DESIGN AND IMPLEMENTATION OF A L-BAND SINGLE ANTENNA POLARIMETRIC ACTIVE RADAR CALIBRATOR

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ABSTRACT

This report serves as a documentation of the design parameters and performance characteristics of a L-band single antenna polarimetric active radar calibrator (SAPARC) developed for JPL and NASA at the University of Michigan's Radiation Laboratory. The device is one of four which are currently being constructed for future JPL/NASA Synthetic Aperture Radar (SAR) missions. The report includes details of the SAPARC's RF and digital / analog electronics design, as well as test results from a number of anechoic chamber measurements. Application notes and suggestions are also included throughout.

CHAPTER I

INTRODUCTION

Active and passive radar calibrators are often used in conjunction with airborne and space borne polarimetric imaging SAR platforms. When strategically placed, these devices serve as ground-based calibration targets with specified radar cross sections (RCS). Trihedrals / corner reflectors are by far the most common type of calibration device used; however, their physical size and weight make them undesirable for field deployment. The drawbacks associated with trihedrals are two-fold. First, an actual deployment of the device can be physically awkward and inconvenient. Trihedrals can be as large as 12 ft by 12 ft by 12 ft, and they can weigh up to 300 pounds. In addition to their cumbersome size and weight, trihedrals tend to act like large rain and snow collectors, thus complicating the chances of performing an accurate calibration.

The second drawback is a bit more subtle, but just as significant. The accuracy of an external calibration of a radar system directly relies on the knowledge of the scattering matrix of the calibration target. Although it is possible to estimate the elements of the scattering matrix of a calibration target analytically, manufacturing tolerances may leave a fair amount of uncertainty in the estimated values. Therefore, it is necessary to measure the calibration targets against a precise calibration target, such as a metallic sphere. This reveals the second drawback of passive calibrators with large physical dimensions, namely that the far field condition and uniform illumination criteria are difficult to meet in the laboratory. Hence, it becomes difficult to accurately define the performance characteristics of passive calibrators of this size and type.

Polarimetric active radar calibrators (PARCs), on the other hand, tend to be much smaller and easier to handle than their passive counterparts. A PARC also yields better calibration measurements since its SAR image can be translated over a dark background, thus providing a higher signal to background ratio. As a result of these advantages, PARCs are rapidly becoming the calibration device of choice for future space borne missions.

As a final point, PARCs traditionally are designed with two antennas which can cause severe degradation in their performance, as will be explained later. Here a new design for the L-band PARC is used which requires a single antenna.

The purpose of this report is to outline of the theory, design, and implementation of the L-band single antenna PARCs developed for NASA and JPL at the University of Michigan. The content of this project reflects the modifications and improvements made to previous PARC and SAPARC units (specifically, an L-band SAPARC prototype built by Sarabandi et al. for the University of Michigan's Radiation Laboratory [2]). Currently, the L-Band SAPARCs are tentatively planned for field deployment in April 1994, where they will be used as calibration devices for NASA's SIR-C (Shuttle Imaging Radar -C) mission.

CHAPTER II

PARC THEORY / DESIGN CRITERIA

In its simplest form, a PARC consists of a receive antenna, an amplifier, and a transmit antenna (see Figure 2.1). With this configuration, the PARC merely acts like a repeater, whereby an incoming radar signal is received, amplified, and re-transmitted back to the SAR platform. Variations on this simple design do, however, lead to a variety of merits.

Figure 2.2 depicts the modifications which are employed in this project's SAPARC units. The most notable difference is the addition of a delay line along with an orthogonal mode transducer (OMT) / single antenna implementation. The device now serves as a specialized type of repeater, where the signal is captured with respect to one polarization and re-transmitted via its opposite polarization. The pre-amplifier and power amplifier ensure the proper amplification of the signal, while the delay line electrically delays the signal for reasons which will be given later. As a final note, the switches provide the attenuation needed for applicability to SIR-C as well a JPL AIRSAR missions.

2.1 PARC Radar Cross Section

The fundamental equation defining the radar cross section (RCS) of a PARC is given by [2]

$$\sigma = G_{Loop} \frac{G_T G_R \lambda^2}{4\pi}$$

where G_T and G_R are the transmit and receive antenna gains, and G_{Loop} is the net loop gain associated with the gains and losses from the system's amplifiers, switches, and delay line. Generally speaking, a larger RCS is more desirable. Hence, the driving

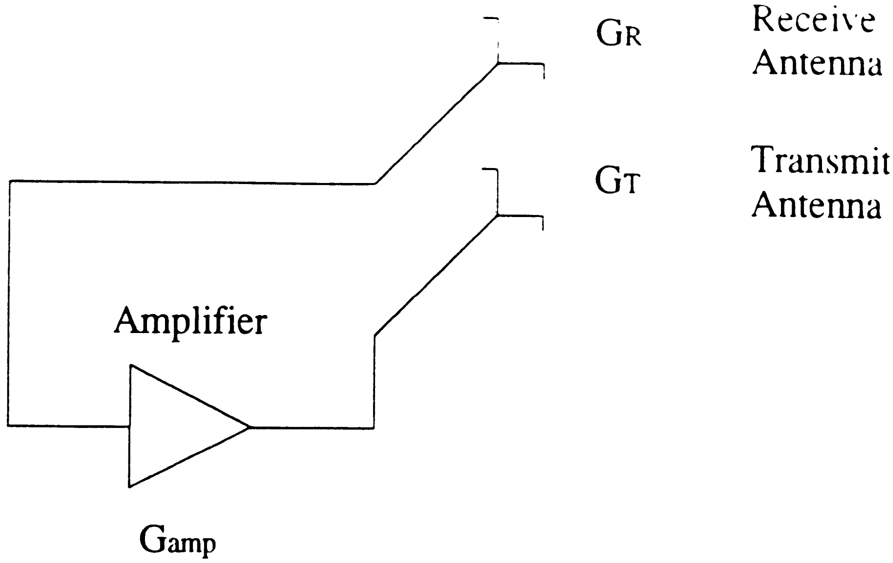


Figure 2.1: Basic PARC Configuration

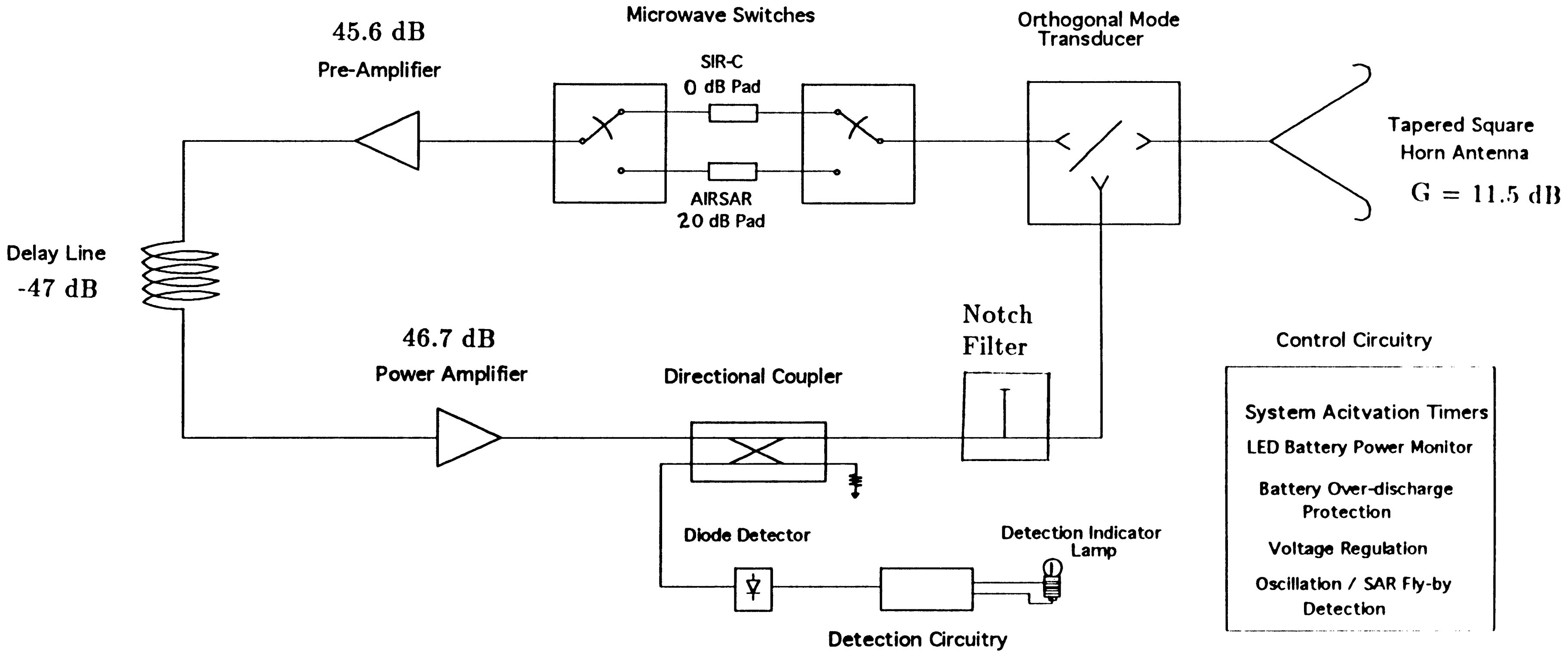


Figure 2.2: L-Band SAPARC Block Diagram

impetus behind most PARC designs is the maximization of G_{Loop}, G_T, and G_R. These parameters, in turn, are limited by beamwidth requirements, transducer isolation performance, and physical size and weight considerations. The following sections address each of these parameters in more detail.

2.2 Antenna Design

In the design of early PARC systems, two antennas, one for transmit and one for receive, were employed to achieve the necessary isolation between the receiver and transmitter modes of the PARC. The transmit and receive antennas were placed in close proximity to one another to meet the compactness requirement of the PARC design. However, since the antennas are in the near field of each other, the RCS pattern of the PARC becomes asymmetric and causes ripples in the phase and amplitude responses which tend to mar the PARC's performance [1] (see Figure 2.3). In order to counter these setbacks and yet to meet the compactness requirement, a single antenna PARC was considered. In this design, the PARC employs a dual polarized horn antenna with a very good polarization isolation and low return loss for both polarization channels. Wide bandwidth and beamwidth with high cross polarization isolation can be achieved through the implementation of an OMT (Orthogonal Mode Transducer) in conjunction with a piecewise tapered square horn.

The geometry of a piecewise tapered horn is shown in Figures 2.4. The waveguide discontinuity at a flared intersection excites higher order waveguide modes which are proportional to the flare angle. Since the waveguide is square, the higher order modes can couple energy into the orthogonal channel (TE_{10} to TE_{01}, for example). It was noticed that when the flare angle is less than 5°, the energy transfer from between the orthogonal channels is minimized. However, in order to get the desired aperture over a reasonable length, the square horn can be flared (with angles less than 5°) at many points along its length, thereby simulating an exponential taper. Note that the length of each section should be longer than the wavelength.

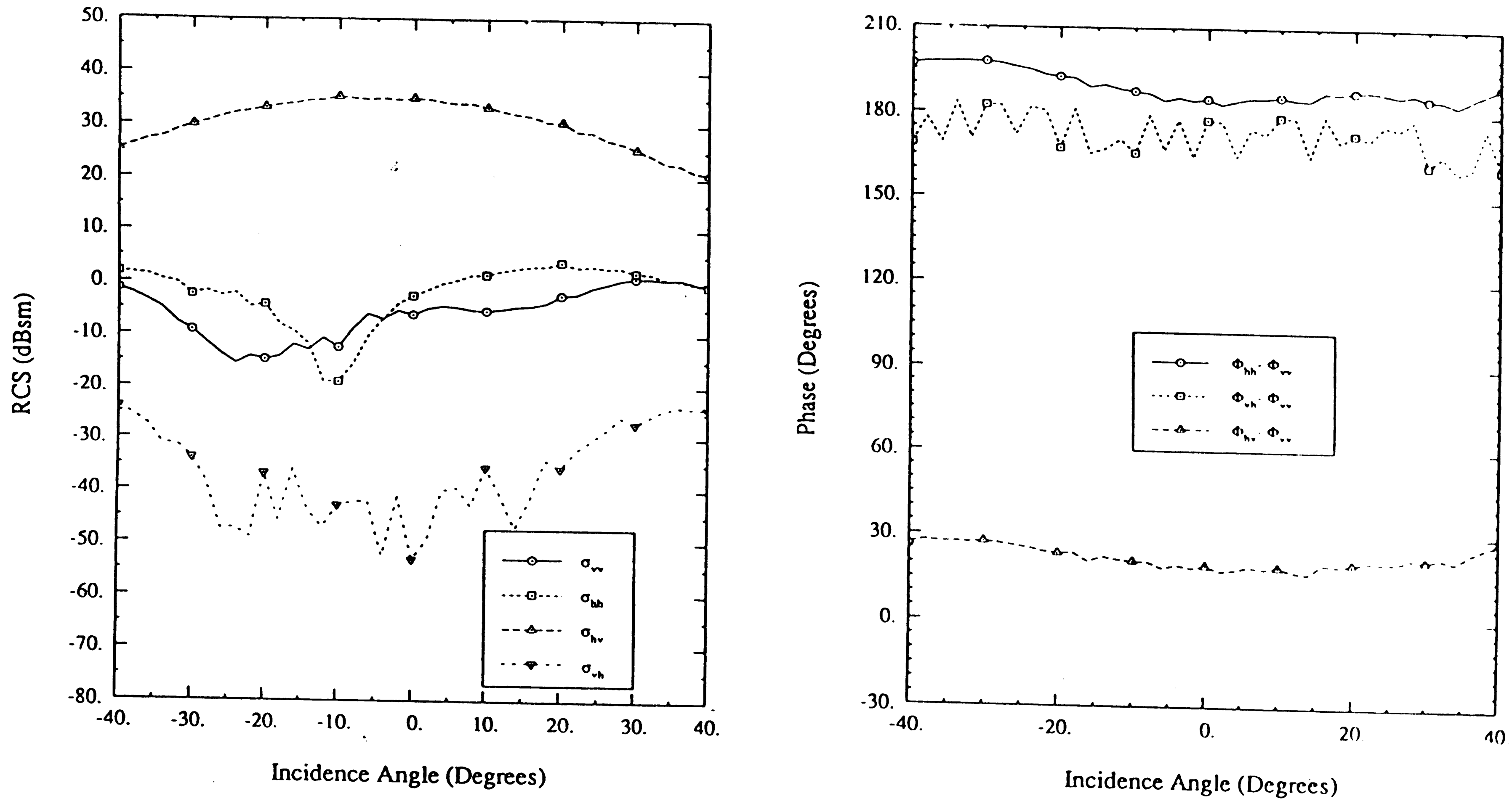


Figure 2.3: Magnitude and Phase Patterns for a Two Antenna PARC System

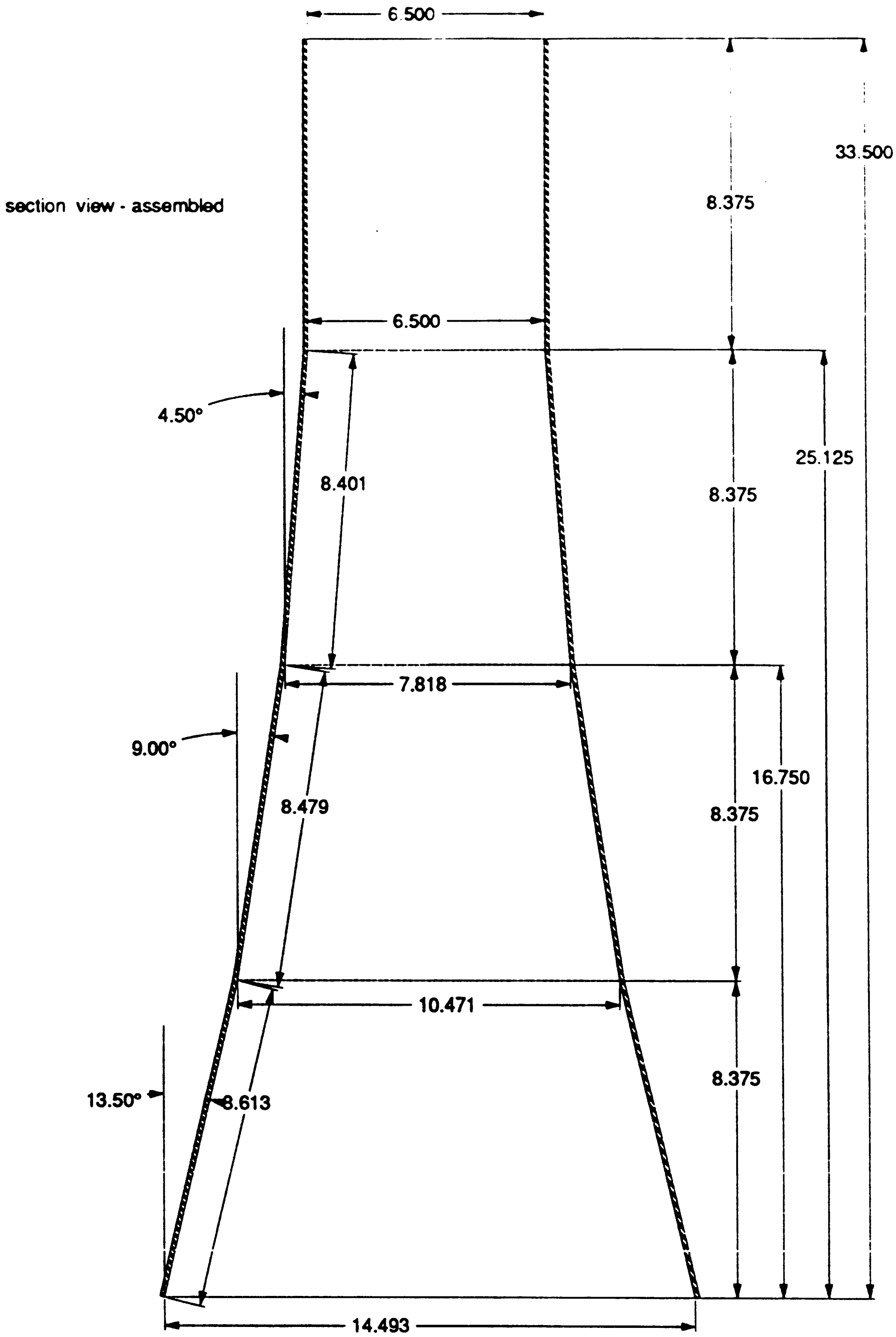


Figure 2.4: Side View of the L-band Tapered Squared Horn Antenna

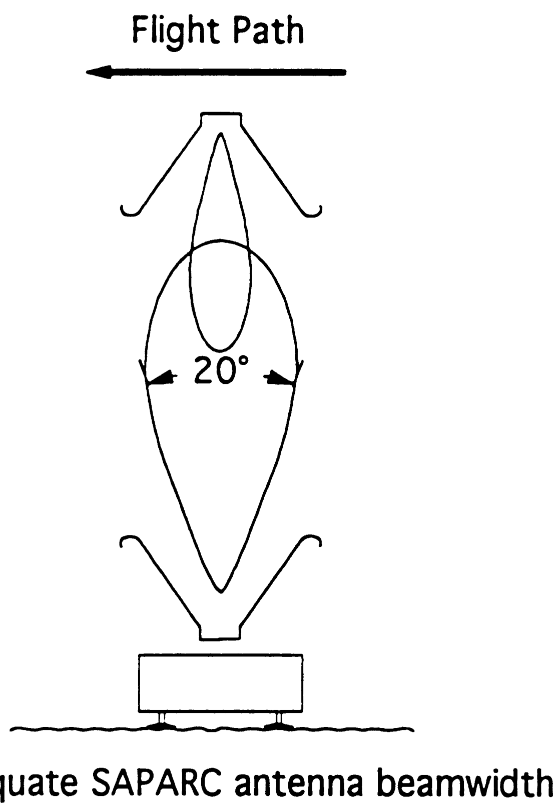
2.2.1 L-Band Antenna Specifications

The goal of the SAPARC's antenna design is to reduce the RF mismatch and cross-talk (i.e. cross polarization generation) while at the same time providing adequate gain, beamwidth, and bandwidth. For the L-band SAPARC, the primary concern of the design was the trade-off between the reciprocal parameters of antenna gain and beamwidth. Physical size and weight were also considered due to the relatively large wavelength of the L-band system.

From a practical point of view, the scattering matrix of the SAPARC must be rather insensitive to orientation angles, i.e. a SAPARC should be immune to possible pointing errors). Thus, one of the design goals is to achieve a two-way antenna beamwidth of around 20°. Note that the relatively large beamwidth ensures a successful calibration even if the SAPARC is not directly within the line of sight of the SAR platform. Figure 2.5 demonstrates pictorially the importance of having a wide antenna beamwidth.

A secondary goal was to reduce the sidelobes radiating from the aperture, thereby minimizing the effect of multipath reflections to and from the SAPARC's ground-based position. Multipath contributions yield inaccurate RCS responses since unwanted electromagnetic energy is effectively being collected by the SAPARC antenna system (see Figure 2.6). The nominal RCS response, however, is measured within an anechoic chamber where multipath contributions are negligible. Hence, measurements taken within anechoic chamber and field environments may differ considerably. Using an antenna with small sidelobes is advantageous in that multipath contributions will be reduced; thus, measurements taken during actual field deployment conditions will more closely resemble measurements taken within the chamber environment.

