21	136.55	122
6.3 GHZ	24.35	7.05	175.42	122
7.2 GHZ	24.35	7.11	160.32	122
7.6 GHZ	24.35	6.74	152.27	122
8.6 GHZ	24.35	7.00	127.77	122
9.6 GHZ	24.35	5.27	114.33	122
10.6 GHZ	24.35	4.73	100.30	122
11.6 GHZ	24.04	4.50	87.50	113
12.6 GHZ	23.69	3.84	75.15	113
13.6 GHZ	23.69	3.66	71.72	113
14.6 GHZ	23.23	3.66	69.33	113
15.6 GHZ	22.90	3.31	61.02	113
16.6 GHZ	21.15	2.95	59.24	104

INCIDENCE ANGLE= 50 DEGREES

FREQ.(GHZ)	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	5.93	4.09	19.03	23
4.4 GHZ	3.71	2.52	7.36	14
4.3 GHZ	3.49	2.38	6.53	13
5.2 GHZ	3.27	2.19	5.64	13
5.6 GHZ	3.05	2.10	5.04	12
6.0 GHZ	2.83	1.96	4.36	11
6.4 GHZ	2.67	1.82	3.34	10
6.3 GHZ	2.54	1.73	3.45	10
7.2 GHZ	2.40	1.63	2.07	9
7.6 GHZ	2.25	1.54	2.72	9
8.6 GHZ	1.96	1.35	2.09	8
9.6 GHZ	1.74	1.21	1.66	7
10.6 GHZ	1.60	1.12	1.40	6
11.6 GHZ	1.45	1.03	1.17	6
12.6 GHZ	1.33	0.93	1.06	5
13.6 GHZ	1.23	0.93	0.95	5
14.6 GHZ	1.16	0.93	0.95	4
15.6 GHZ	1.09	0.93	0.90	4
16.6 GHZ	1.01	0.89	0.71	4

INCIDENCE ANGLE= 60 DEGREES

FREQ.(GHZ)	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	9.37	5.27	40.16	41
4.4 GHZ	6.16	3.25	15.72	27
4.3 GHZ	5.79	3.07	13.95	25
5.2 GHZ	5.43	2.33	12.04	24
5.6 GHZ	5.06	2.70	10.74	22
6.0 GHZ	4.69	2.52	9.70	20
6.4 GHZ	4.15	2.31	8.19	19
6.3 GHZ	4.21	2.22	7.34	18
7.2 GHZ	3.97	2.10	6.54	17
7.6 GHZ	3.72	1.98	5.79	16
8.6 GHZ	3.24	1.74	4.43	14
9.6 GHZ	2.83	1.56	3.53	12
10.6 GHZ	2.64	1.44	2.93	11
11.6 GHZ	2.40	1.32	2.43	10
12.6 GHZ	2.23	1.26	2.25	10
13.6 GHZ	2.04	1.26	2.01	9
14.6 GHZ	1.92	1.20	1.81	8
15.6 GHZ	1.80	1.20	1.69	8
16.6 GHZ	1.68	1.14	1.50	7

INCIDENCE ANGLE= 70 DEGREES

FREQ.(GHZ)	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	13.65	7.03	95.55	64
4.4 GHZ	12.50	4.79	49.70	59
4.3 GHZ	12.20	4.51	43.99	57
5.2 GHZ	11.70	4.15	38.13	55
5.6 GHZ	10.30	3.97	33.97	51
6.0 GHZ	10.10	3.70	29.35	47
6.4 GHZ	9.57	3.43	25.81	45
6.3 GHZ	9.04	3.26	23.13	43
7.2 GHZ	8.52	3.09	20.59	40
7.6 GHZ	7.99	2.90	18.21	38
8.6 GHZ	6.95	2.64	13.90	33
9.6 GHZ	6.17	2.29	11.06	29
10.6 GHZ	5.65	2.11	9.75	27
11.6 GHZ	5.14	1.93	7.73	24
12.6 GHZ	4.88	1.84	7.05	23
13.6 GHZ	4.36	1.84	6.31	20
14.6 GHZ	4.10	1.75	5.65	19
15.6 GHZ	3.95	1.75	5.29	18
16.6 GHZ	3.59	1.66	4.69	17