One of the project's early prototypes incorporated the use of a corrugated horn with a square aperture. Note that corrugated horns generally offer improved performance since they reduce the sidelobes in the antenna pattern. Unfortunately, this prototype yielded a high degree of co-polarized mismatch and extremely poor cross polarization isolation. The concept of employing a dielectric lense was also tried; however, the costs of constructing adequate lenses or custom made corrugated horns became much too



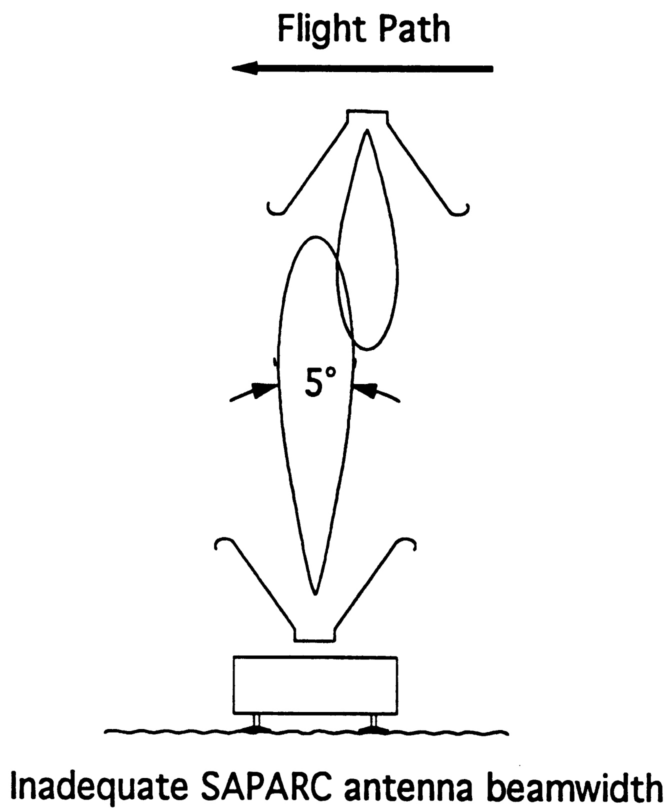


Figure 2.5: Depiction of Adequate and Inadequate Beamwidths for the Tapered Square Horn

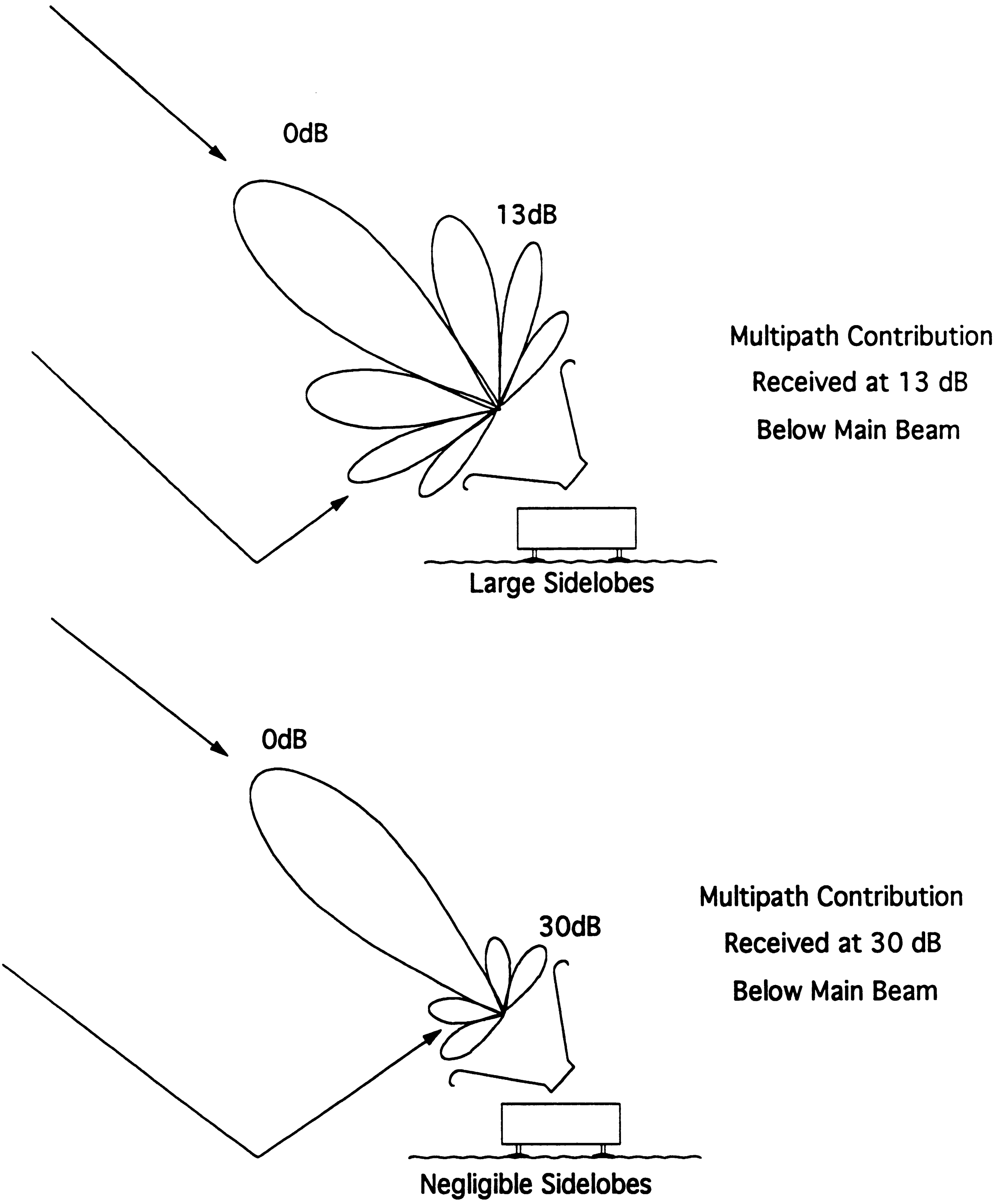


Figure 2.6: Multipath Contribution Scenarios for Horn Antennas With and Without Significant Sidelobes

prohibitive. Therefore, it was decided that the most economically feasible design would forego the multipath considerations.

The physical dimensions of the prototype horn was chosen to be 84.2 cm in length with a square aperture of 36.8 cm by 36.8 cm (1.5λ by 1.5λ). Based on these promising results, a final design was implemented using four equi-length sections flared in 4.5° steps. As shown in Figure 2.4, the overall length of the horn is 86 cm with an aperture of 36.8 cm by 36.8 cm (1.5λ by 1.5λ).
As a final point, the L-band SAPARC employs an OMT designed and fabricated in the Radiation Laboratory of the University of Michigan [2]. The polarization separation is realized in a squared T-junction using wire grids (Figs. 2.7b and 2.7c). The positions of the wires are chosen such that the return-loss and cross-talk are minimum. This device provides cross polarization isolation of better than 40 dB with a return loss less than -18 dB over the frequency range of 1.1 - 1.4 GHz. See Appendix A for the detailed OMT test specifications. Figure 2.7a depicts the completed horn and OMT combination.

2.2.2 L-Band Antenna Performance

From the plots given in Figure 3.6, we can deduce that the antenna system (horn and OMT combination) yields a cross polarization isolation exceeding 32 dB. It should be noted that the maximization of G_{Loop} is dependent upon the level of isolation between the receive and transmit ports on the antenna. Refer to Figure 2.1. From this simple diagram, one can see how a feedback scenario results whenever a small fraction of energy is coupled from the transmit antenna to the receive antenna. The coupled electromagnetic wave is then repeatedly amplified as the energy continues along the feedback loop. Eventually, the coupled energy will increase to a magnitude which saturates the amplifiers. For obvious reasons, this situation cannot be tolerated for a PARC design. Therefore, the antenna system's cross polarization isolation must be large enough to prevent the occurrence of a feedback loop.

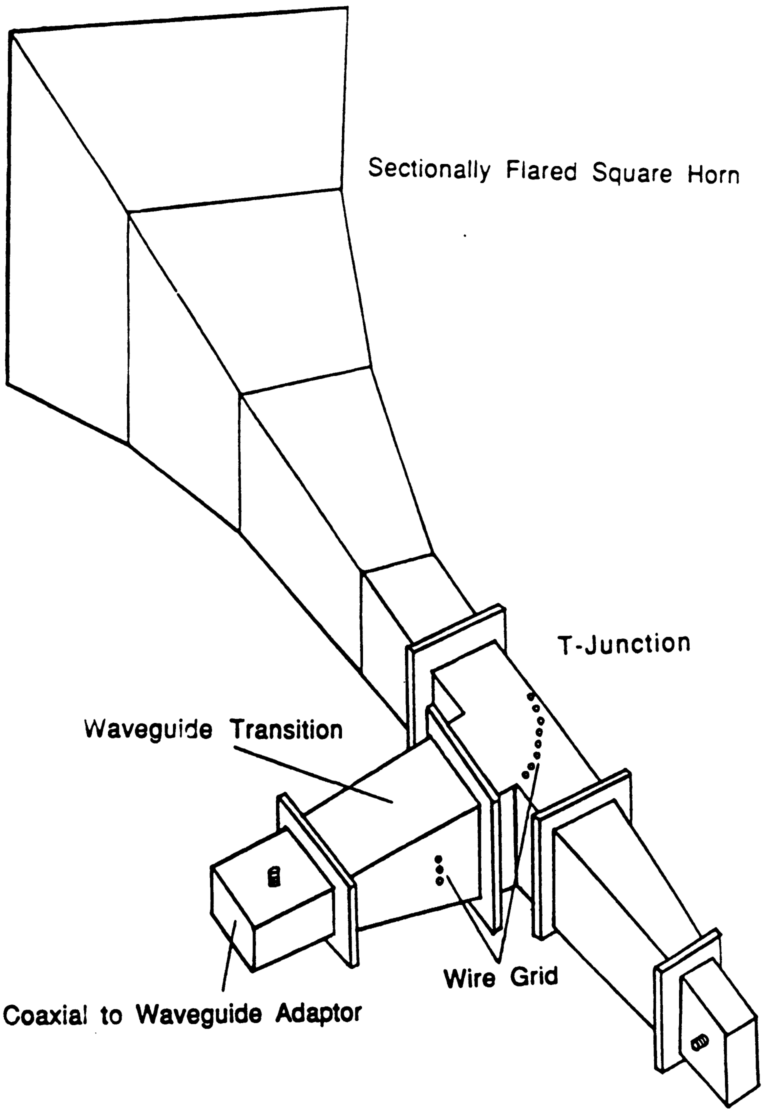


Figure 2.7a: L-band SAPARC Antenna System

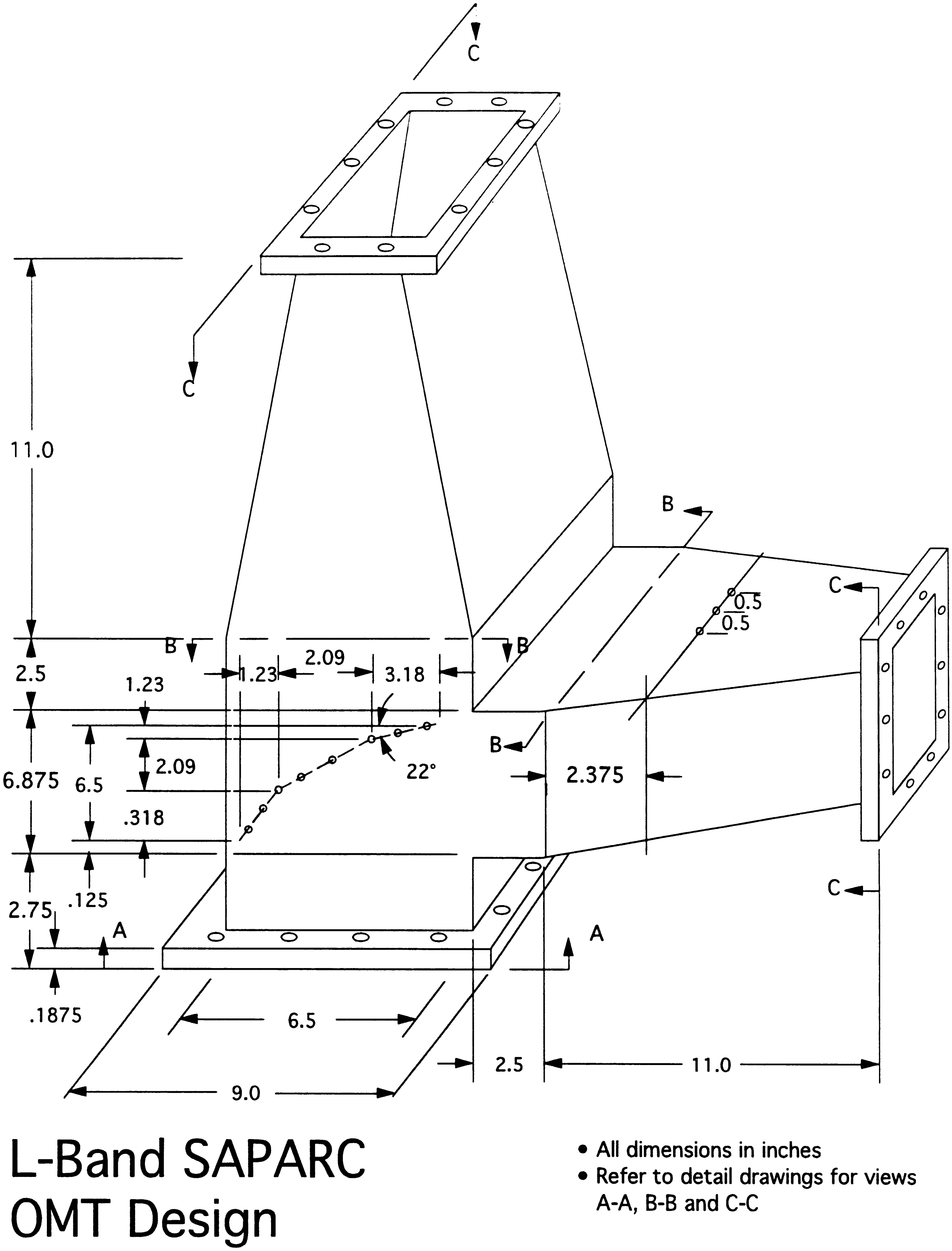


Figure 2.7b: View of the L-band OMT

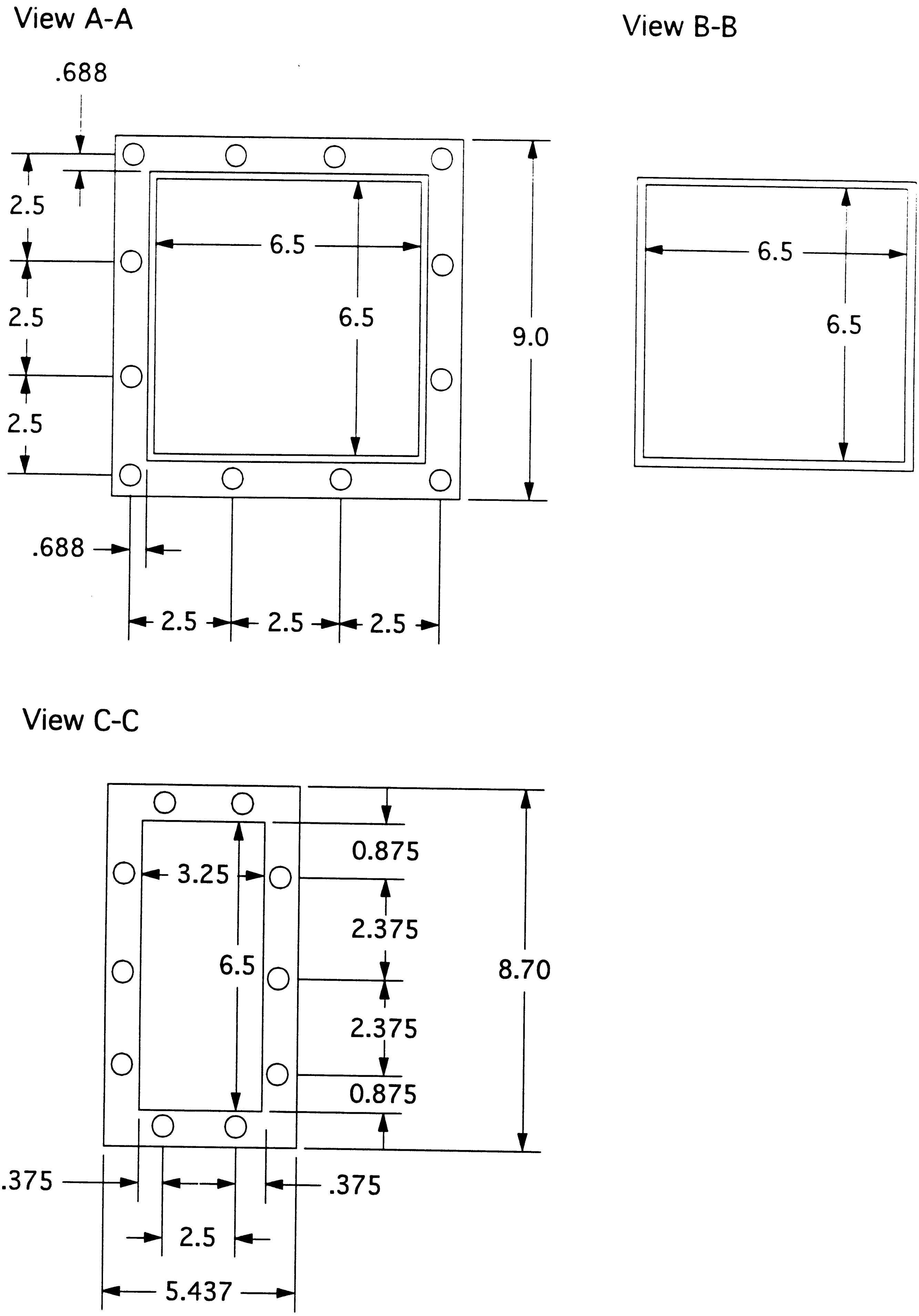


Figure 2.7c: Detail Drawings of the L-band OMT

2.2.3 Summary of Horn Performance

Physical Characteristics		Electrical Characteristics	
Aperture Size:	36.8cm X 36.8cm	Gain:	11.5 dB
Length:	86 cm	2-Way 3 dB	
Weight:	15 lbs.	Beamwidth:	25°
Material:	Aluminum		

Table 2.1: L-Band Antenna System Characteristics

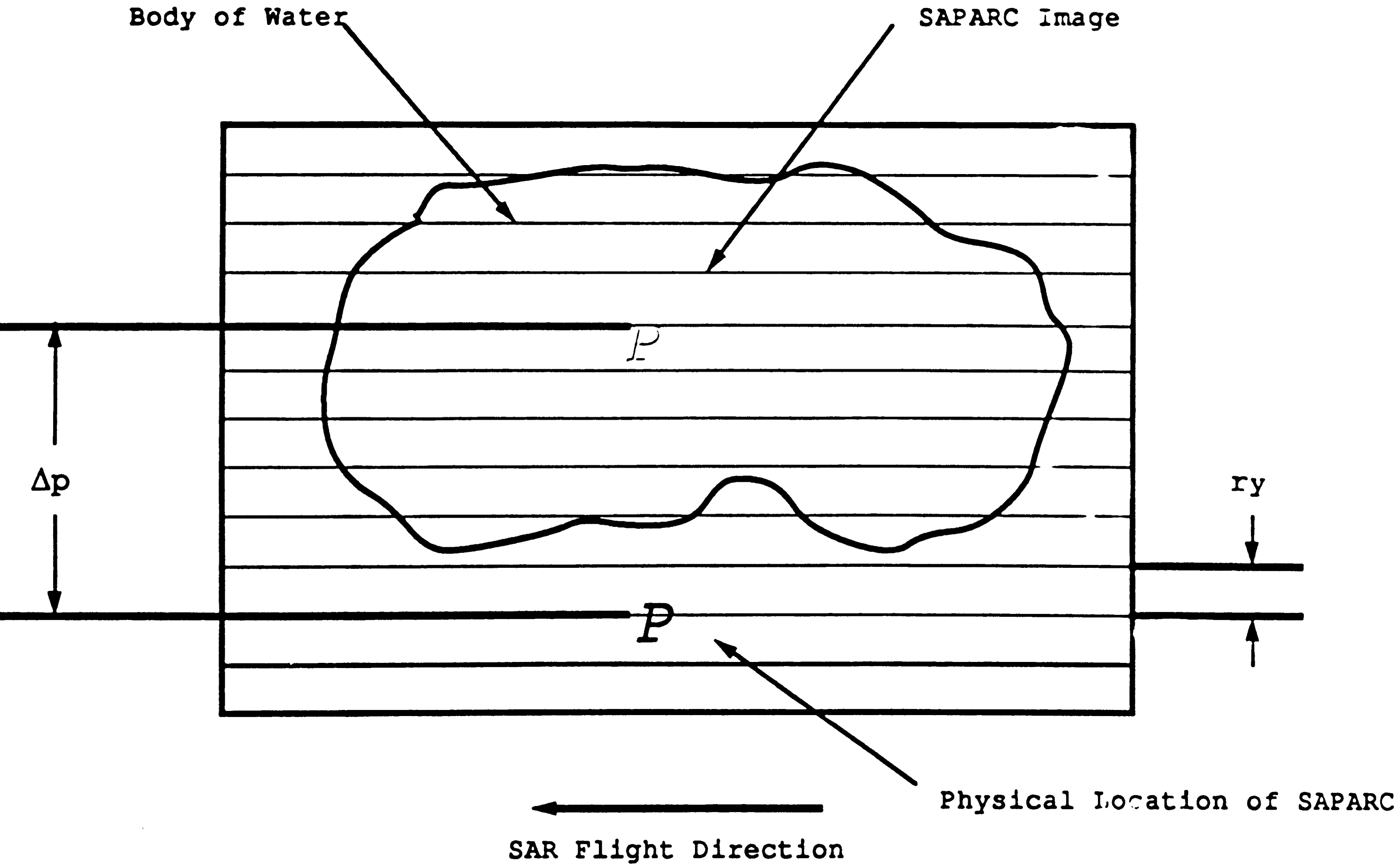
2.3 G_{Loop} Design

2.3.1 Delay Line

At the heart of any PARC system is the G_{Loop} component of the RCS. As mentioned above, a PARC can enhance a calibration measurement by translating its SAR response over a dark background (i.e. a background with a specular surface, such as an airport runway or a large body of water -- See Figure 2.8). This technique is easily implemented by adding a low loss delay line between the receiver and transmitter, as shown in Figure 2.2.

When calculating the length of the delay line, a number of system parameters had to be incorporated in order to insure an adequate SAR delay. The slant range resolution, r_y, is given as 6.67 m for JPL's AIRSAR. As shown in Figure 2.8, the SAPARC should "appear" as if it is situated directly over a body of water. The quantity Δp corresponds to the distance between the physical location of the PARC and its desired SAR image position. An acceptable Δp is approximately 10 pixels (i.e. 10 range bins); therefore,

$$\Delta p = 10 r_y = 66.7m$$



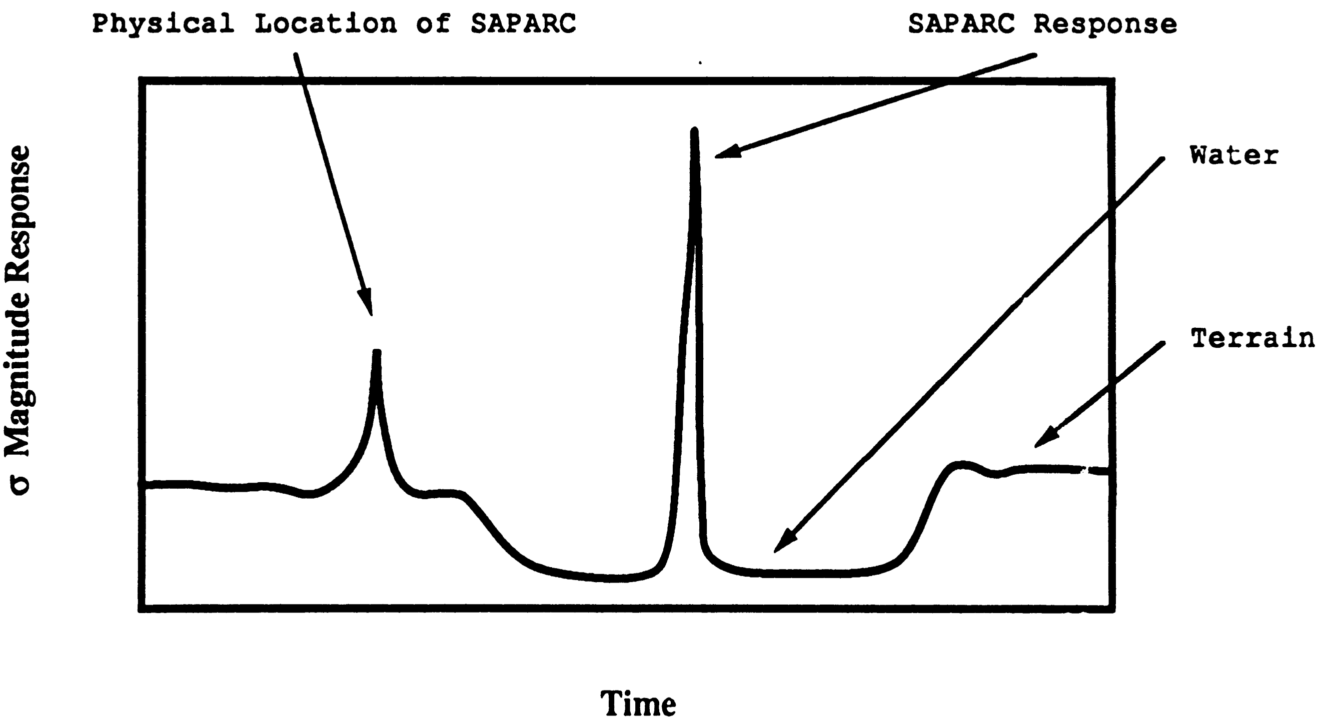


Figure 2.8: The Effects of Placing a Delay Line Within the PARC System

With Δp now known, the delay D can be found through the simple relationship

$$D = \frac{\Delta p}{c}$$

where c is the speed of light in free space. L_{min}, the minimum length of line needed, is

$$L_{\min} = Dv_{coax} = \frac{\Delta p(0.69c)}{c} = 46.02m = 150.99ft$$

Note that v_{coax} is the velocity of the wave within a coaxial medium. The minimum length of line required is approximately 151 feet, yet in actuality, all of the L- and C-band SAPARCs developed for this project use line lengths of 200 feet (therefore guaranteeing a sufficient delay).

At L-band frequencies, the 0.085 inch semirigid microporous coaxial cable (manufactured in 25 ft-long pieces by Precision Tube, Inc.) was used. The total attenuation resulting from the eight 25 ft-long sections was measured with a Hewlett Packard 8510 Network Analyzer, and was found to be approximately 47 dB at 1.25 GHz (see Figure 2.9).

2.3.2 Amplifiers

The role of amplification in a PARC is to increase the RCS of the antenna system and to compensate for the losses associated with the PARC's delay line and other passive components. The amplifier gain of a SAPARC system must be chosen such that the amplifier operates in the linear region. Amplifier saturation may occur for two reasons: 1. saturation due to high levels of input power received from the SAR platform, and 2. saturation due to feedback oscillations. The latter of the two results from a finite receive and transmit channel isolation (determined by the performance of the OMT and horn antenna).

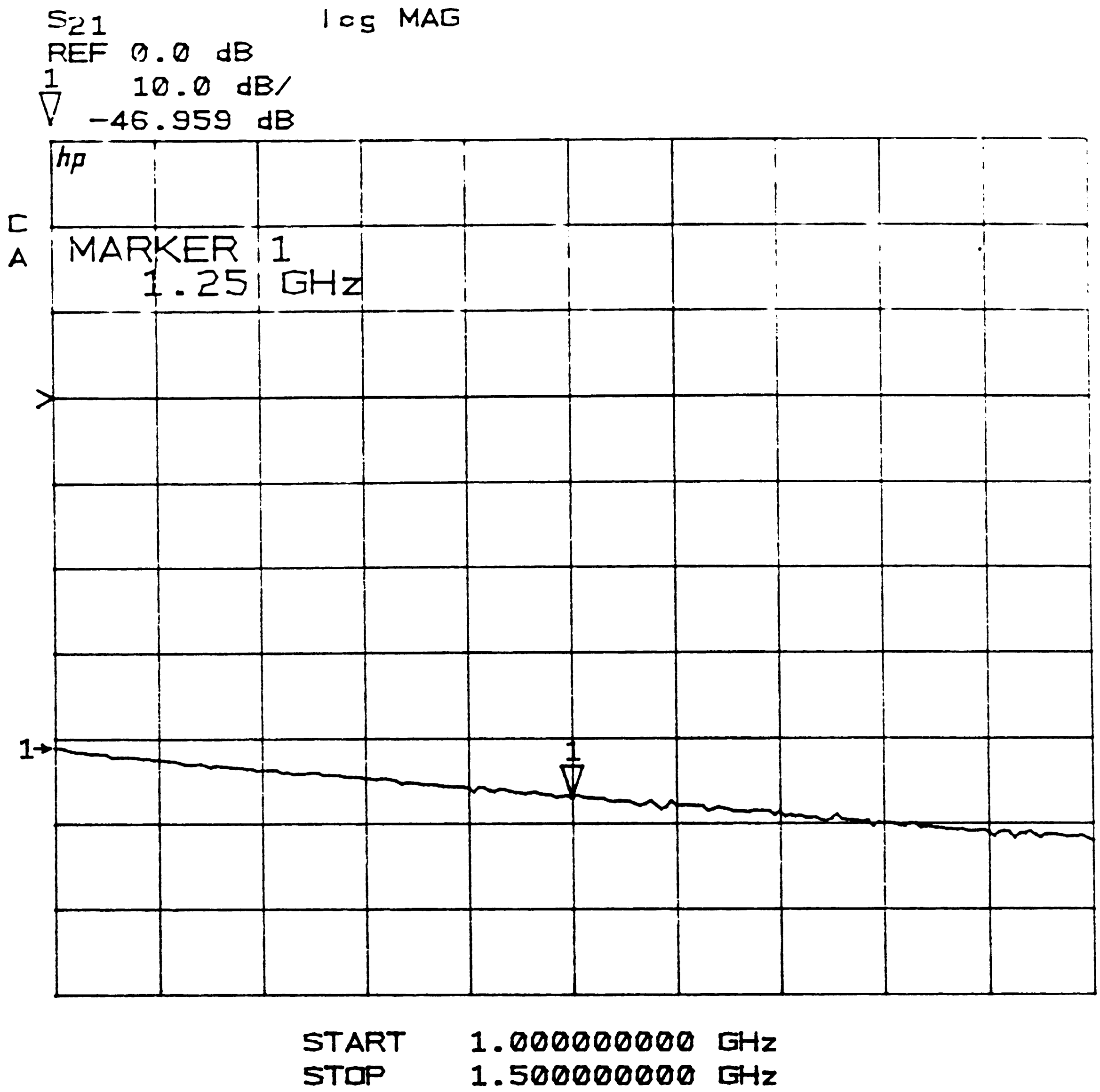


Figure 2.9: S_{21} Frequency Domain Response of the L-band Delay Line at 24°C

2.3.2.1 Input Power Calculations

In order to insure that the amplifiers would not be saturated by the received RF, a number of preliminary calculations were made using the Friis transmission formula and known system parameters for JPL's AIRSAR and NASA's Shuttle Imaging Radar (SIR-C). Tables 2.2 and 2.3, respectively, summarize the JPL AIRSAR and NASA SIR-C parameters.

Peak Power	P_t = 6 kW (67.8 dBm)
Wavelength	λ = 0.24 m
Antenna Gain	G = 18.3 dB
Altitude	15,000 - 40,000 ft (4,572 - 12,192 m)
Incidence Angles	20° - 70°
Pixel Resolution	3.03 m or 12.01 m (1 or 4 Look Azimuth)
	6.67 m (Slant Range)

Table 2.2: JPL AIRSAR Parameters

Peak Power	P_t = 4.45 kW (66.5 dBm)
Wavelength	λ = 0.24 m
Antenna Gain	G = 18 dB
Altitude	200 - 225 km
Incidence Angles	15° - 55°
Pixel Resolution	10 - 60 m Range Resolution

Table 2.3: SIR-C Parameters

For JPL's AIRSAR system, the following Friis transmission calculations are applicable. Figure 2.10a depicts the geometry of a typical fly-by, where h is the height of the platform and R is the corresponding range (i.e. distance between the SAR and the calibration unit). The values used in this calculation are for the "worst case" scenario with respect to possible amplifier saturation. Therefore, the dimensions correspond to the case where the maximum amount of power will be received by the SAPARC

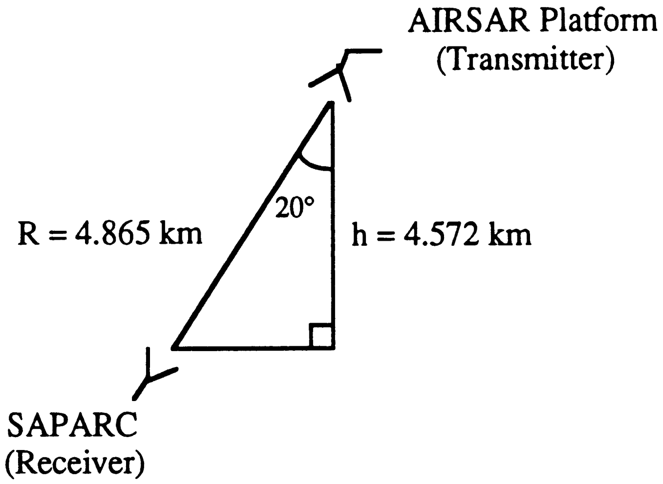


Figure 2.10a: JPL AIRSAR Fly-by Geometry

The general form of the Friis transmission formula is

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

whereas

$$R = \frac{h}{\cos(\theta)} = 4.8654km$$

$$P_T = 6KW = 67.8dBm$$

$$\left(\frac{\lambda}{4\pi R}\right)^2 = \left(\frac{0.24m}{4\pi(4865.4m)}\right)^2 = -108.1dB$$

$$G_T = 18.3dB$$

$$G_R \approx 11.5dB$$

Therefore, the maximum input power received by the first stage amplifier will be

$$P_R = 67.8 + 18.3 + 11.5 - 108.1 = -10.5dBm$$

Similarly, NASA's SIR-C system, shown in Figure 2.10b, will yield the following results.

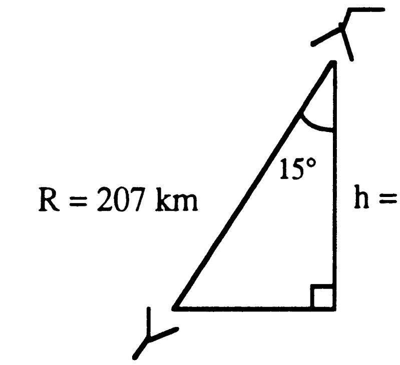


Figure 2.10b: NASA SIR-C Fly-by Geometry

The Friis transmission formula gives

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

whereas

$$R = \frac{h}{\cos(\theta)} = 207.05km$$

$$P_T = 4.45KW = 66.5dBm$$

$$\left(\frac{\lambda}{4\pi R}\right)^2 = \left(\frac{0.24m}{4\pi(207.05km)}\right)^2 = -140.7dB$$

$$G_T = 18dB$$

$$G_R \approx 11.5dB$$

Therefore, the maximum input power received by the first stage amplifier will be

$$P_R = 66.5 + 18.0 + 11.5 - 140.7 = -44.7 dBm$$

The gain of the first stage amplifier (i.e. the pre-amplifier) is about 45.6 dB (see Appendix B). Hence, the first stage amplifier must be capable of producing the following output power levels in order to insure operation within the linear range of the amplifier.

$$AIRSAR\ P_{out} = P_R + G_{preamp} = -10.5\ dBm + 45.6\ dB = 35.1\ dBm$$

$$SIR\text{-}C\ P_{out} = P_R + G_{preamp} = -44.7\ dBm + 45.6\ dB = 0.9\ dBm$$

As shown in Figure 2.2, an additional attenuator of 20 dB was added to the front end of the pre-amplifier as an extra precaution to deter possible saturation during AIRSAR calibrations. Figure B-1 shows the gain of the pre-amplifier at 24°C.

Adding an attenuator "in front" of the amplifier degrades the signal to noise ratio; however, in this case, the signal level is much higher than the thermal noise, thus the effect of the additional attenuator is negligible. As will be pointed out in the next section, the noise inherent within the loop can lead to internal oscillations. Therefore, minimizing the noise will theoretically lead to a maximization of G_{Loop}. Yet, in light of the seriousness of amplifier saturation, it was agreed that the benefits resulting from this potentially lower noise performance could not outweigh the assurance that the pre-amplifier is operating within its proper linear range.

2.3.2.2 Feedback Oscillations

An equally serious problem can arise when the system is driven into a state of feedback oscillation. Section 2.3.2.1 alluded to the fact that noise inherent within the system can be amplified just as easily as any incoming RF signal. Oscillations result whenever the amplified noise exceeds the isolation of the antenna system. For the L-band SAPARC design, the net G_{Loop} gain must not exceed 32 dB (the antenna system's cross polarization isolation).

Since G_{Loop} must be less than 32 dB, it follows that

$$G_{Loop} = G_{Amp} + L_{Line} < 32\ dB$$

where L_{Line} is the loss from the delay line, component insertion, and flexible cables. Rearranging this equation gives

$$G_{Amp} < 32\ dB + L_{Line} = 32\ dB + 47\ dB + 2.2\ dB + 1.8\ dB$$

Therefore

$$G_{Amp} < 83\ dB$$

Due to the relatively high loss of the delay line, a second amplifier is needed to help boost the signal before it is transmitted back to the SAR platform. As was done with the preamplifier, care must be taken to insure that the second stage amplifier is not driven into saturation. Figure B-2 shows the gain of the power amplifier at 24°C.

2.3.3 Attenuation Switches

The principle goal of the attenuation switch (see Figure 2.2 and Appendix C, pg. C-6) is to reduce the loop gain thereby allowing the SAPARC to be used for both JPL AIRSAR and NASA SIR-C missions with the maximum allowable RCS. As pointed out in Section 2.3.2.1, JPL's AIRSAR, which flies at significantly lower altitudes than SIR-C, has a correspondingly higher risk for saturating the SAPARC's amplifiers. Conversely, an excessively large G_{Loop} can lead to the saturation of the SAR platform's own receiver.

Note that the results shown throughout this report reflect the SAPARC's operation within the SIR-C mode. Similar results can easily be found for the AIRSAR case by simply subtracting 20 dB from the overall SIR-C RCS measurements.

2.3.4 Notch Filter

It was found that the system would slip into a feedback oscillation with SIR-C mode at about 990 MHz. Since the frequency of 990 MHz is outside of the frequency band of the system (1.1 - 1.4 GHz), a notch filter was inserted at the outgoing port (See Fig. 2.2) to elliminate the feedback oscilation at 990 MHz. The notch filter consists simply of a half-wavelength short stub of a rigid coaxial cable. Figure 2.11 shows the frequency response of the notch filter. The insertion loss at 1.25 GHz is about 0.8 dB and the attenuation at 990 MHz is about 17 dB as shown in Fig. 2.11.

2.4 Control and RF Detection Circuitry

The control and RF detection circuitry serves a two-fold purpose. First, it provides the necessary switching and timing functions for the various power loads; secondly, the circuits display the operating status of the entire system, thereby alerting the user of changes in battery capacity and calibration readiness. The system is comprised of three major components: the Control Printed Wiring Assembly (PWA), the Detection PWA, and the Control Panel. A more detailed description of each of these subsystems is given in the following sections.

2.4.1 Control Circuitry / Control Panel

The single antenna PARCs developed through this project feature custom made control and detection circuits. The features of the control circuitry are as follows:

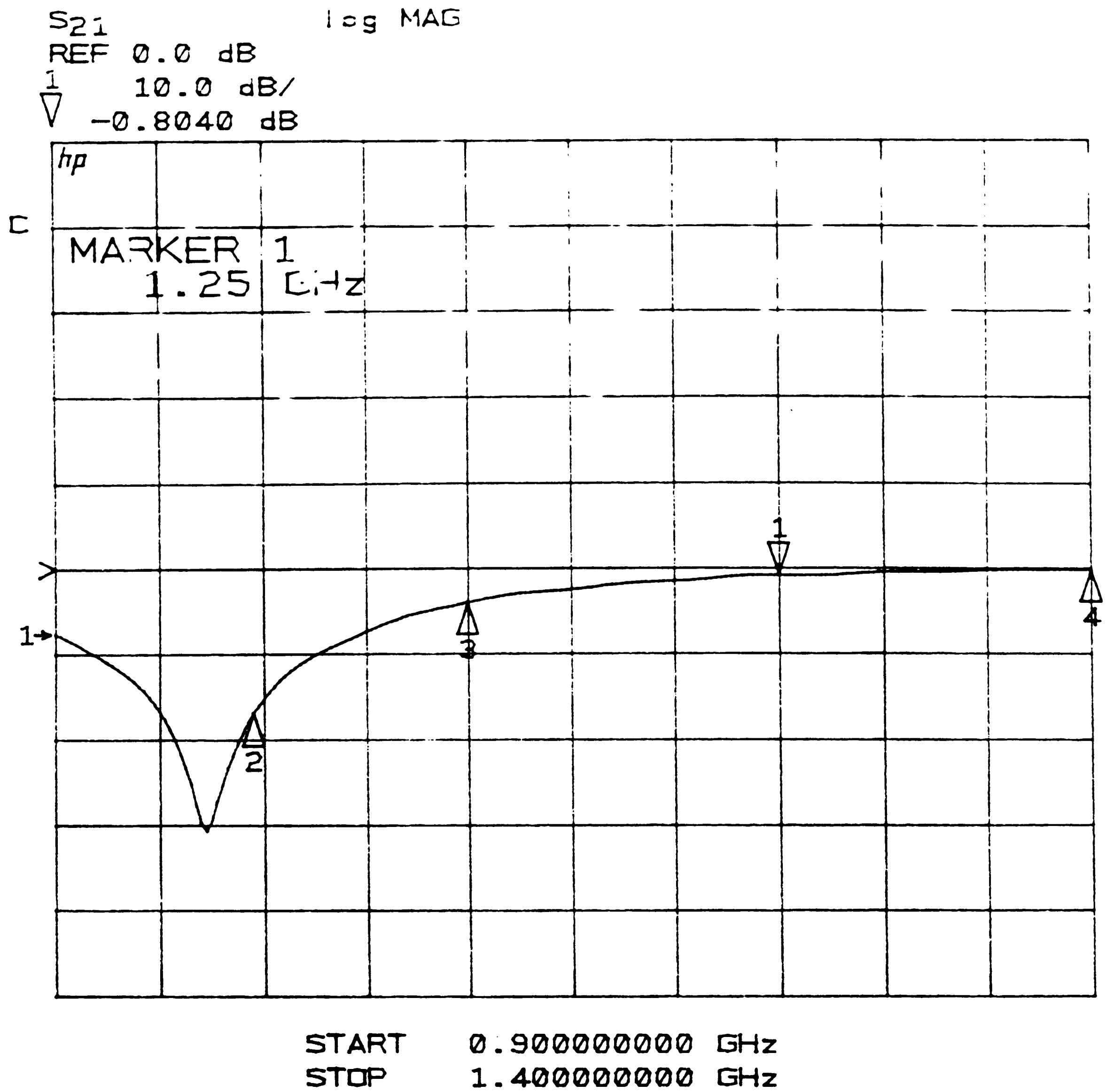


Figure 2.11: Frequency Response of the Notch Filter

- LED Battery Power Monitor
- Battery Over-discharge Protection
- Automatic System Activation Timers
- Voltage Regulation
- Auxiliary Switching Capability
- External Source Hook-up
- Recharge Ports for Internal Sources
- Easy Detachability for Maintenance

Most of the circuitry (for the functions listed above) is mounted on the Control PWA. This board was designed with EE Designer, a PWA layout software package which can be run on most IBM pc's. The PWA was then manufactured by L. Ross industries in Ann Arbor. (See Figures 2.12 and 2.13).

As a final note, the entire Control PWA / Detection PWA combination can be removed from the system chassis by disconnecting the 50 - pin connector. Before doing so, however, it is advised that the user first disconnect the internal supplies by removing the 7A fuses; the "BATTERIES" switch must then be turned on, and the "POWER RESET" button depressed (for 10 seconds) so that all residual charge held by the internal capacitance of the system can be safely discharged. (See Figure 2.14 and 2.15, both of which depict the front control panel).

2.4.1.1 LED Battery Power Monitor

The LED display mounted on the control panel is driven by a differential amplifier circuit which monitors the gradual drop in voltage of each separate lead acid battery (see Appendix C, pg. C-3). Preliminary tests showed that this drop is a linear function of time, whereby the safe operating range exists between $10V \leq V \leq 12.5V$ (refer to the battery operating curves given in Figures 3.13, 3.14, and 3.15). The entire system becomes fully loaded whenever the LED display is activated, thus yielding a more accurate measurement of the battery's remaining capacity. Note that under room temperature conditions, the Yuasa 7 A·hr 12V batteries can operate for up to 5.5 hours (under a full load of 1.2A) before the lower operating voltage threshold is reached. Colder temperatures will significantly limit this capacity; at -10°C, the system can only operate for 4.5 hours before the same lower threshold causes the system to shut down.