INCIDENCE ANGLE= 80 DEGREES

FREQ.(GHZ)	RE(H)	RA(H)	AREA(H**2)	NUM.INDEP.
1.5 GHZ	24.35	16.87	356.32	122
4.4 GHZ	24.35	9.72	221.36	122
4.3 GHZ	24.35	9.14	207.31	122
5.2 GHZ	24.35	8.73	190.10	122
5.6 GHZ	24.35	7.99	170.32	122
6.0 GHZ	24.35	7.45	160.23	122
6.4 GHZ	24.35	6.88	152.77	122
6.3 GHZ	24.35	6.51	147.26	122
7.2 GHZ	24.35	6.14	139.34	122
7.6 GHZ	24.35	5.74	128.22	122
8.6 GHZ	24.04	5.00	101.27	113
9.6 GHZ	22.90	4.59	84.37	113
10.6 GHZ	22.12	4.17	72.06	109
11.6 GHZ	20.12	3.82	50.32	99
12.6 GHZ	19.01	3.64	54.60	96
13.6 GHZ	17.01	3.64	49.02	91
14.6 GHZ	16.22	3.36	44.97	79
15.6 GHZ	15.70	3.36	40.71	74
16.6 GHZ	14.15	3.00	36.11	59

ANTENNA HEIGHT= 30.4 METERS(100. FEET)

POLARIZATION= VV (1.3 INCH DIAM)

INCIDENCE ANGLE= 10 DEGREES

FREQUENCY	RE(A)	RA(A)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	3.77	7.70	55.06	9
4.4 GHZ	4.52	4.02	14.26	4
4.8 GHZ	4.14	5.71	12.09	4
5.2 GHZ	3.33	3.41	10.27	3
5.6 GHZ	3.53	3.23	9.09	3
6.0 GHZ	3.40	2.92	7.80	3
6.4 GHZ	2.34	2.90	6.25	2
6.8 GHZ	2.72	2.62	5.59	2
7.2 GHZ	2.66	2.43	5.03	2
7.6 GHZ	2.60	2.31	4.71	2
8.6 GHZ	2.16	2.01	3.41	2
9.6 GHZ	2.04	1.82	2.92	2
10.6 GHZ	1.91	1.64	2.47	2
11.6 GHZ	1.67	1.52	1.99	1
12.6 GHZ	1.61	1.34	1.69	1
13.6 GHZ	1.61	1.28	1.61	1
14.6 GHZ	1.54	1.29	1.55	1
15.6 GHZ	1.43	1.16	1.35	1
16.6 GHZ	1.30	1.03	1.05	1

INCIDENCE ANGLE= 20 DEGREES

FREQUENCY	RE(A)	RA(A)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	9.45	9.08	61.26	17
4.4 GHZ	4.96	4.21	16.43	9
4.8 GHZ	4.55	3.99	13.92	9
5.2 GHZ	4.21	3.57	11.32	7
5.6 GHZ	3.34	3.39	10.46	7
6.0 GHZ	3.74	3.06	8.93	6
6.4 GHZ	3.12	2.33	7.20	5
6.8 GHZ	2.99	2.74	6.43	5
7.2 GHZ	2.92	2.55	5.85	5
7.6 GHZ	2.35	2.42	5.43	5
8.6 GHZ	2.39	2.10	3.93	4
9.6 GHZ	2.24	1.91	3.36	4
10.6 GHZ	2.10	1.72	2.94	4
11.6 GHZ	1.93	1.53	2.29	3
12.6 GHZ	1.76	1.40	1.94	3
13.6 GHZ	1.76	1.34	1.95	3
14.6 GHZ	1.70	1.34	1.78	3
15.6 GHZ	1.63	1.21	1.55	3
16.6 GHZ	1.42	1.03	1.21	2