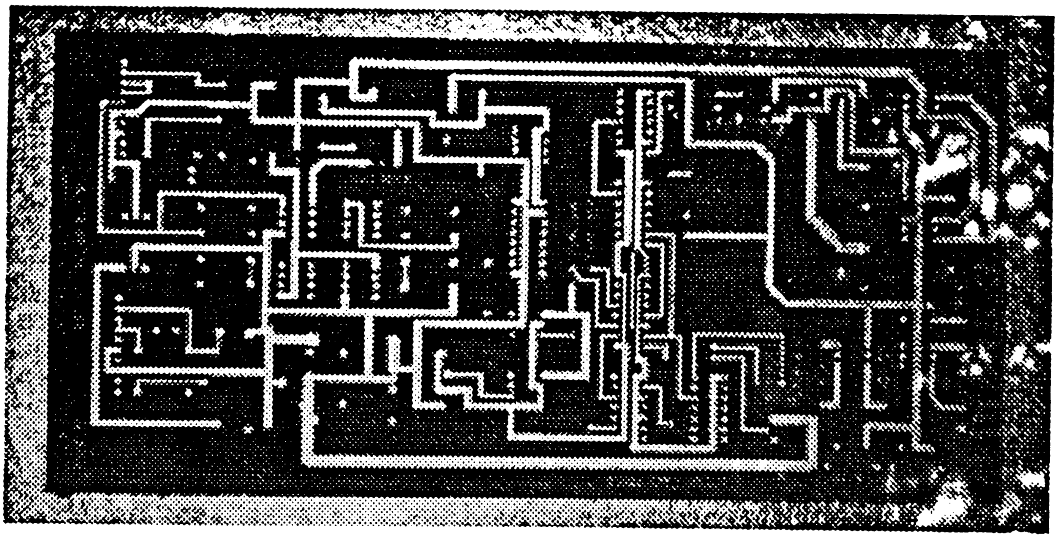


Figure 2.12: SAPARC Control Printed Wiring Assembly (Unstuffed)

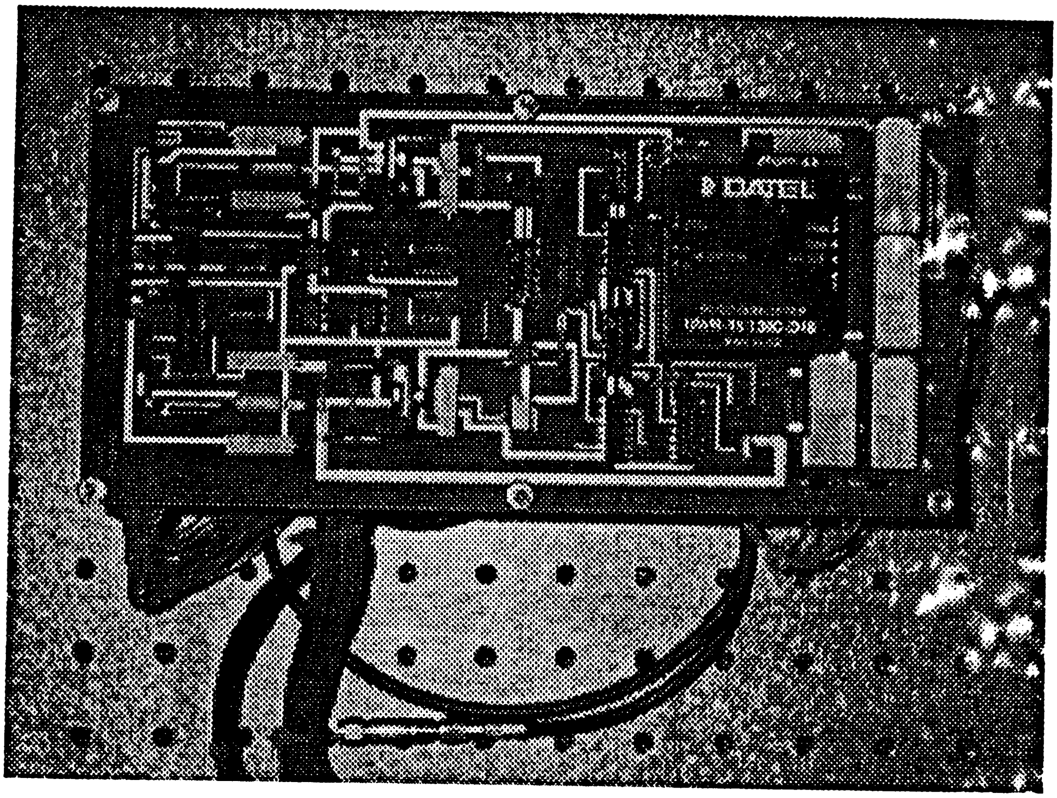


Figure 2.13: SAPARC Control Printed Wiring Assembly (Stuffed)

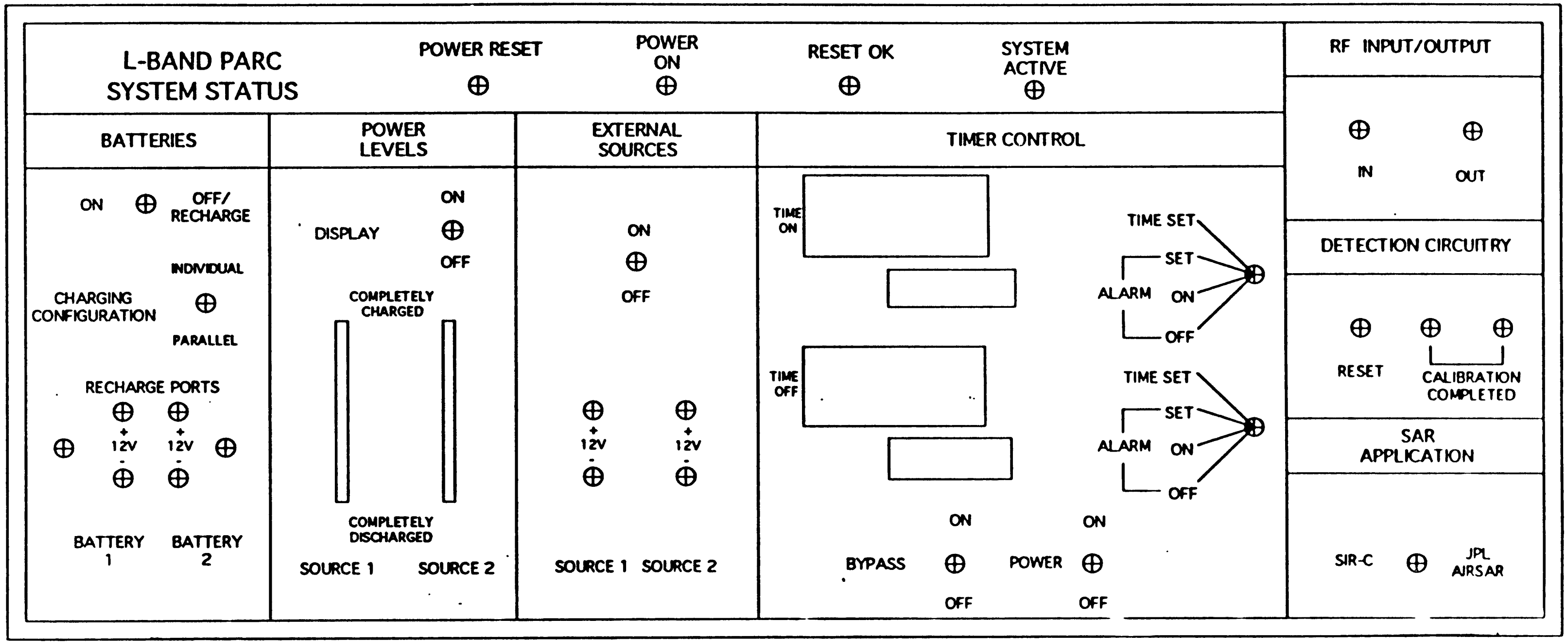


Figure 2.14: Blueprint of the SAPARC Front Control Panel

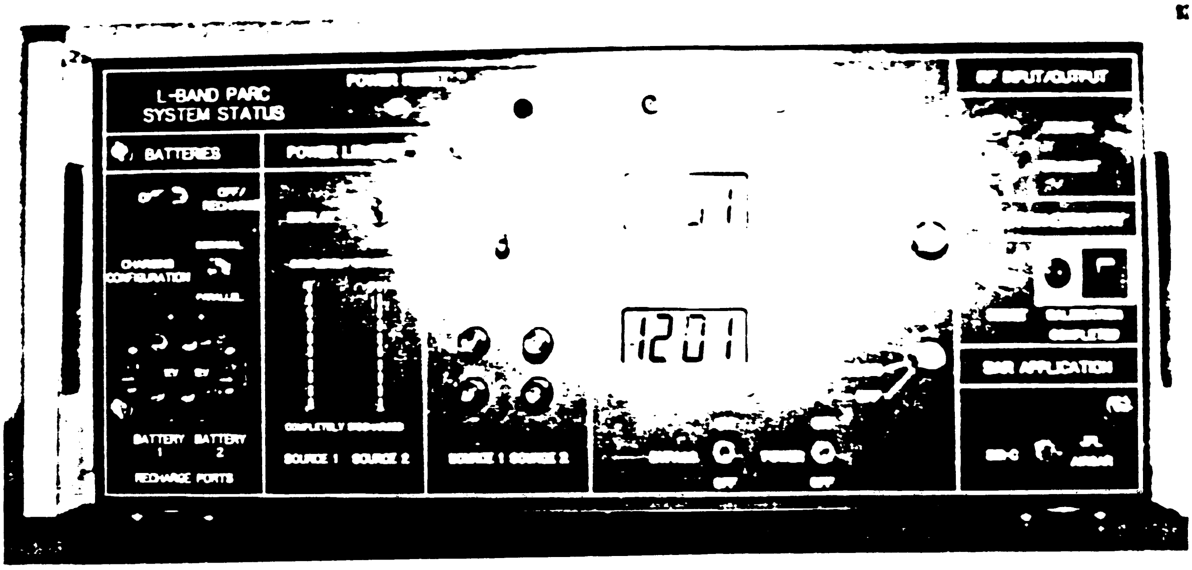


Figure 2.15: SAPARC Front Control Panel

Figure 2.16: Internal Components of the L-band SAPARC Unit

The LED display is currently set to measure a voltage range of $10.5V \leq V \leq 12.5V$ for each supply. This range can be adjusted for supplies 1 and 2 by tweaking the potentiometers R8 and R17, respectively.

2.4.1.2 Battery Over-discharge Protection

In conjunction with the LED bar graph display, the discharge protection circuitry similarly monitors the supply voltages through the use of comparitors (see Appendix C, pg. C-4). When the lower voltage threshold is reached (i.e. 10V), power to the entire system will be shut off, thus protecting the lead acid batteries from excessive discharging. (The battery's capacity is severely degraded whenever this lower voltage threshold is exceeded for extended periods of time.) This lower threshold can be easily adjusted by tweaking potentiometers R3 and R15 (for supplies 1 and 2, respectively).

2.4.1.3 Automatic System Activation Timers

The system's built-in activation timers can control the operation interval for the SAPARC. In almost all practical situations, the SAPARC needs to be on for a relatively short period of time which can be programmed using the activation timers, thus prolonging the SAPARC's use by conserving battery capacity (see Appendix C, pp. C-5-6). Two separate clocks are used: one for activating the high load components, and one for deactivating the entire circuit. The wiring design consists of a number of buffers and opto-isolators which connect the output of the timers (i.e. piezo-electric connections) with the rest of the control circuitry. Note that these connections were made with shielded 20 gauge wire; the first prototype, which did not use shielded wire, experienced occasional transient responses resulting from the switching of the high load components (e.g. amplifiers etc.). Proper shielding and the use of opto-isolators eliminated this problem altogether.

The timer activation mode can be bypassed for manual operation as well. In the manual mode, the system loads are all activated for immediate and constant operation, thus making this mode ideal for testing purposes. When deploying the SAPARC within a field environment, one should use the bypass in order to insure that the system cannot be driven into a feedback state. Feedback oscillations will occur whenever an object is placed within the SAPARC's antenna beam pattern. Hence, a low-lying tree branch or other similar object may drive the system into an oscillation state. Using the bypass allows the user to "see" if any objects are within range of causing such problems. If the system can operate correctly in the bypass state, then the user will have confidence that the SAPARC will also work while in the automatic mode.

As a last note, the activation timers are independently powered by small cell 1.25V batteries. These cells can be easily replaced by removing the top cover on the SAPARC chassis. A small plastic cover on the clock units must also be removed in order to gain access to the battery compartments.

2.4.1.4 Voltage Regulation

The various subsystems within the SAPARC require supply voltages of ±15V, ±8V, and +5V. The +5V and ±8V regulation is performed by basic 7800 series regulators, whereas the ±15V modes are supplied from DC-DC converters (one on the Detection PWA, and the second on the Control PWA - see Appendix C, pp. C-3,4, and 7). The +15V DC-DC converter possesses an efficiency of greater than 80%; hence, the converter outperforms conventional voltage regulation by a considerable margin (i.e. in terms of efficient power use). It should also be noted that conventional regulators cannot supply the relatively large amount of current which is required for the operation of the amplifiers and other possible auxiliary loads.

2.4.1.5 Auxiliary Switching Capability

As mentioned above, the Control PWA is configured so that additional loads can be added (and thus controlled) as the user sees fit (see Appendix C, pg. C-2). The voltage output for these auxiliary ports includes ±15V and +24V. Possible loads include recording devices which can monitor the RF power levels received during SAR fly-bys, thereby providing a means for measuring the pattern of the SAR's illuminating footprint.

The Detection PWA does provide a correlation between detected RF and a specific DC output voltage. This capability may be utilized for use with recording devices. Heaters can also be connected to this circuit; however, testing has shown that their use is of little value for reliable temperature stabilization. (See section 2.5).

2.4.1.6 External Source Hook-up

The user can bypass the internal battery supplies by employing the use of the external hook-up jacks located on the front control panel (see Figures 2.14 and 2.15, as well as Appendix C, pg. C-1). If external sources are to be used, simply flip the "EXTERNAL SOURCES" switch to the ON position. Hit the "POWER RESET" pushbutton and continue the system operation in the normal fashion. As a final note, **DO NOT CONNECT THE GROUNDS FROM THE EXTERNAL BATTERIES TOGETHER.**

2.4.1.7 Recharge Ports

The user can also recharge the internal batteries via the recharging ports located on the front control panel (see Figures 2.14 and 2.15, as well as Appendix C, pg. C-1). Two different port types are provided for the support of varying recharging devices. When recharging, have the "BATTERIES" switch in the OFF / RECHARGE position. The "CHARGING CONFIGURATION" switch permits the user to charge the batteries individually or together in a parallel mode.

2.4.2 Detection Circuitry

The Detection PWA was acquired from an existing two-antenna PARC system developed by Applied Microwave (see Appendix C, pg. C-7). This subsystem monitors the power levels which exist at the output of the power amplifier. The threshold for this detection has been set low enough ($P_{min\ detection}$ = -48.6 dBm) so that oscillations as well as SAR fly-bys can be recorded. In the original circuit design, a detection would illuminate a small red bulb; in addition to this, a .25A circuit breaker switch (which serves as a permanent recording device) has been added to signal the user that a successful calibration is complete. Note that the circuit breaker takes approximately 60 seconds to trip once a detection is made.

When deploying the SAPARC, the user must be certain that feedback oscillations will not occur during the calibration. Therefore, one must always monitor the detection lamp during final setup preparations. (Recall that the SAPARC system is extremely sensitive to adjacent objects which may reside within the antenna's beamwidth. These objects include nearby bushes, tree limbs, etc.). If a feedback scenario is present, simply press the RESET to clear the Detection PWA circuitry. Continue to re-position the SAPARC as needed so that no errant detections are made.

2.5 Temperature Stabilization

During the initial design phase, one of the primary goals was to develop a system which was insensitive to changes in the ambient temperature. It was assumed that the most sensitive devices would be those which are active, namely the preamp and power amp. To this end, a 24W hybrid heater had been placed on the amplifier combination. Unfortunately, the temperature stabilization tests showed that the most sensitive device was the passive delay line, and not the amplifiers as first suspected (Refer the test results reported in the report for C-band SAPARC [6])

Temperature stabilization would require either a number of high power heaters or a variable attenuator / gain feedback circuit. The former of these alternatives is somewhat impractical since it would require excessive amounts of battery power. Similarly, the latter option is too expensive for a practical implementation.

An acceptable solution requires a mapping of the G_{Loop} component of the RCS as a function of temperature. Such a mapping is shown in Section 3.3. The goal, then, is to accurately record the system's temperature during an actual field test. The temperature (recorded as a function of time) will then be compared to the G_{Loop} vs. Temperature chart from Section 3.3.

Hence, an accurate description of the system's total RCS can be calculated for the exact fly-by time of the SAR platform.

An automatic measurement is obtained through the use of a Dickson 24-hour Temperature Recorder. This device is nestled within the delay line loop located at the base of the SAPARC chassis. For an actual field deployment scenario, the user must activate the temperature recorder while noting the exact time of initial operation. Once this is done, the user is free to leave the deployment area while the rest of the equipment remains in its automated mode.

2.6 Assembled Prototype

Figures 2.17a and b show how to attach the OMT unit to a tripod. Figures 2.18 a and b show the SAPARC in its completed state for 0° and 45° orientations, respectively. Note how the horn antenna is detachable for quick and easy transport of the device.