INCIDENCE ANGLE= 30 DEGREES

FREQUENCY	RE(A)	RA(A)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	11.41	3.79	78.72	23
4.4 GHZ	5.35	4.57	21.02	15
4.8 GHZ	5.37	4.23	17.81	13
5.2 GHZ	4.36	3.09	15.12	12
5.6 GHZ	4.64	3.67	13.38	12
6.0 GHZ	4.40	3.32	11.49	11
6.4 GHZ	3.68	3.18	9.20	9
6.8 GHZ	3.52	2.93	8.22	9
7.2 GHZ	3.44	2.77	7.47	9
7.6 GHZ	3.36	2.63	6.94	8
8.6 GHZ	2.30	2.29	5.02	7
9.6 GHZ	2.64	2.09	4.30	7
10.6 GHZ	2.43	1.87	3.63	6
11.6 GHZ	2.16	1.73	2.93	5
12.6 GHZ	2.08	1.52	2.48	5
13.6 GHZ	2.03	1.45	2.37	5
14.6 GHZ	2.00	1.45	2.28	5
15.6 GHZ	1.92	1.31	1.93	5
16.6 GHZ	1.69	1.19	1.55	4

INCIDENCE ANGLE= 40 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	14.63	9.97	115.00	48
4.4 GHZ	7.49	5.19	30.45	24
4.8 GHZ	6.37	4.73	25.80	22
5.2 GHZ	6.35	4.39	21.39	20
5.6 GHZ	5.34	4.15	19.37	13
6.0 GHZ	5.63	3.76	16.62	13
6.4 GHZ	4.70	3.60	13.31	15
6.8 GHZ	4.50	3.37	11.39	14
7.2 GHZ	4.40	3.13	10.81	14
7.6 GHZ	4.29	2.97	10.03	14
8.6 GHZ	3.58	2.93	7.25	12
9.6 GHZ	3.37	2.35	6.21	11
10.6 GHZ	3.17	2.11	5.25	10
11.6 GHZ	2.76	1.96	4.23	9
12.6 GHZ	2.66	1.72	3.59	9
13.6 GHZ	2.65	1.64	3.43	9
14.6 GHZ	2.55	1.61	3.27	9
15.6 GHZ	2.45	1.53	2.96	9
16.6 GHZ	2.11	1.33	2.21	7

ANTENNA HEIGHT= 30.4 METERS(100. FEET)

POLARIZATION= HH (21 INCH DIAM)

INCIDENCE ANGLE= 10 DEGREES

FREQ.(GHZ)	RE(A)	RA(A)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	5.01	5.30	20.33	1
4.4 GHZ	3.15	3.29	8.14	3
4.8 GHZ	2.97	3.10	7.23	3
5.2 GHZ	2.73	2.46	6.25	2
5.6 GHZ	2.60	2.74	5.53	2
6.0 GHZ	2.41	2.56	4.34	2
6.4 GHZ	2.29	2.37	4.26	2
6.8 GHZ	2.16	2.25	3.02	2
7.2 GHZ	2.01	2.13	3.41	2
7.6 GHZ	1.91	2.01	3.02	2
8.6 GHZ	1.67	1.76	2.31	1
9.6 GHZ	1.43	1.53	1.34	1
10.6 GHZ	1.30	1.46	1.56	1
11.6 GHZ	1.21	1.34	1.30	1
12.6 GHZ	1.17	1.23	1.13	1
13.6 GHZ	1.05	1.29	1.05	1
14.6 GHZ	0.99	1.22	0.94	1
15.6 GHZ	0.93	1.22	0.99	1
16.6 GHZ	0.96	1.16	0.73	1

INCIDENCE ANGLE= 20 DEGREES

FREQ.(GHZ)	RE(A)	RA(A)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	5.51	5.56	24.06	9
4.4 GHZ	3.46	3.45	9.37	6
4.8 GHZ	3.26	3.25	9.33	6
5.2 GHZ	3.05	3.00	7.17	5
5.6 GHZ	2.35	2.37	6.43	5
6.0 GHZ	2.65	2.68	5.57	5
6.4 GHZ	2.51	2.49	4.90	4
6.8 GHZ	2.39	2.36	4.40	4
7.2 GHZ	2.24	2.23	3.32	4
7.6 GHZ	2.10	2.10	3.43	4
8.6 GHZ	1.33	1.35	2.66	3
9.6 GHZ	1.63	1.66	2.12	3
10.6 GHZ	1.49	1.53	1.79	3
11.6 GHZ	1.36	1.40	1.49	2
12.6 GHZ	1.23	1.34	1.36	2
13.6 GHZ	1.15	1.34	1.21	2
14.6 GHZ	1.07	1.27	1.09	2
15.6 GHZ	1.02	1.27	1.02	2
16.6 GHZ	0.95	1.21	0.90	2

INCIDENCE ANGLE= 30 DEGREES

FREQ.(GHZ)	RE(A)	RA(A)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	6.50	6.04	30.30	16
4.4 GHZ	4.09	3.74	11.38	10
4.8 GHZ	3.34	3.53	10.65	10
5.2 GHZ	3.60	3.25	9.19	9
5.6 GHZ	3.36	3.11	8.21	8
6.0 GHZ	3.12	2.91	7.12	8
6.4 GHZ	2.96	2.70	6.27	7
6.8 GHZ	2.90	2.56	5.62	7
7.2 GHZ	2.64	2.42	5.02	7
7.6 GHZ	2.43	2.28	4.44	6
8.6 GHZ	2.16	2.01	3.40	5
9.6 GHZ	1.92	1.80	2.71	5
10.6 GHZ	1.76	1.66	2.29	4
11.6 GHZ	1.60	1.52	1.91	4
12.6 GHZ	1.52	1.45	1.73	4
13.6 GHZ	1.36	1.45	1.55	3
14.6 GHZ	1.29	1.38	1.39	3
15.6 GHZ	1.20	1.38	1.30	3
16.6 GHZ	1.12	1.31	1.15	3

INCIDENCE ANGLE= 40 DEGREES

FREQ.(GHZ)	RE(A)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	8.32	6.83	44.65	27
4.4 GHZ	5.22	4.23	17.34	17
4.8 GHZ	4.31	3.99	15.40	16
5.2 GHZ	4.60	3.63	13.30	15
5.6 GHZ	4.29	3.52	11.33	14
6.0 GHZ	3.99	3.29	10.29	13
6.4 GHZ	3.73	3.05	9.06	12
6.8 GHZ	3.53	2.90	9.13	12
7.2 GHZ	3.37	2.74	7.25	11
7.6 GHZ	3.17	2.53	6.42	10
8.6 GHZ	2.76	2.27	4.91	9
9.6 GHZ	2.45	2.03	3.91	8
10.6 GHZ	2.25	1.39	3.31	7
11.6 GHZ	2.04	1.72	2.76	7
12.6 GHZ	1.94	1.64	2.50	6
13.6 GHZ	1.74	1.64	2.21	6
14.6 GHZ	1.63	1.56	2.01	5
15.6 GHZ	1.53	1.55	1.83	5
16.6 GHZ	1.43	1.44	1.67	5

INCIDENCE ANGLE= 50 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	17.32	11.37	173.48	66
4.4 GHZ	10.63	6.14	51.34	41
4.8 GHZ	9.79	5.71	45.37	39
5.2 GHZ	9.05	5.24	37.21	35
5.6 GHZ	8.46	4.95	32.90	32
6.0 GHZ	8.01	4.48	29.23	31
6.4 GHZ	6.69	4.50	22.57	26
6.8 GHZ	6.40	4.01	20.17	25
7.2 GHZ	6.25	3.73	18.33	24
7.6 GHZ	6.11	3.55	17.01	23
9.6 GHZ	5.03	3.03	12.23	13
9.6 GHZ	4.79	2.30	10.53	18
10.6 GHZ	4.50	2.52	8.90	17
11.6 GHZ	3.92	2.33	7.17	15
12.6 GHZ	3.77	2.05	6.03	14
13.6 GHZ	3.77	1.96	5.30	14
14.6 GHZ	3.63	1.96	5.58	14
15.6 GHZ	3.43	1.77	4.84	13
16.6 GHZ	3.05	1.58	3.79	12