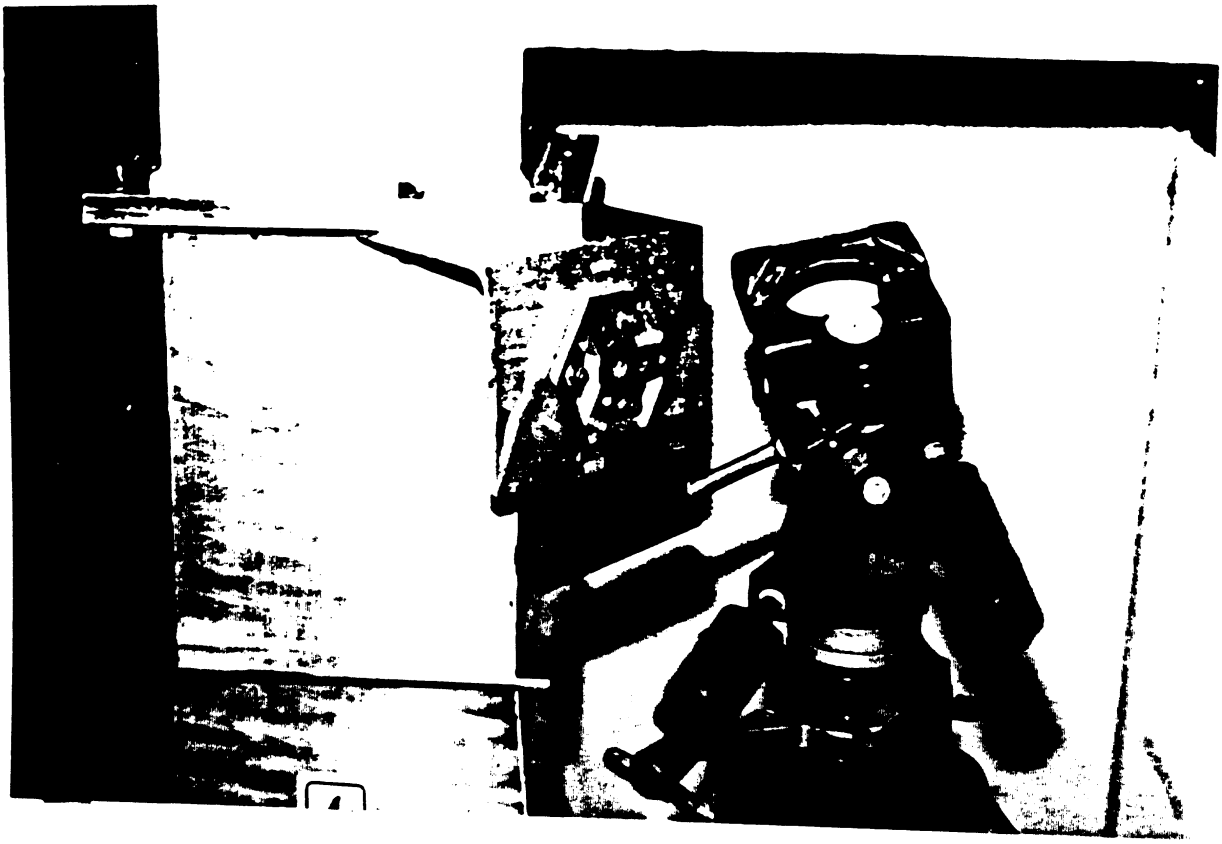


Figure 2.17a: Disassembled L-band Antenna Unit and Support

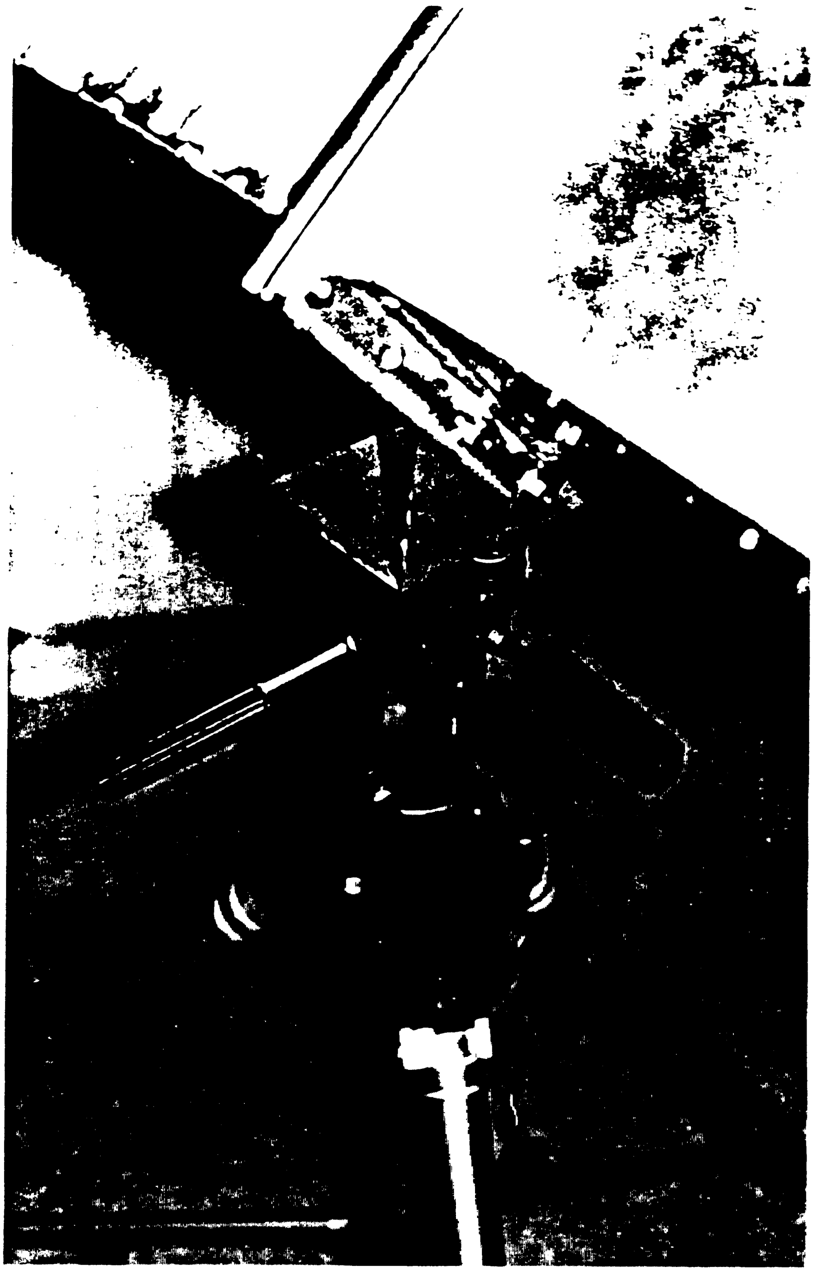


Figure 2.17b: Assembled L-band Antenna Unit and Support

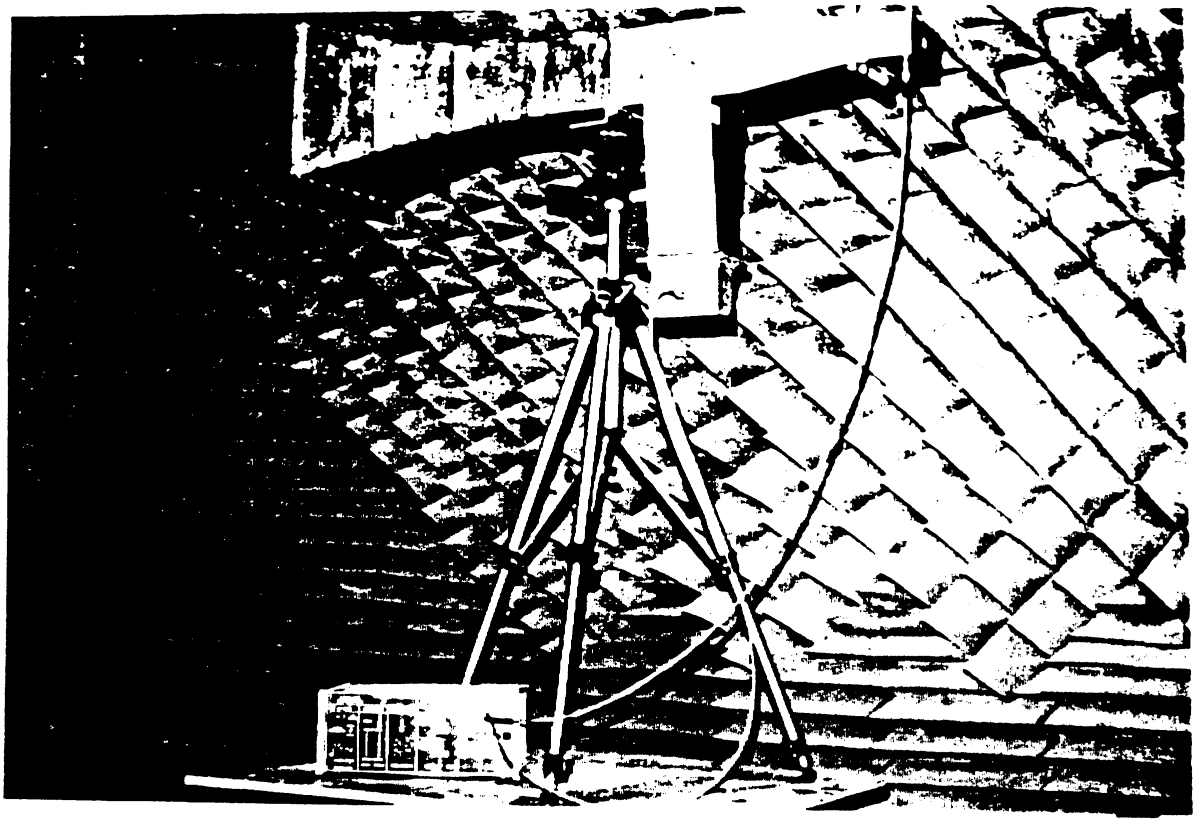


Figure 2.18a: Fully Assembled L-band SAPARC for the 0° Antenna Orientation

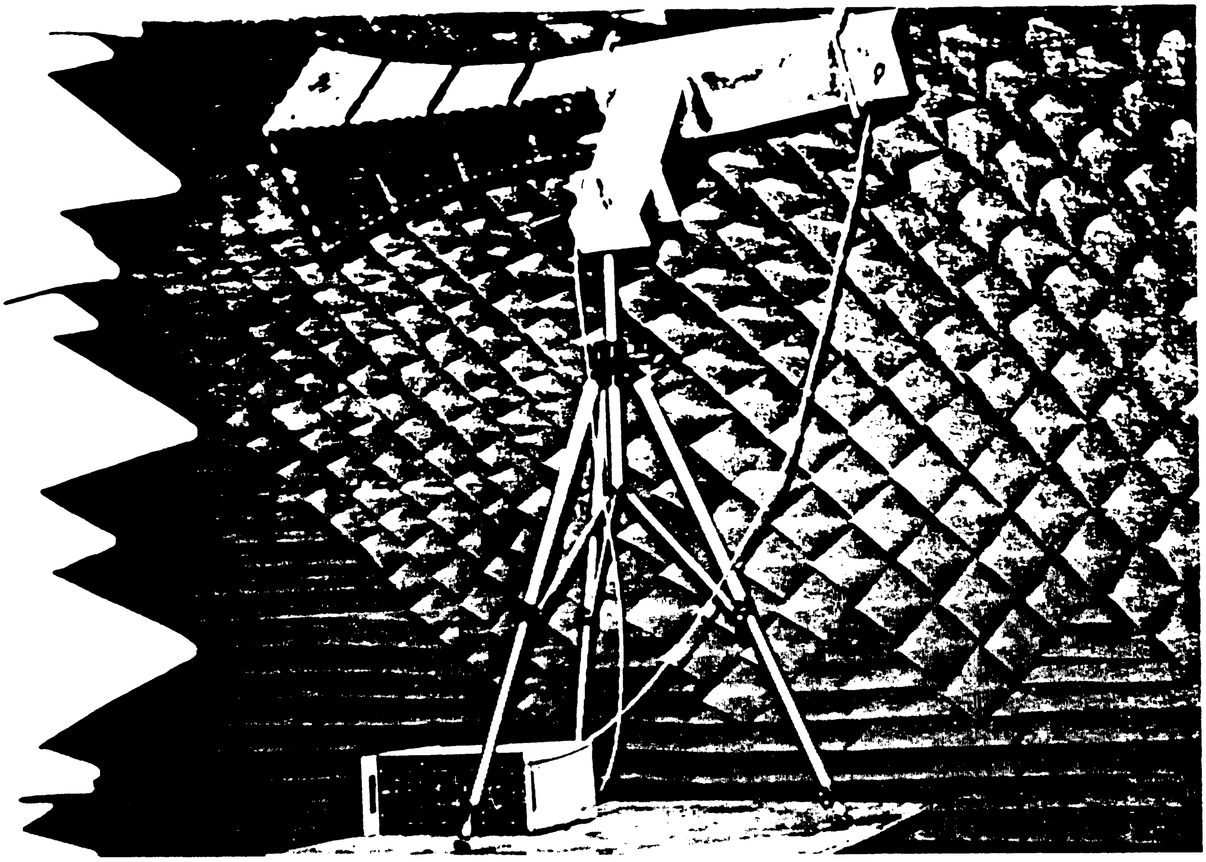


Figure 2.18b: Fully Assembled L-band SAPARC for the 45° Antenna Orientation

CHAPTER III

EXPERIMENTAL RESULTS

As mentioned in Chapter 1, the accuracy of a SAR calibration is highly dependent upon the measured performance of the calibration device. Hence, the measurements taken in accordance with this project must adhere to the following goals:

- Accurate measurement of the scattering matrix for the 0° and 45° antenna orientations.

- 0.2 dB accuracy in the mapping of the thermal gain variations.

- Overall characterization of SAPARC performance with respect to field deployment conditions, including extremes in temperature, all-weather performance, and battery capacity.

3.1 G_{Loop} Measurements

Figure 3.1 depicts the S_{21} frequency responses of G_{Loop} for room temperature operation (24° C). For this measurement, a 40 dB attenuator was placed on the receive channel of the SAPARC in order to prevent amplifier saturation. From these measurements, G_{Loop} is found to be 43.14 dB at 1.25 GHz. However, as section 3.3 will show, G_{Loop} is highly dependent upon the SAPARC's operating temperature. To find the correct value of G_{Loop} for each SAR calibration, one must refer to the thermal variation chart shown in Figure 3.12.

The SAPARC anechoic chamber tests were performed at room temperature

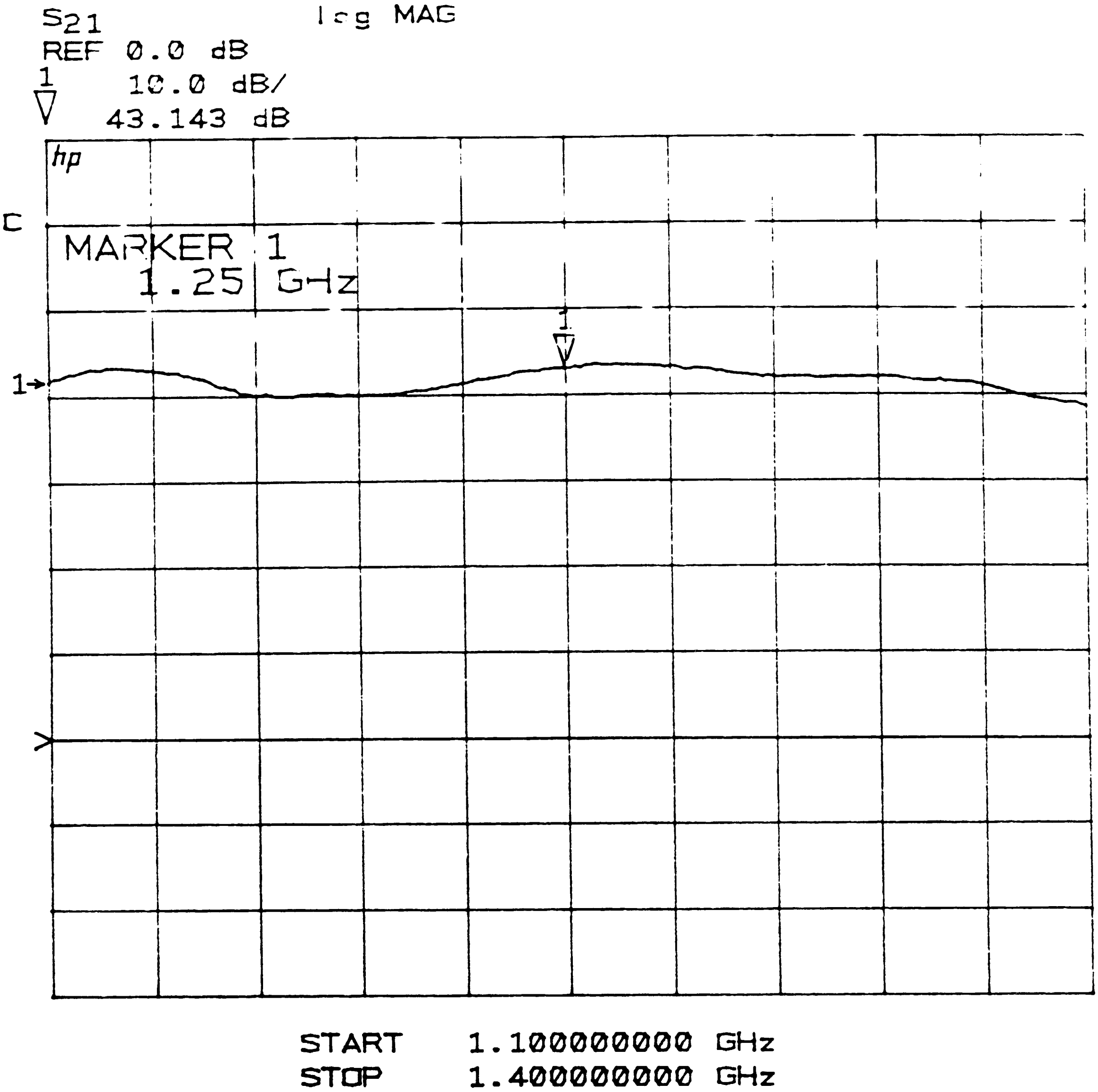


Figure 3.1: Frequency Domain Response of G_{Loop} at 24°C

(approximately 20° C). Figure 3.6 (SAPARC RCS for the 0° Orientation) shows that the maximum achievable value for the RCS is 42.6 dBsm. Using this data in conjunction with the theoretical equation given in section 2.1, the gain of the L-band antenna system is found to be 11.5dB. The following calculations demonstrate this result.

$$\sigma = G_{Loop} \frac{G_T G_R \lambda^2}{4\pi} L_{cable}$$

where

$$L_{cable} = -1.8dB$$
$$\sigma \approx 42.6dBsm$$
$$G_{Loop} = 44.8dB$$
$$G_T = G_R = G_{Antenna}$$
$$\frac{\lambda^2}{4\pi} = \frac{(0.24m)^2}{4\pi} = -23.4dB$$

Rearranging the equation gives

$$G_{Antenna} = \sqrt{\frac{\sigma}{G_{Loop}\frac{\lambda^2}{4\pi}L_{cable}}} = \frac{1}{2}(42.6dBsm - 44.8 + 1.8dB + 23.4dB$$

$$G_{Antenna} = 11.5dB$$

The equations above demonstrate how the user can easily find the RCS of the SAPARC for any given operating temperature. In other words, when the operating temperature is known, the corresponding value of G_{Loop} will also be known, and hence so will the RCS of the SAPARC unit. The equations are similarly applicable to the 45° SAPARC orientation. For this case, simply subtract the 6 dB difference from the 0° orientation antenna results described above.

3.2 Anechoic Chamber Tests

The University of Michigan Radiation Laboratory maintains a fully equipped 60-footlong, tapered anechoic chamber which is used for conducting antenna pattern measurements and for measuring the scattering characteristics of man-made and natural targets. This chamber is ideal for making accurate measurements of the SAPARC's RCS within a relatively noise-free environment.

A major component of the Radiation Laboratory's polarimetric radar measurement facility is the LCX POLARSCAT system. The parameters of the L-band subsystem used for this measurement are as follows:

Center Frequency	1.25 GHz
Frequency Bandwidth	0.3 GHz
Antenna Type	Dual Polarized Pyramidal Horn
Antenna Gain	15 dB
Beamwidth	17.0°
Far Field ($2d^2 / \lambda$)	2.6 m
XPOL Isolation	35 dB
Calibration Accuracy	± 0.3 dB
Phase Accuracy	± 3°

Table 3.1: L-Band Measurement System Parameters

A large percentage of this system consists of Hewlett Packard components, including an HP 8753 Network Analyzer and HP 9000 Computer with an additional disc drive. Using computer control, polarimetric measurements of the phase and magnitude responses can be taken with respect to changes in target elevation and azimuth angles (Figure 3.2).

The chamber experiments required a center frequency of 1.25 GHz with a 300 MHz bandwidth. Calibrations were performed by using a 14" metallic sphere in accordance with a calibration technique developed by Sarabandi [5] (See Appendix D). Time gating was also employed, whereby a gate span of 10 ns (centered on the target's response) provides an automatic subtraction of background scatterers. A block diagram of the measuring facility is given in Figure 3.3.

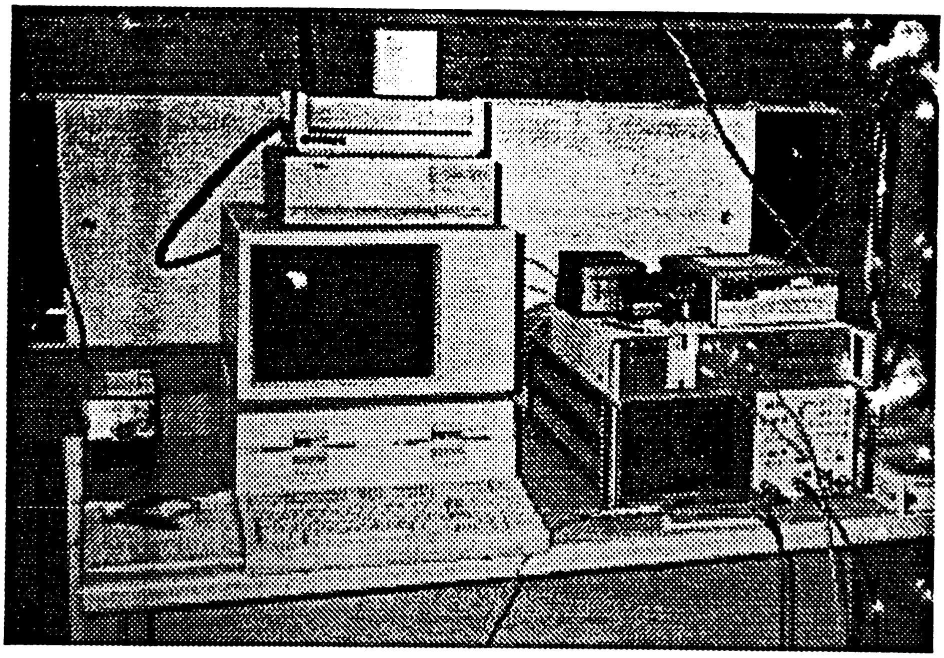


Figure 3.2: L/C/X-Band POLARSCAT Test Equipment

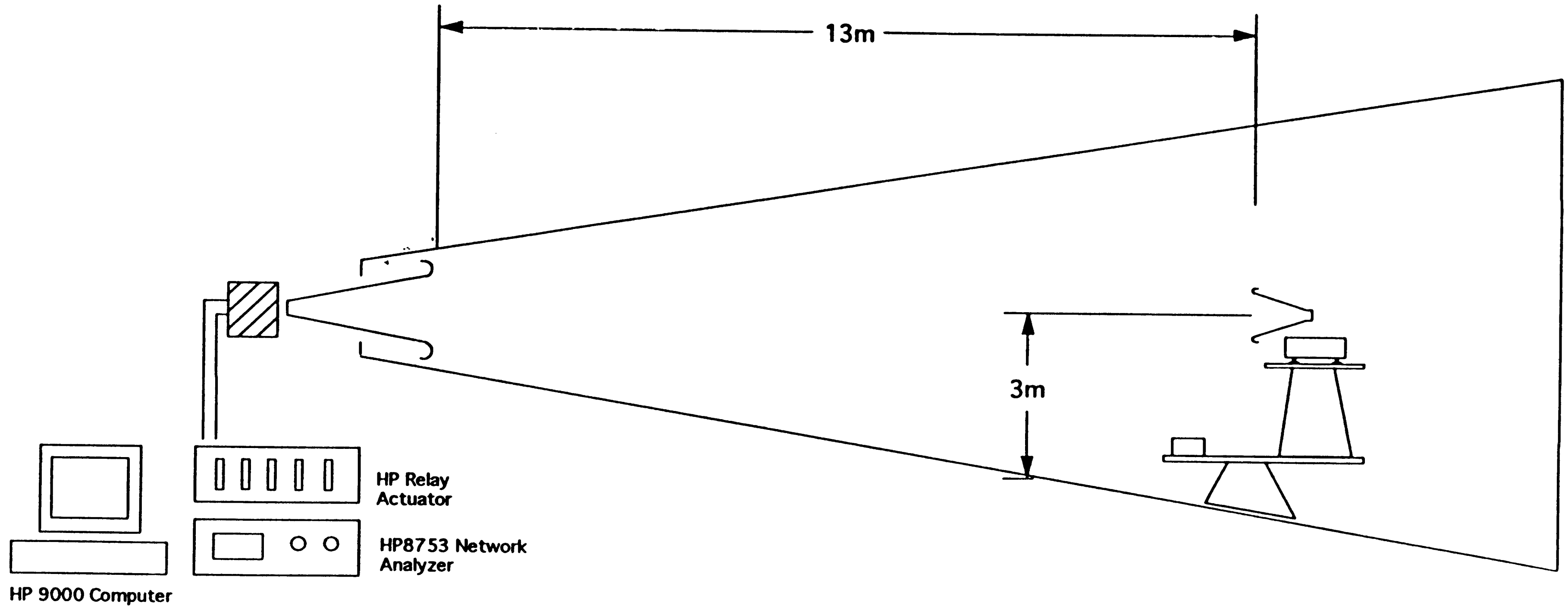


Figure 3.3: Anechoic Chamber Measurements at the University of Michigan's Radiation Laboratory

3.1.1 SAPARC Time Domain Response

Section 2.3 mentioned that a SAR calibration can be enhanced by time shifting the PARC's radar response so that it appears to originate over a dark background (refer to Figure 2.8). Recall that a 200 foot delay line is incorporated into the SAPARC design to accomplish such a feat. The effect of this delay is clearly shown in Figure 3.4, the time domain response of the L-band SAPARC system. As an addendum, Table 3.2 provides an identification of the five markers given in Figure 3.4.

Marker	Identification
1	Leakage from a circulator of the radar system
2	Leakage from the OMT and antenna unit of the radar system
3	Backscatter from the SAPARC's antenna and chassis (physical location of the SAPARC)
4	Primary time-delayed SAPARC response
5	Response due to the *ringing* of the SAPARC unit

Table 3.2: Marker Identification for Figure 3.4

Table 3.2 leads to a number of important conclusions. First, the electrical length of the delay line is found to be the difference between markers 3 and 4, namely 340 ns. This, in turn, corresponds to an electrical length of 102 m; hence, the SAPARC's SAR response has effectively been translated by 102 m (i.e. approximately 340 feet). Also note the ringing effect (marker 5) where a replica of the original SAR response is periodically repeated every 340 ns, or 102 m. The subsequent replicas are a product of the limited isolation of the OMT. During the transmission of the first SAR response, a small amount of leakage RF makes its way through the SAPARC loop where it is amplified, delayed, and re-transmitted as another SAR response. Figure 3.4 shows how each of the recurring responses will decay by approximately 15 dB; hence, this process continues until the net amount of leakage becomes negligible. When processing the imaging data, the ringing effect inherent with each SAPARC allows for easy identification and location of the calibration system, thus providing another advantage over passive calibration devices.

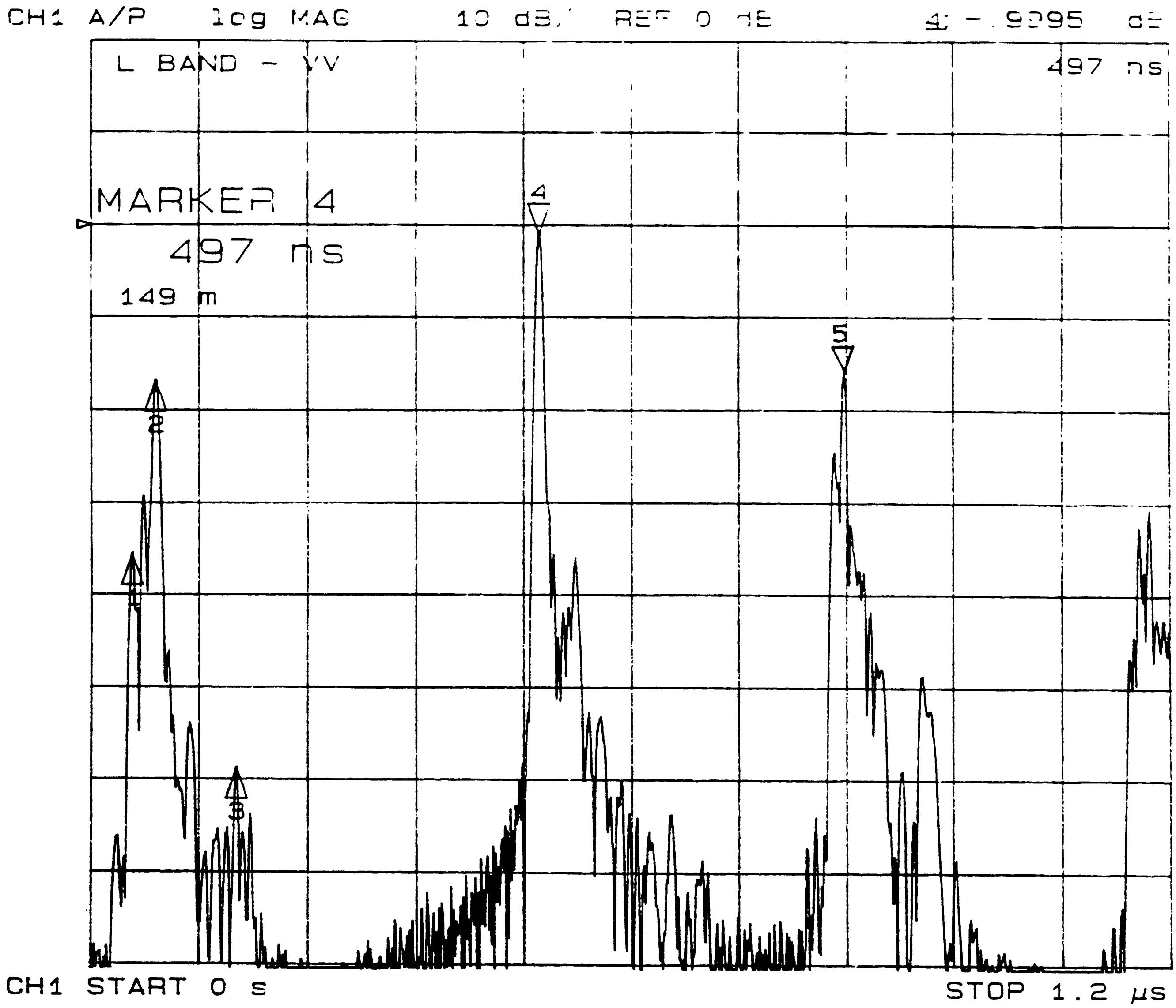


Figure 3.4: SAPARC Time Domain Response

As a final point, the SAPARC provides an exceptional signal to noise ratio (SNR). The difference between the SAR response (labeled as marker 4) and the anechoic chamber's noise floor is over 75 dB. A 55 dB signal to clutter ratio (i.e. the difference between markers 3 and 4) is also shown to be quite extraordinary. These relatively large values of SNR will prove to be very beneficial for actual SAR calibrations.

3.1.2 0° Orientation Test

The 0° orientation of a SAPARC refers to the case when there is no polarization mismatch between the radar's antenna and the SAPARC antenna. In this mode, the SAPARC provides a calibration of σ_{hv}, where a received vertically polarized signal is amplified, delayed, and transmitted back to the radar with a horizontal polarization. The phasor polarizations are given in Figure 3.5.

Figure 3.6 demonstrates the measured azimuthal pattern response for this orientation. As shown, the SAPARC yields a maximum RCS response of 42.6 dBsm with a 25° half-power beamwidth (for the σ_{hv} case). (Note that the traditional convention of listing the target's polarimetric RCS as σ_{xy}, where x and y refer to the received and transmitted polarizations, respectively, is used.) A cross polarization isolation of 32 dB exists between σ_{hv} and σ_{vv} , σ_{hh} , thereby giving credence to the excellent cross polarization isolation performance of the horn / OMT design described in section 2.2.

As a final point, the σ_{vh} response reveals the "noise floor" inherent with this measurement. This RCS response is characterized by a 100% polarization mismatch for both the radar and SAPARC antennas, and hence the extremely low RCS response of -40 to -60 dBsm is expected.

3.1.3 45° Orientation Test

The 45° orientation is accomplished by rotating the SAPARC horn as demonstrated in Figure 3.7. Doing so allows a complete calibration of the Scattering Matrix since each transmit and receive combination, namely σ_{vv}, σ_{hh}, σ_{hv}, and σ_{vh}, yields the same RCS azimuthal pattern response with a half-power beamwidth of 25°. Figure 3.8 depicts

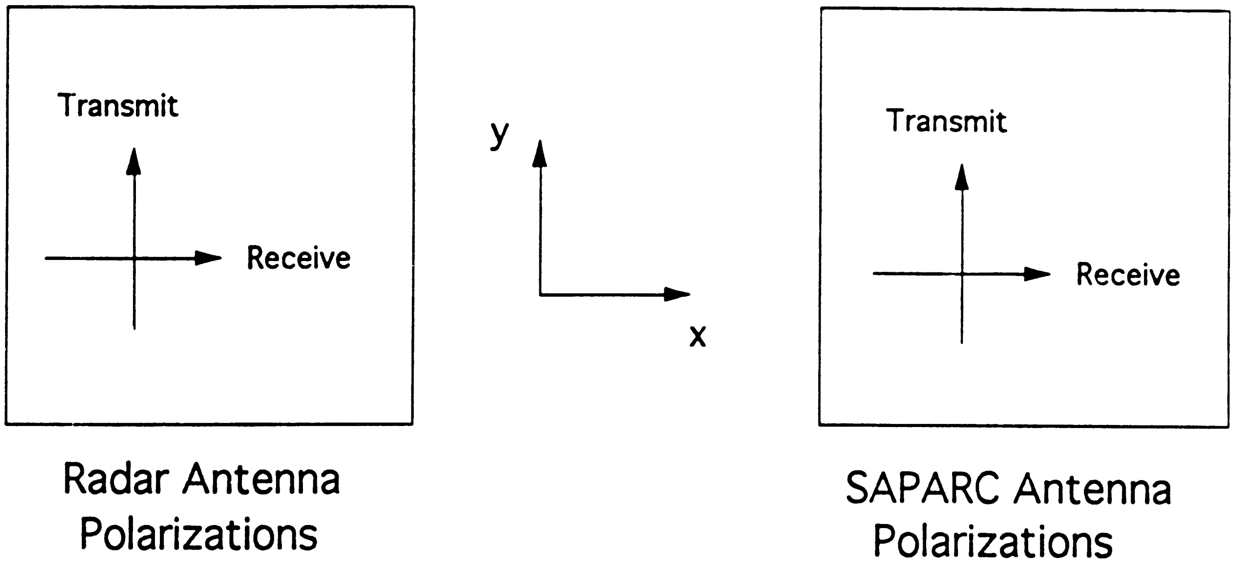


Figure 3.5: SAPARC 0° Orientation Phasor Polarizations

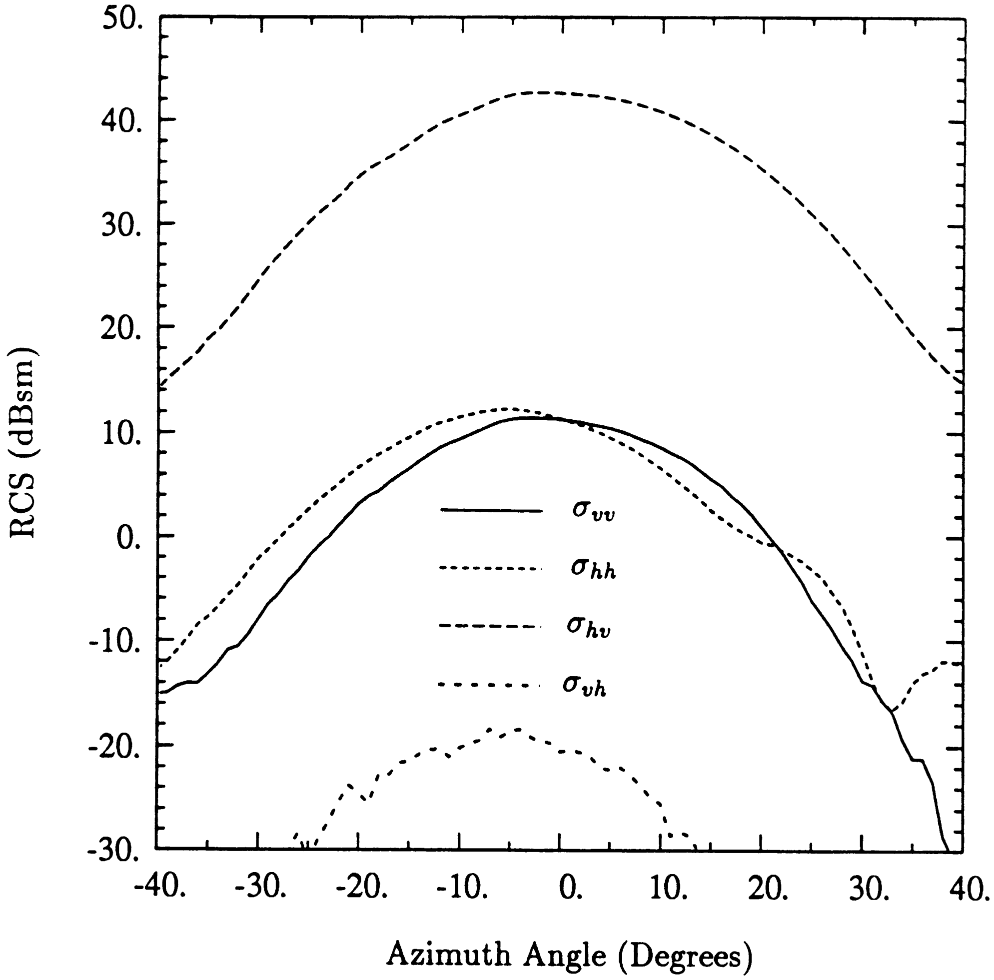


Figure 3.6: SAPARC 0° Orientation RCS Azimuthal Patterns at 20°C (SIR-C Mode)

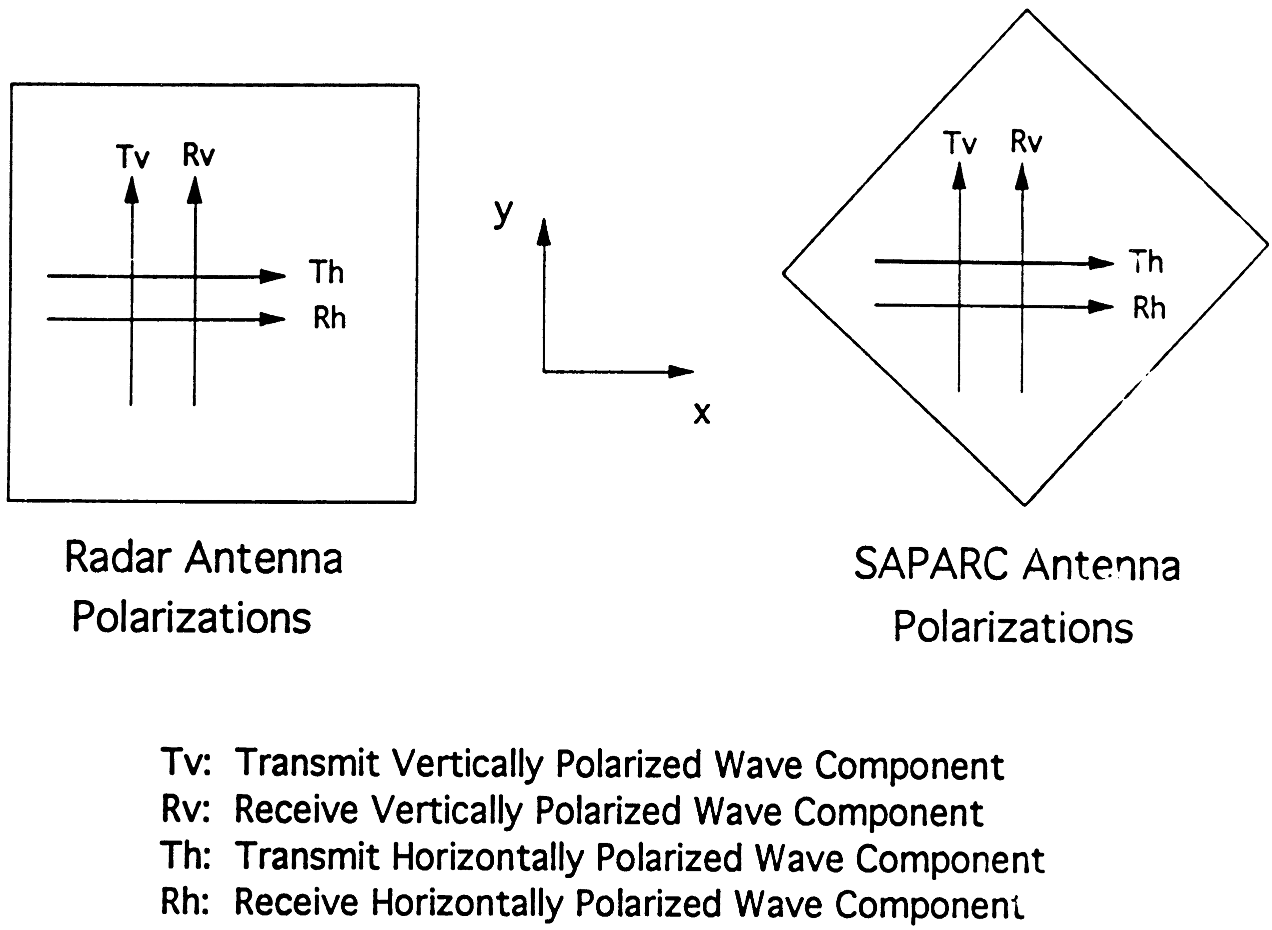


Figure 3.7: SAPARC 45° Orientation Phasor Polarizations

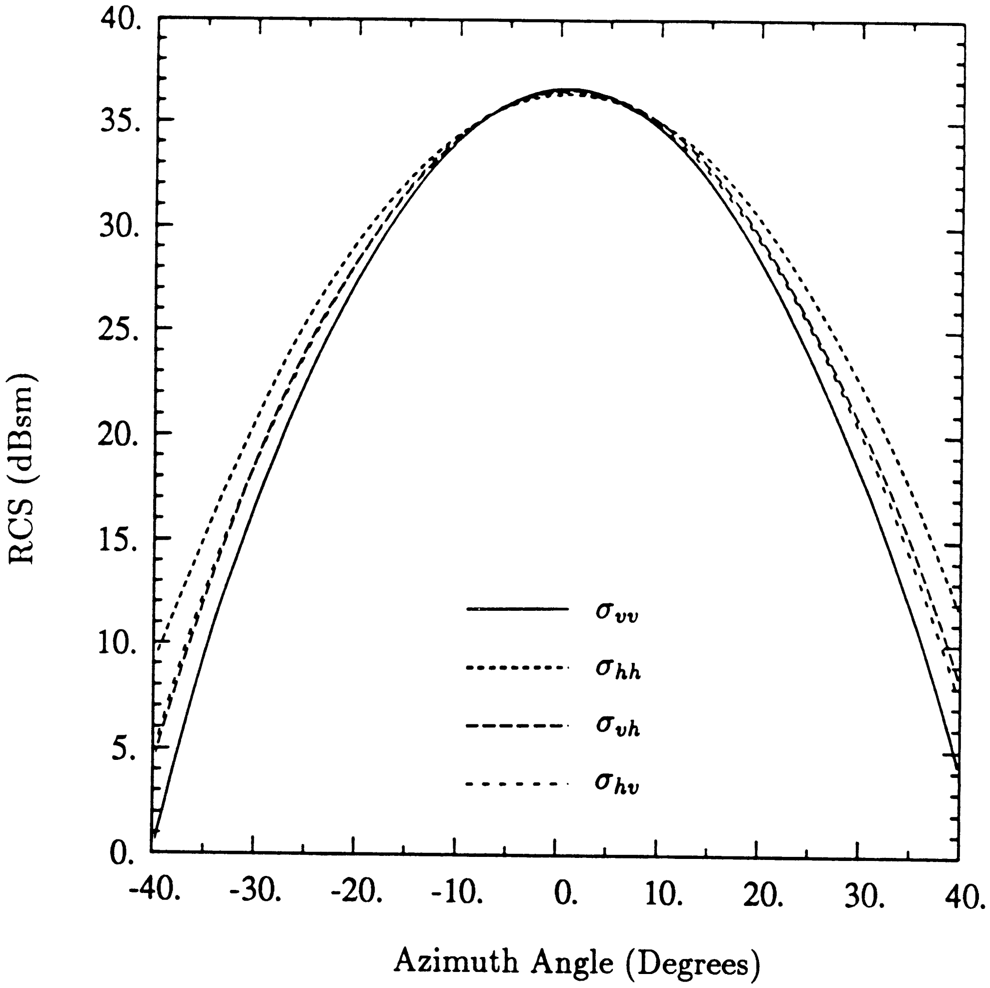


Figure 3.8: SAPARC 45° Orientation RCS Azimuthal Patterns at 20°C (SIR-C Mode)

the RCS azimuthal pattern response for the 45° orientation. Note how each trace is symmetric and virtually equal over a 40° beamwidth, as expected. Also note how the peak RCS of 36.6 dBsm is exactly 6 dB below the 0° orientation response of 42.6 dBsm. Again, this result is in excellent agreement with the theoretical expectations (the two 45° polarization mismatches, one for transmit and the second for receive, correspond to a total loss in power of 1/2 • 1/2 = 1/4 = 6 dB).

The phase responses shown in Figure 3.9 are also noteworthy. Theoretically, we expect

$$\phi_{hv} - \phi_{vv} = 0^\circ$$

$$\phi_{hh} - \phi_{vv} = \phi_{vh} - \phi_{vv} = 180^\circ$$

over an 80° beamwidth. The phase diagrams in Figure 3.10 help to explain these results.

Section 2.2 referred to the drawbacks encountered when using a two-antenna PARC system; more specifically, these problems include pattern asymmetry and ripples in the phase and magnitude responses. Figure 2.3 is an example of one two-antenna system tested by Sarabandi and Oh [1]. By comparing Figure 2.3 with those in Figures 3.6, 3.8, and 3.9, one can easily see the notable SAPARC improvements in magnitude and phase performance.

3.3 Thermal Gain Testing

Section 2.5 alluded to the fact that PARC's are susceptible to gain variations due to changes in the ambient temperature. Countering these thermal gain variations is formidable task; therefore, it is much easier to compensate for the changes in the SAPARC's RCS by mapping the G_{Loop} dependency on ambient temperature.
Figure 3.11 reflects the results of the experiment whereby G_{Loop} is plotted over a temperature range of -10°C to 40°C.

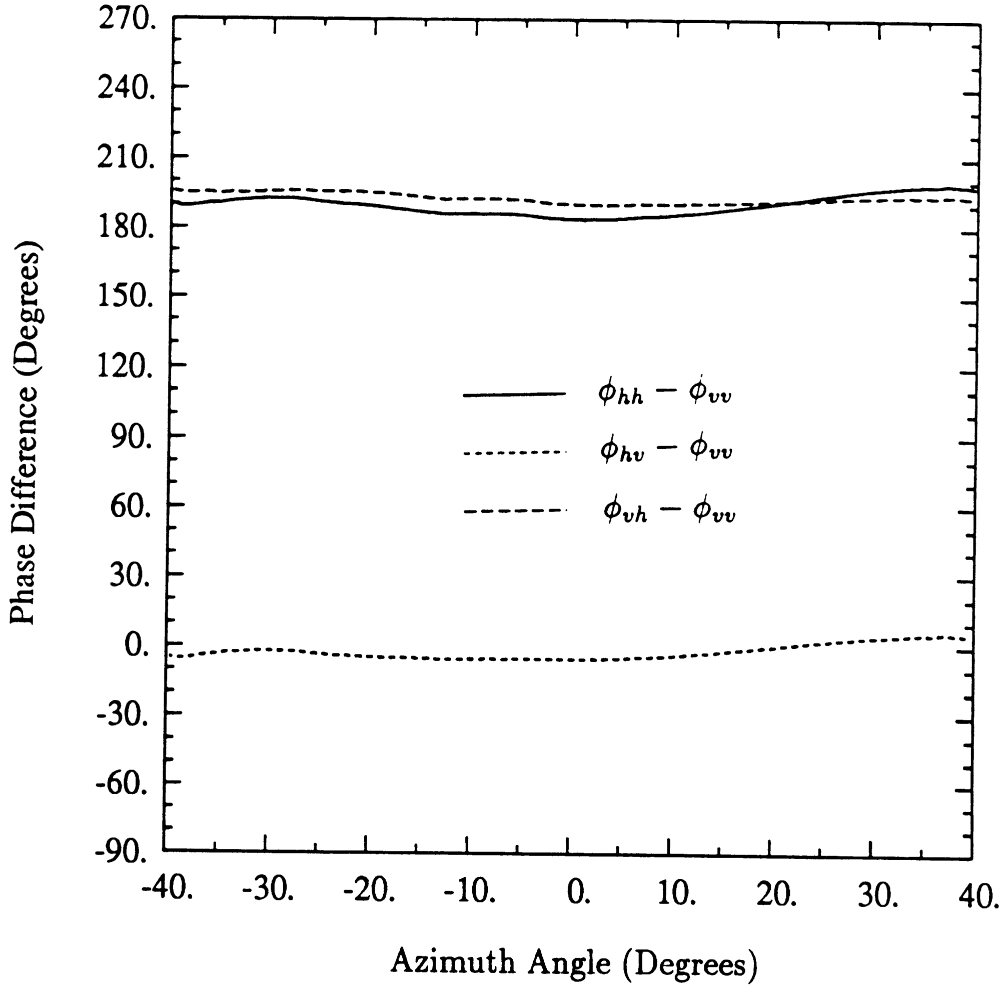


Figure 3.9: SAPARC 45° Orientation Phase Patterns at 20°C (SIR-C Mode)