INCIDENCE ANGLE= 60 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	19.98	15.64	231.43	86
4.4 GHZ	17.54	7.98	111.18	76
4.8 GHZ	16.29	7.36	94.20	71
5.2 GHZ	15.04	6.75	79.76	65
5.6 GHZ	14.05	6.39	70.45	61
6.0 GHZ	13.31	5.79	60.40	59
6.4 GHZ	11.10	5.53	49.20	48
6.8 GHZ	10.61	5.17	43.06	46
7.2 GHZ	10.35	4.81	39.12	45
7.6 GHZ	10.12	4.57	36.28	44
8.6 GHZ	9.42	3.96	26.19	36
9.6 GHZ	7.93	3.60	22.43	34
10.6 GHZ	7.45	3.24	18.95	32
11.6 GHZ	6.43	3.00	15.27	23
12.6 GHZ	6.24	2.64	12.93	27
13.6 GHZ	6.21	2.52	12.35	27
14.6 GHZ	6.00	2.52	11.87	26
15.6 GHZ	5.76	2.23	10.31	25
16.6 GHZ	5.04	2.04	8.06	22

INCIDENCE ANGLE= 70 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	26.44	24.02	569.18	124
4.4 GHZ	26.44	11.31	276.53	124
4.8 GHZ	26.44	10.83	249.31	124
5.2 GHZ	26.44	9.96	223.06	124
5.6 GHZ	25.34	9.41	204.07	122
6.0 GHZ	25.36	8.51	179.33	119
6.4 GHZ	23.57	8.12	152.24	111
6.8 GHZ	22.37	7.59	136.27	109
7.2 GHZ	22.33	7.06	123.75	105
7.6 GHZ	21.80	6.70	114.71	103
9.6 GHZ	18.09	5.81	92.49	95
9.6 GHZ	17.04	5.23	70.60	90
10.6 GHZ	15.99	4.75	59.59	75
11.6 GHZ	13.90	4.39	47.93	65
12.6 GHZ	13.38	3.86	40.59	63
13.6 GHZ	13.33	3.69	38.75	63
14.6 GHZ	12.36	3.69	37.23	60
15.6 GHZ	12.34	3.33	32.32	53
16.6 GHZ	10.79	2.93	25.26	51

INCIDENCE ANGLE= 80 DEGREES

FREQUENCY	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	43.37	41.67	2110.74	240
4.4 GHZ	43.87	24.77	1033.05	240
4.8 GHZ	43.87	22.72	1007.05	240
5.2 GHZ	46.85	20.61	917.25	240
5.6 GHZ	43.85	19.34	864.52	240
6.0 GHZ	43.85	17.41	730.63	240
6.4 GHZ	43.85	16.47	705.26	240
6.8 GHZ	43.85	15.71	637.67	240
7.2 GHZ	47.37	14.22	674.03	240
7.6 GHZ	43.33	13.43	600.45	240
8.6 GHZ	43.33	11.61	504.63	240
9.6 GHZ	48.77	10.57	507.64	240
10.6 GHZ	47.04	9.46	400.07	210
11.6 GHZ	47.04	8.72	343.00	200
12.6 GHZ	45.04	7.67	275.50	190
13.6 GHZ	45.04	7.70	275.22	221
14.6 GHZ	48.15	7.30	273.27	221
15.6 GHZ	45.35	6.61	249.13	220
16.6 GHZ	42.70	5.70	175.17	200

INCIDENCE ANGLE= 50 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	11.37	8.16	76.12	46
4.4 GHZ	7.43	5.05	29.42	29
4.8 GHZ	6.93	4.76	25.13	27
5.2 GHZ	6.55	4.39	22.56	25
5.6 GHZ	6.11	4.20	20.15	23
6.0 GHZ	5.67	3.92	17.45	22
6.4 GHZ	5.33	3.64	15.36	21
6.8 GHZ	5.03	3.45	13.73	19
7.2 GHZ	4.79	3.26	12.29	18
7.6 GHZ	4.50	3.03	10.83	17
9.6 GHZ	3.92	2.70	8.32	15
9.6 GHZ	3.43	2.42	6.63	13
10.6 GHZ	3.19	2.24	5.61	12
11.6 GHZ	2.90	2.05	4.67	11
12.6 GHZ	2.76	1.96	4.24	11
13.6 GHZ	2.47	1.96	3.79	9
14.6 GHZ	2.32	1.86	3.40	9
15.6 GHZ	2.18	1.96	3.19	8
16.6 GHZ	2.03	1.77	2.82	8

INCIDENCE ANGLE= 60 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	19.23	10.55	153.24	79
4.4 GHZ	12.32	6.50	62.89	53
4.8 GHZ	11.59	6.13	55.82	50
5.2 GHZ	10.95	5.65	48.16	47
5.6 GHZ	10.12	5.41	42.98	44
6.0 GHZ	9.39	5.04	37.20	41
6.4 GHZ	8.30	4.63	32.75	39
6.8 GHZ	8.42	4.44	29.37	36
7.2 GHZ	7.33	4.20	26.17	34
7.6 GHZ	7.45	3.96	23.17	32
8.6 GHZ	6.43	3.43	17.71	28
9.6 GHZ	5.76	3.12	14.10	25
10.6 GHZ	5.23	2.83	11.93	23
11.6 GHZ	4.90	2.64	9.94	21
12.6 GHZ	4.56	2.52	9.01	20
13.6 GHZ	4.03	2.52	8.06	19
14.6 GHZ	3.84	2.40	7.22	17
15.6 GHZ	3.60	2.40	6.77	16
16.6 GHZ	3.36	2.23	6.00	15

INCIDENCE ANGLE= 70 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	26.44	15.65	372.37	124
4.4 GHZ	24.53	9.56	192.74	115
4.8 GHZ	23.99	9.01	174.59	113
5.2 GHZ	23.37	8.30	152.49	110
5.6 GHZ	21.80	7.94	135.37	103
6.0 GHZ	20.20	7.40	117.41	95
6.4 GHZ	19.14	6.37	103.25	90
6.8 GHZ	18.09	6.51	92.50	85
7.2 GHZ	17.04	6.16	82.37	80
7.6 GHZ	15.99	5.90	72.35	75
9.6 GHZ	13.90	5.07	55.60	65
9.6 GHZ	12.34	4.55	44.23	53
10.6 GHZ	11.31	4.21	37.33	53
11.6 GHZ	10.27	3.86	31.13	48
12.6 GHZ	9.75	3.63	23.21	46
13.6 GHZ	8.72	3.63	25.22	41
14.6 GHZ	9.21	3.51	22.60	39
15.6 GHZ	7.69	3.51	21.19	36
16.6 GHZ	7.13	3.33	19.77	34

INCIDENCE ANGLE= 80 DEGREES

FREQ.(GHZ)	RE(M)	RA(M)	AREA(M**2)	NUM.INDEP.
1.5 GHZ	48.33	33.75	1441.79	240
4.4 GHZ	48.83	18.45	872.12	240
4.8 GHZ	48.87	18.27	819.32	240
5.2 GHZ	49.83	16.76	749.33	240
5.6 GHZ	48.83	15.39	711.06	240
6.0 GHZ	48.83	14.45	650.07	240
6.4 GHZ	48.83	13.75	603.41	240
6.8 GHZ	48.83	13.02	565.79	240
7.2 GHZ	49.83	12.23	527.43	240
7.6 GHZ	48.83	11.56	488.01	240
8.6 GHZ	47.04	10.42	400.00	210
9.6 GHZ	45.04	9.05	355.54	220
10.6 GHZ	43.30	8.14	300.05	216
11.6 GHZ	40.23	7.23	241.03	191
12.6 GHZ	40.23	7.23	241.03	193
13.6 GHZ	44.04	7.23	241.03	193
14.6 GHZ	42.04	6.41	204.04	193
15.6 GHZ	40.23	6.41	204.04	193
16.6 GHZ	37.04	5.57	175.17	193

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