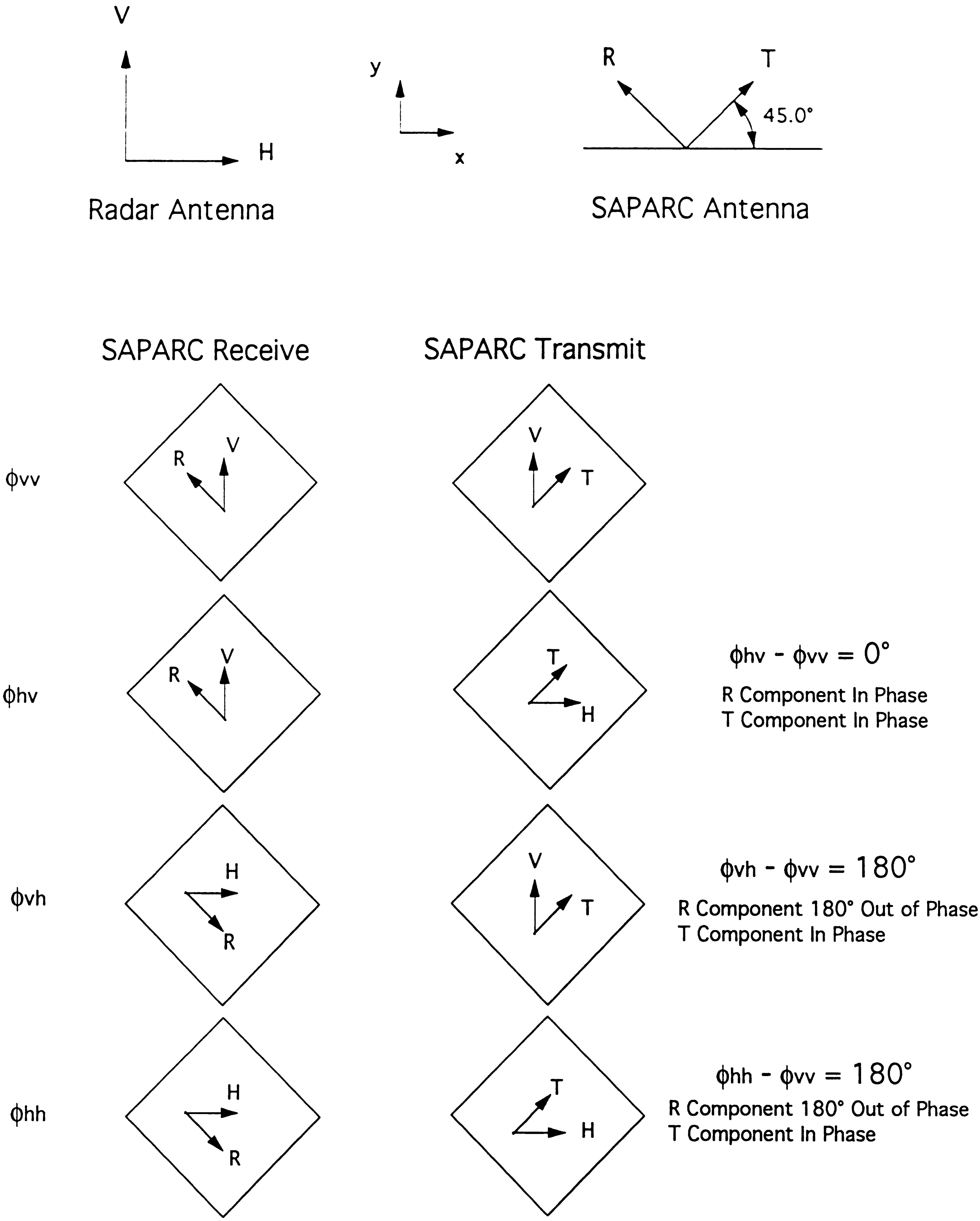


Figure 3.10: Phasor Diagram for the 45° Orientation

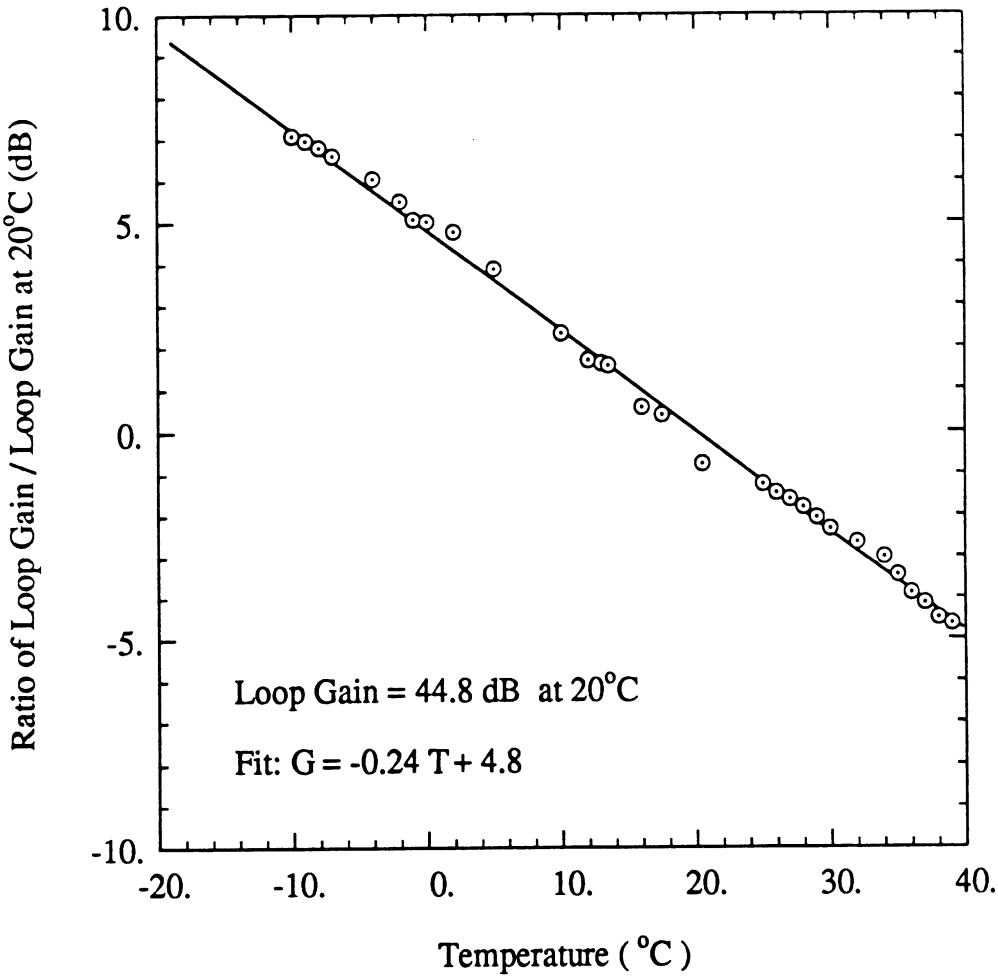


Figure 3.11: L-band SAPARC Thermal Gain Variations

The user of the device must remember, however, that component aging may alter the overall performance of G_{Loop}. Therefore, periodic calibrations of G_{Loop} vs. temperature is recommended.

As a final note, special precautions must be taken when operating the SAPARC in cold weather scenarios. Currently, the system is configured to provide the maximum allowable RCS for temperatures of 20°C or greater (see section 2.3.3). However, Figure 3.11 clearly shows how G_{Loop} can increase by as much as 7 dB for temperatures below 20°C. Therefore, the user is encouraged to add a 10 dB attenuator between microwave switches (see Fig. 2.2) whenever cold operating temperatures are anticipated.

3.4 Field Deployment Conditions

3.4.1 Battery Capacity

The SAPARC units developed through this project require two 12V, 7 Amp•H lead acid batteries. The power demands on Supply 2 (see Appendix C, pg. C-1) is given as follows:

SAPARC Operating Condition	Current Draw	Power Demand
Timing Circuitry On	0.37 A	4.44 W
System Active	1.09 A	13.08 W
System Active with LED Display On	1.20 A	14.40 W

Table 3.3: Power Demands on Supply 2

Figure 3.12 (1 A case) depicts the capacity performance of the Yuasa 12V battery used in the SAPARC design. Figure 3.13 shows the results for the full load case (i.e. a current draw of 1.2 A). Under full load conditions, the SAPARC can operate (at temperatures above 20°C) for up to 5.5 hours; longer operating times are achievable when using the Activation Timers.

Figure 3.14 shows the marked decrease in capacity during cold weather operation. During this test, the Yuasa 12V battery was subjected to a temperature of -10°C while providing a current of 1.2 amps. Under these conditions, the SAPARC's full load operating time is reduced by one hour; therefore, the user must take special precautions when planning to operate the SAPARC in cold climates.

3.4.2 All-Weather Performance

Ideally, the SAPARC can be used in all types of weather; of course, there are a number of practical limitations which concern the aperture on the horn antenna. Obviously, rain and snow can accumulate inside the horn / OMT, and thus the calibration would be ruined. In order to compensate for this occurrence, a polyethylene film (e.g. Saran Wrap) was placed over the aperture to serve as a radome. This film was very effective in keeping water out of the horn / OMT combination; however, an accumulation of water droplets on the radome eventually lead to a feedback oscillation scenario (see Sections 2.3.2.2 and 2.4.2). Therefore, applying a thin-filmed polyethylene radome is suggested for weatherproofing the horn, OMT, and waveguide adapters. Yet, do not expect the SAPARC to operate correctly in adverse weather conditions.

As a sidenote, if the rainfall ceases and the radome is allowed to dry, the SAPARC will "break-out" of its oscillation mode and return to its normal operating condition. The only notable change is that the detection circuitry will be triggered prematurely. Finally, the chassis of the SAPARC unit should be shrouded with a rain tarp to prevent excess exposure to the elements.

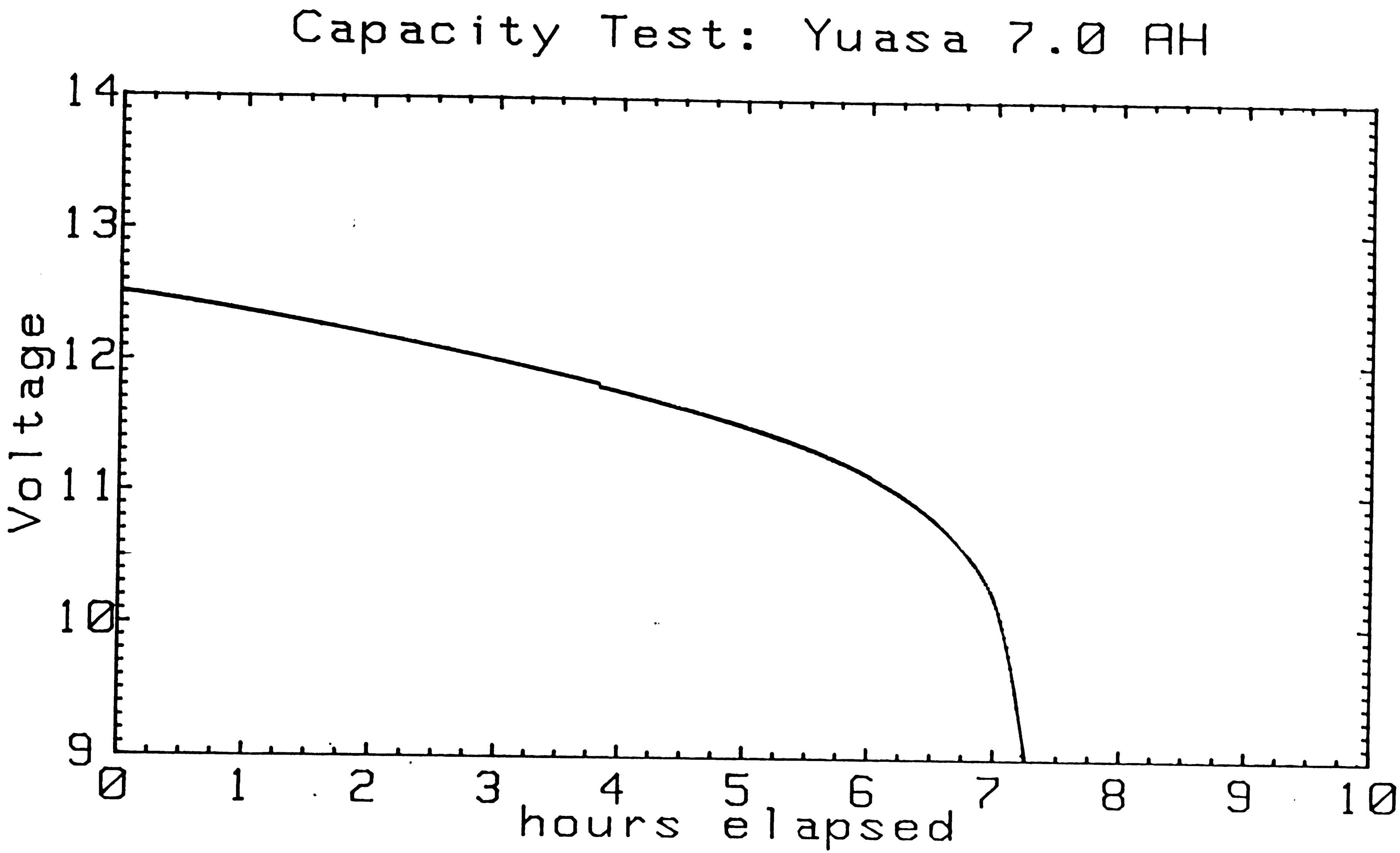


Figure 3.12: Battery Capacity Test (1.0A Load, 22°C)

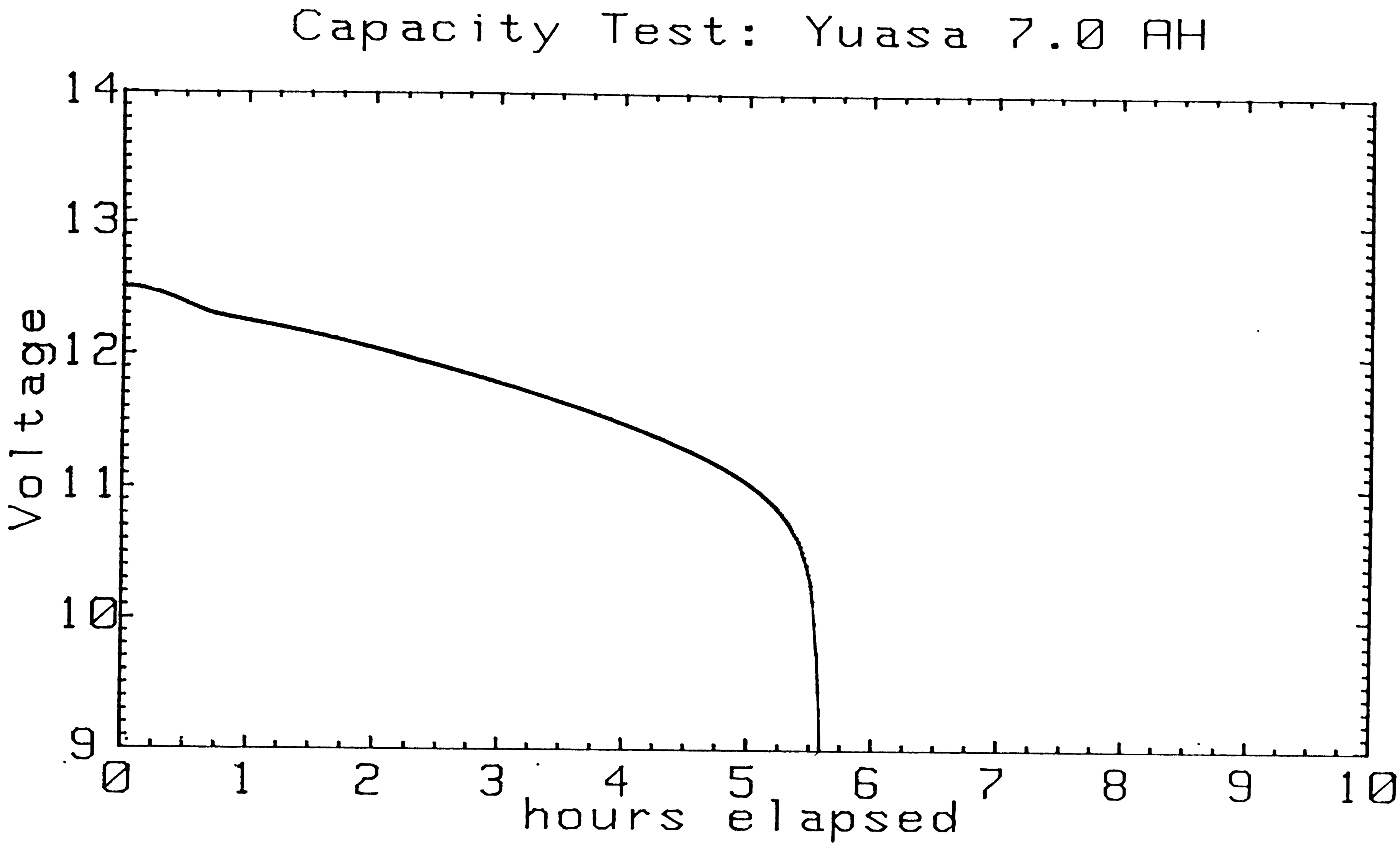


Figure 3.13: Battery Capacity Test (1.2A Load, 22°C)

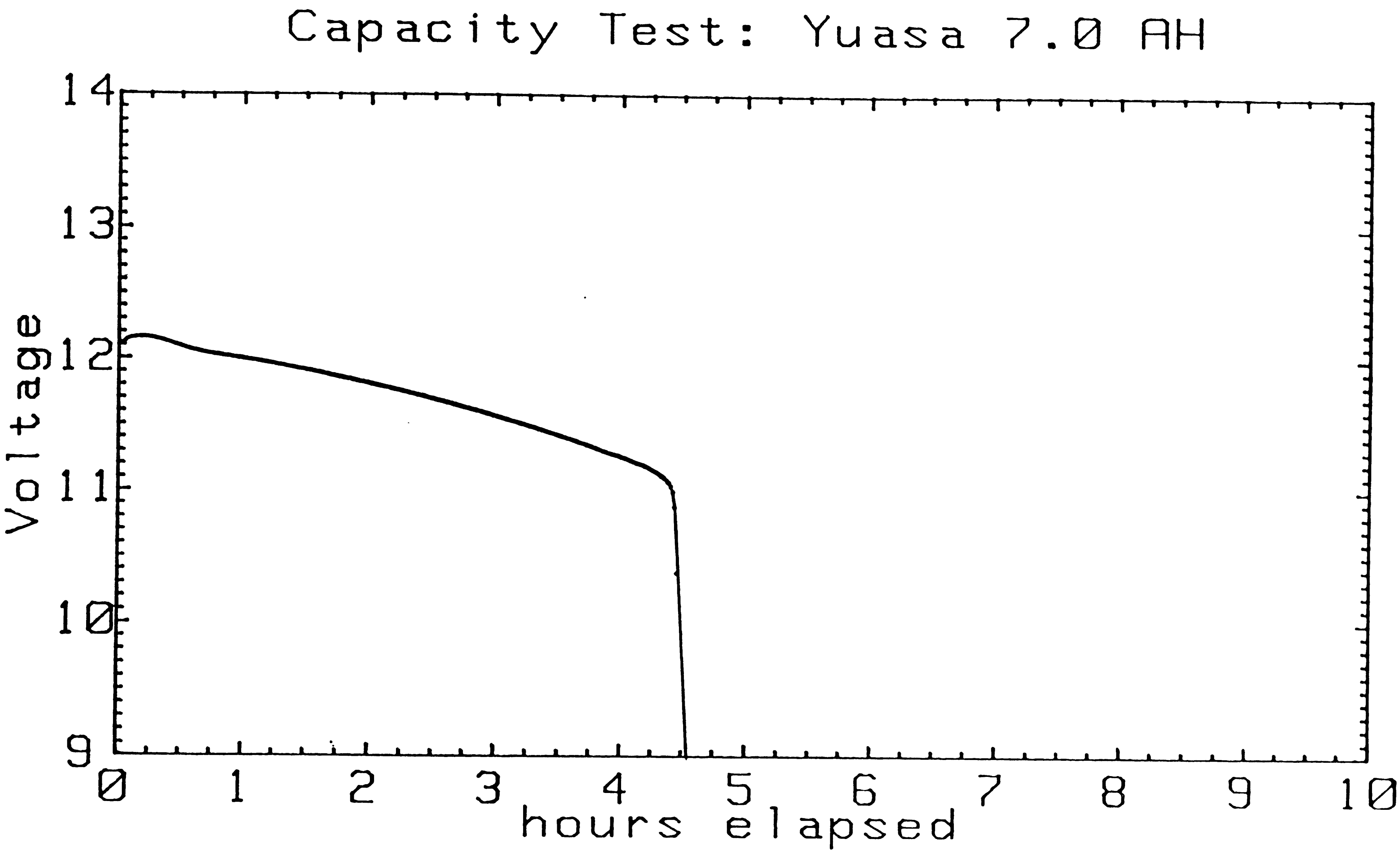


Figure 3.14: Battery Capacity Test (1.2A Load, −10°C)

CHAPTER IV

CONCLUDING REMARKS

The report outlines the design and performance characteristics of the first single antenna polarimetric active radar calibrator (SAPARC) prototype developed for NASA's SIR-C mission at the University of Michigan's Radiation Laboratory. In addition to this specific unit, a second L-band and two C-band versions are currently being constructed as part of a continuation of this project.

This L-band SAPARC possesses a nominal RCS of 36.6 dBsm with a 3 dB beamwidth of 25°. One of its best attributes, however, is the fact that it can outperform conventional PARCs though its implementation of a single dual-polarized antenna. More specifically, the pattern asymmetry and phase and magnitude ripples are eliminated through the use of this design.

In addition to these RF characteristics, the prototype is also noteworthy in that it provides a number of features which accommodate prolonged operation intervals and useful system status updates. In the future, subsequent modifications to this basic design will hopefully lead to more accurate and convenient calibrations of SAR platforms.

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[5] Sarabandi, Kamal and Fawaaz T. Ulaby, "A Convenient Technique for Polarimetric Calibration of Radar Systems," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 28, pp. 1022-1033, 1990.

[6] Ahne, James, Kamal Sarabandi, and Fawaaz T. Ulaby, "Design and Implementation of a C-band Single Antenna Polarimetric Active Radar Calibrator", *Radiation Laboratory Report No. 027587-1-T,* The University of Michigan, July 1993.

Appendix A

OMT Specifications

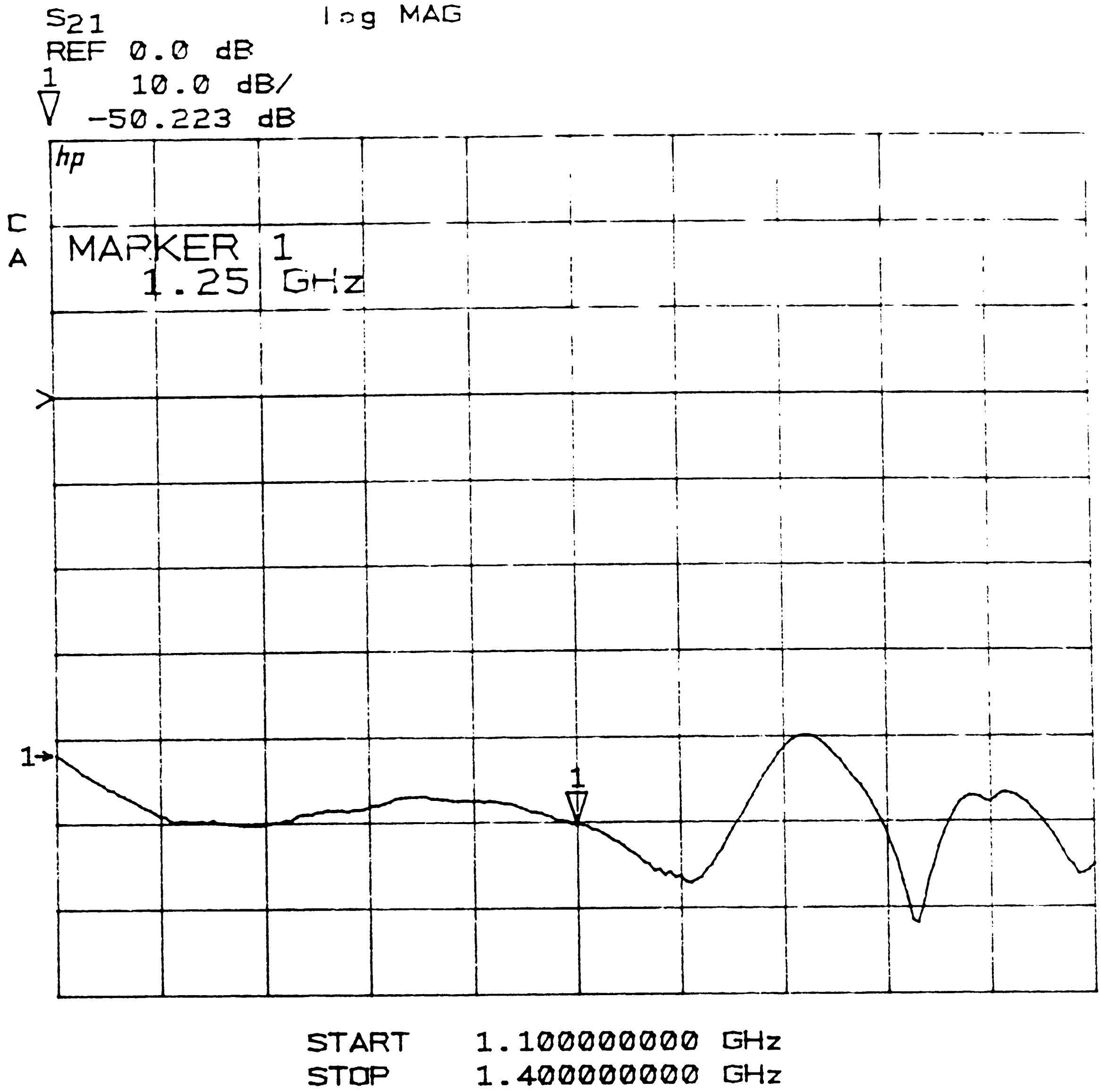


Figure A-1: Isolation of L-band OMT

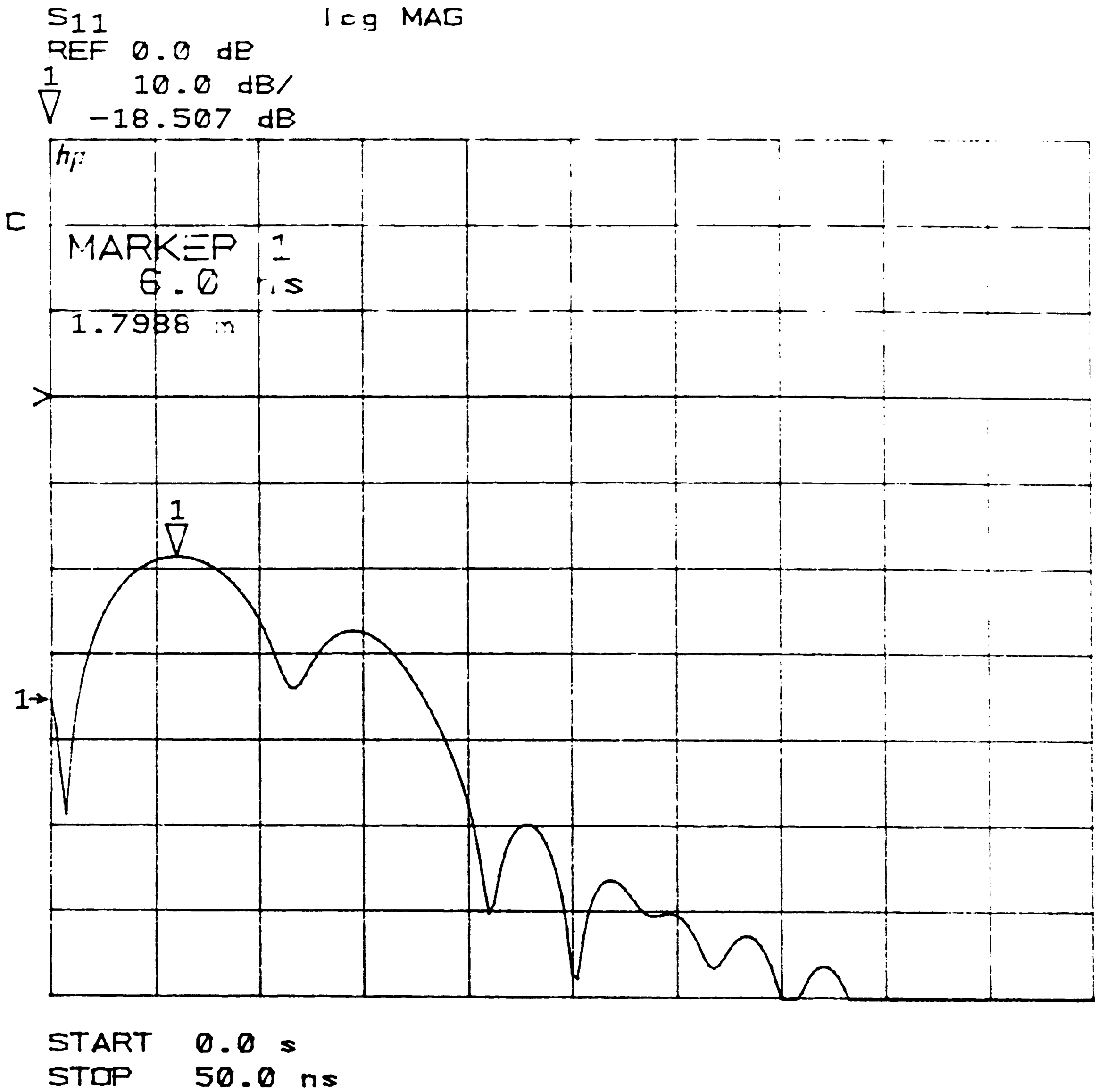


Figure A-2: Return Loss of L-band OMT (Side Arm)
(1.1 - 1.4 GHz)

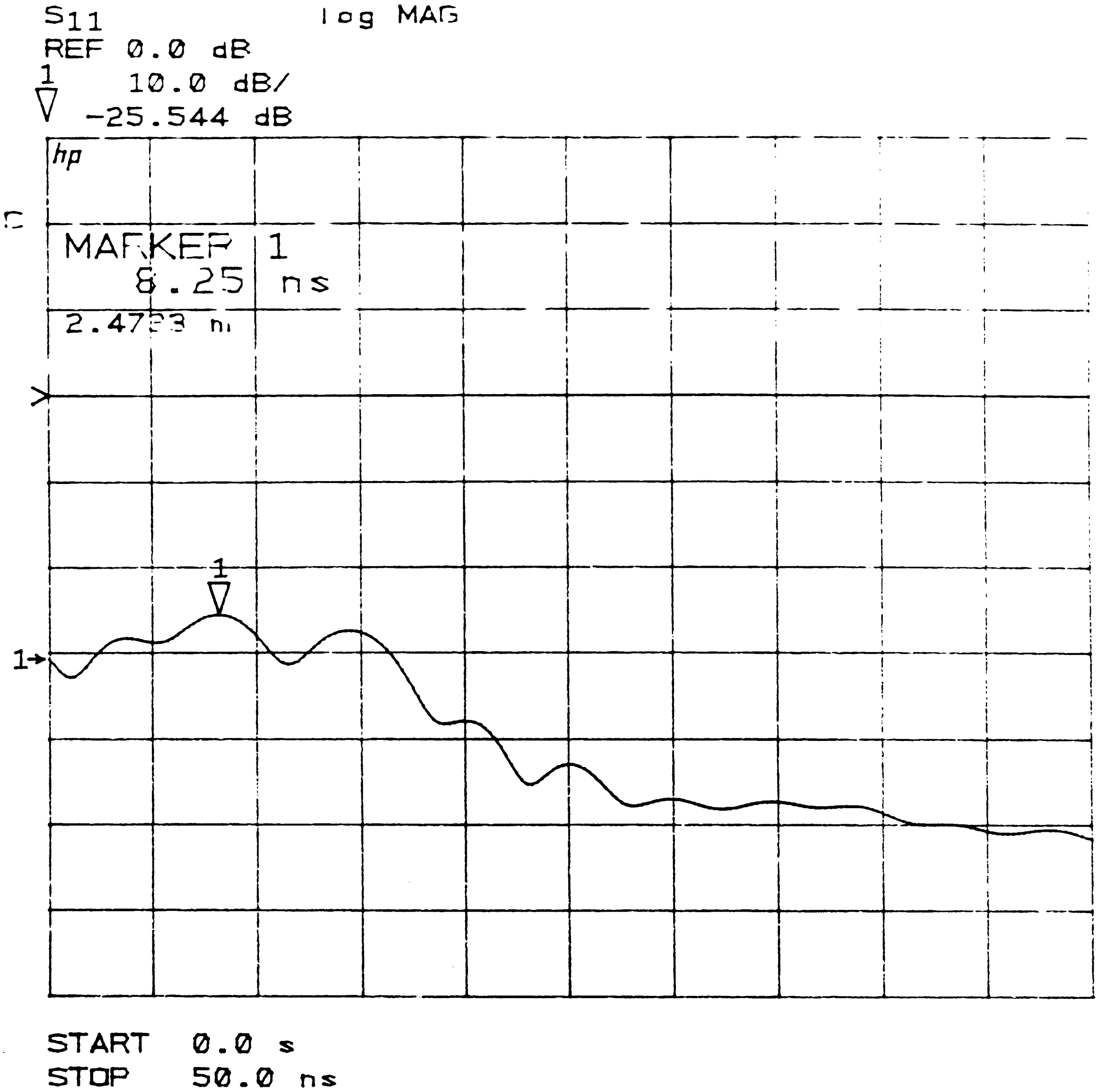


Figure A-3: Return Loss of L-band OMT (Streight Arm)
(1.1 - 1.4 GHz)

APPENDIX B

AMPLIFIER SPECIFICATIONS

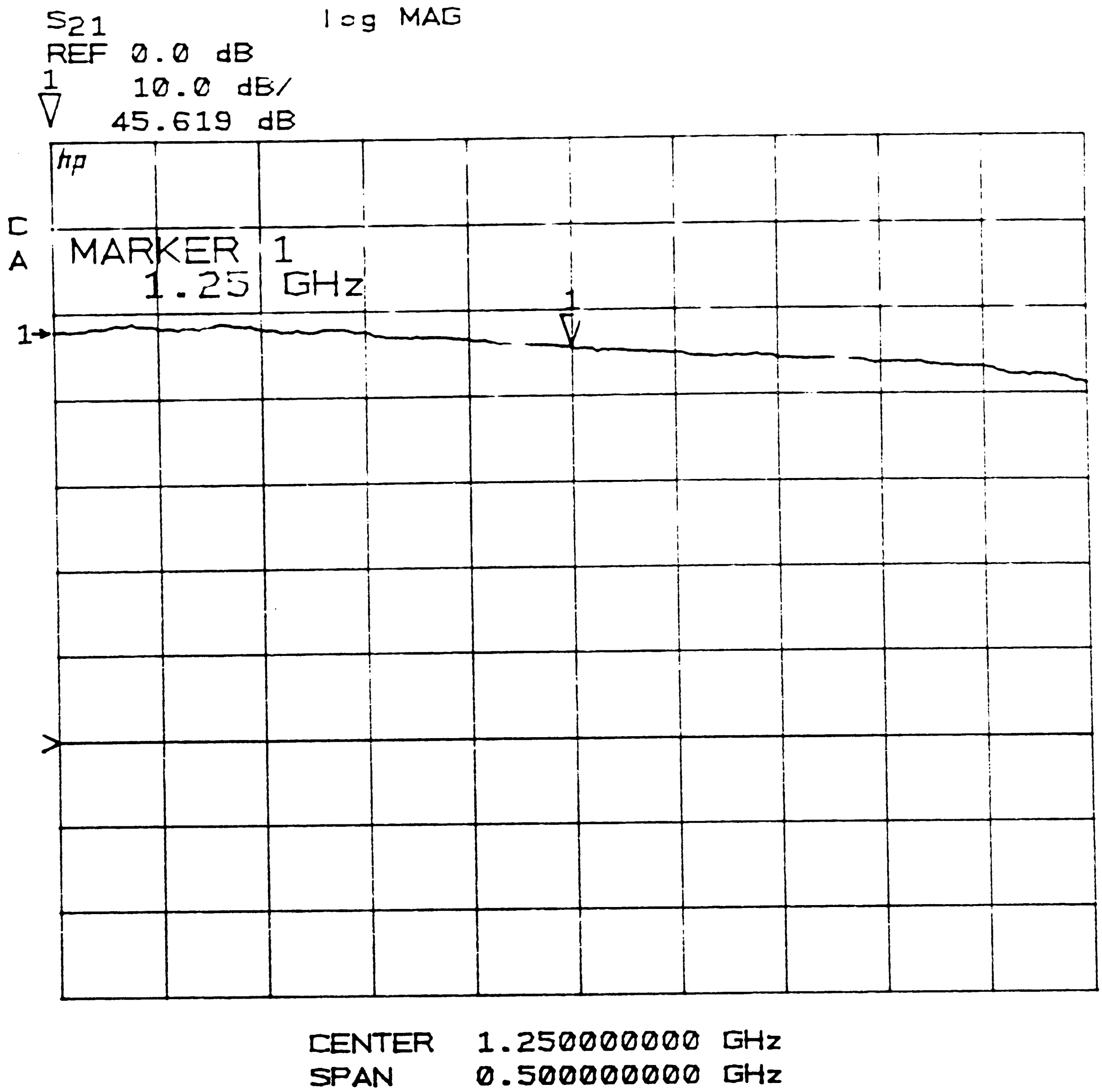


Figure B-1: Gain of the Pre-amplifier at 24°C

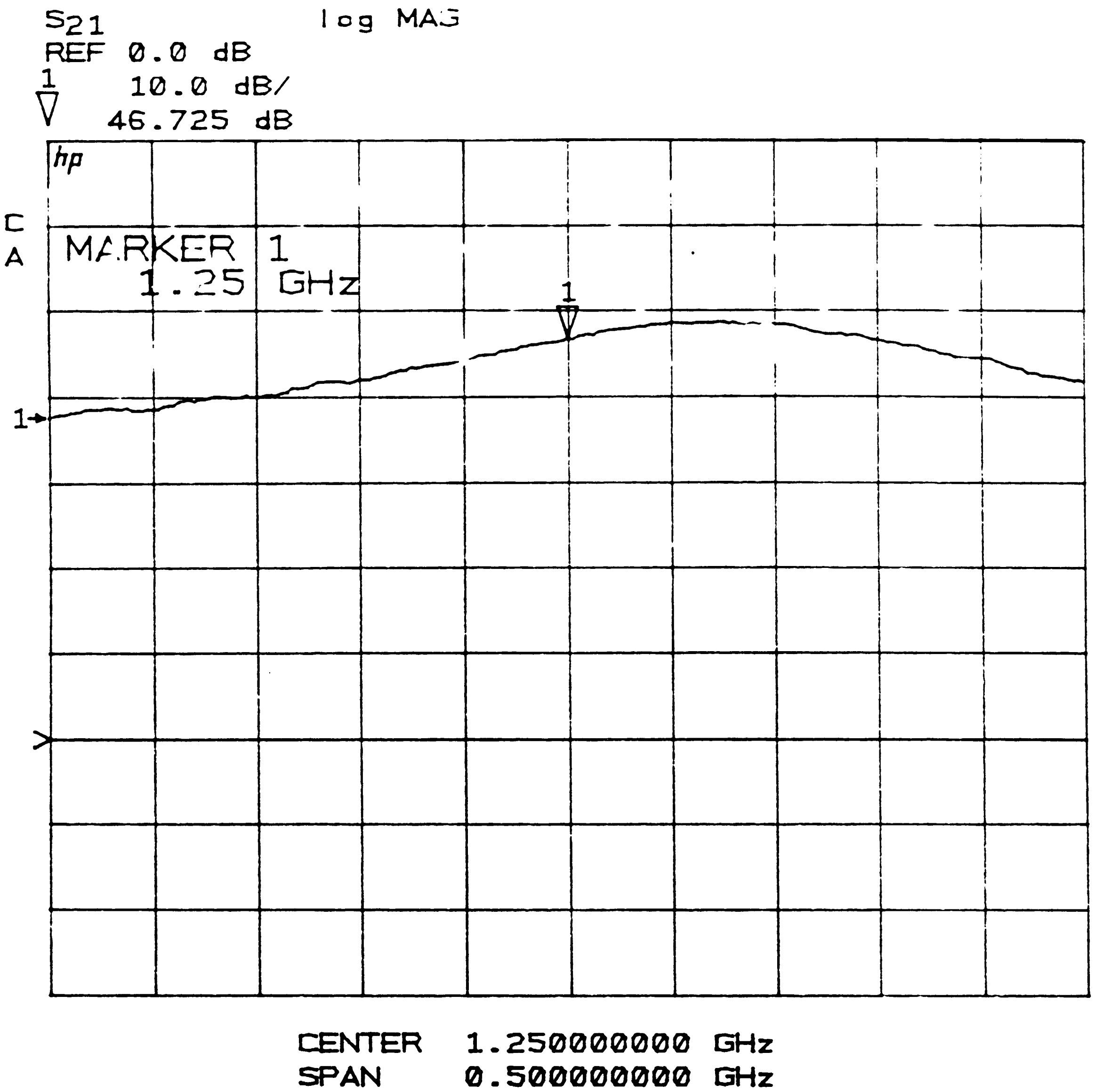
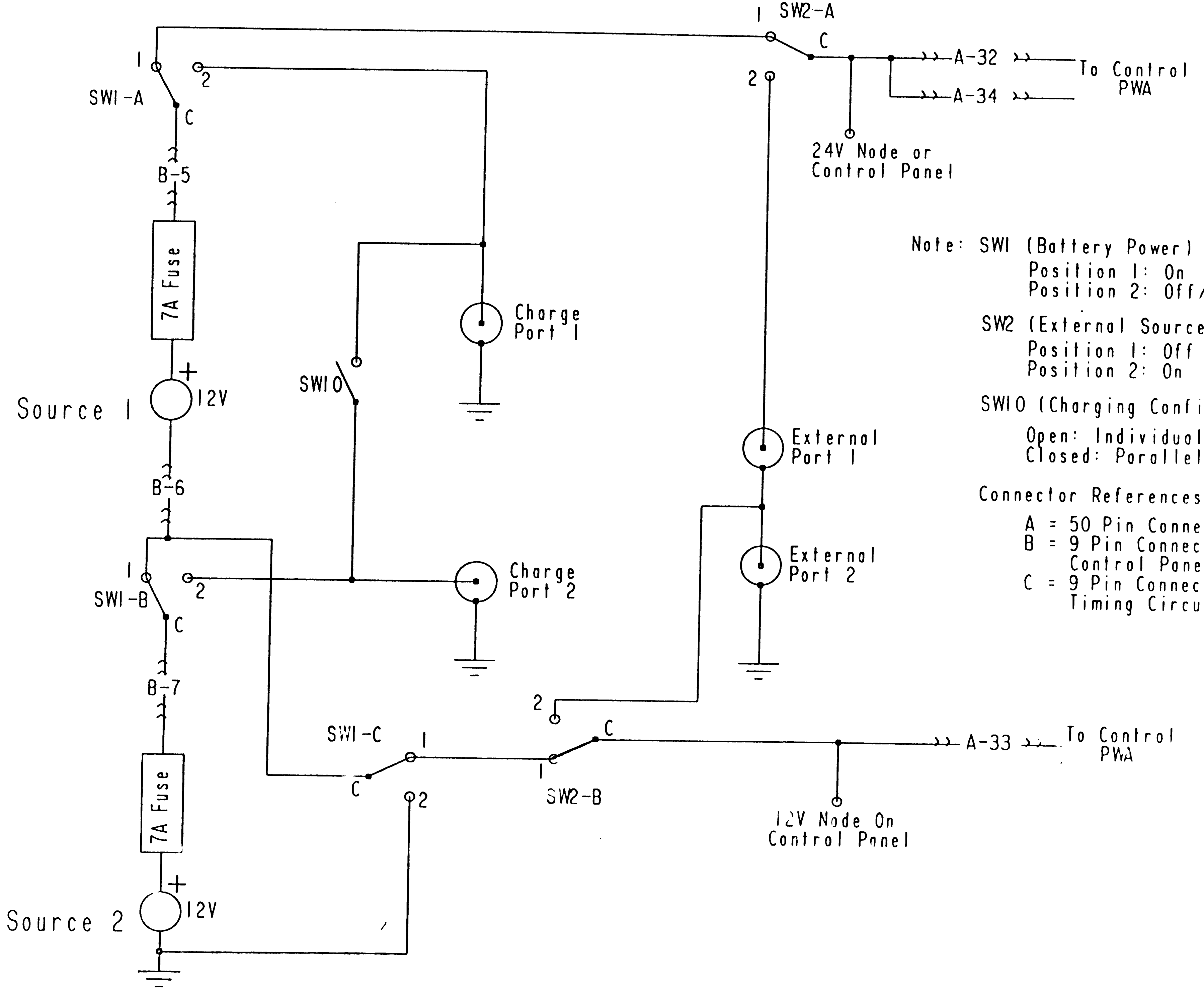


Figure B-2: Gain of the Power Amplifier at 24°C

APPENDIX C

CONTROL CIRCUITRY SCHEMATICS

Control Panel Power Connections



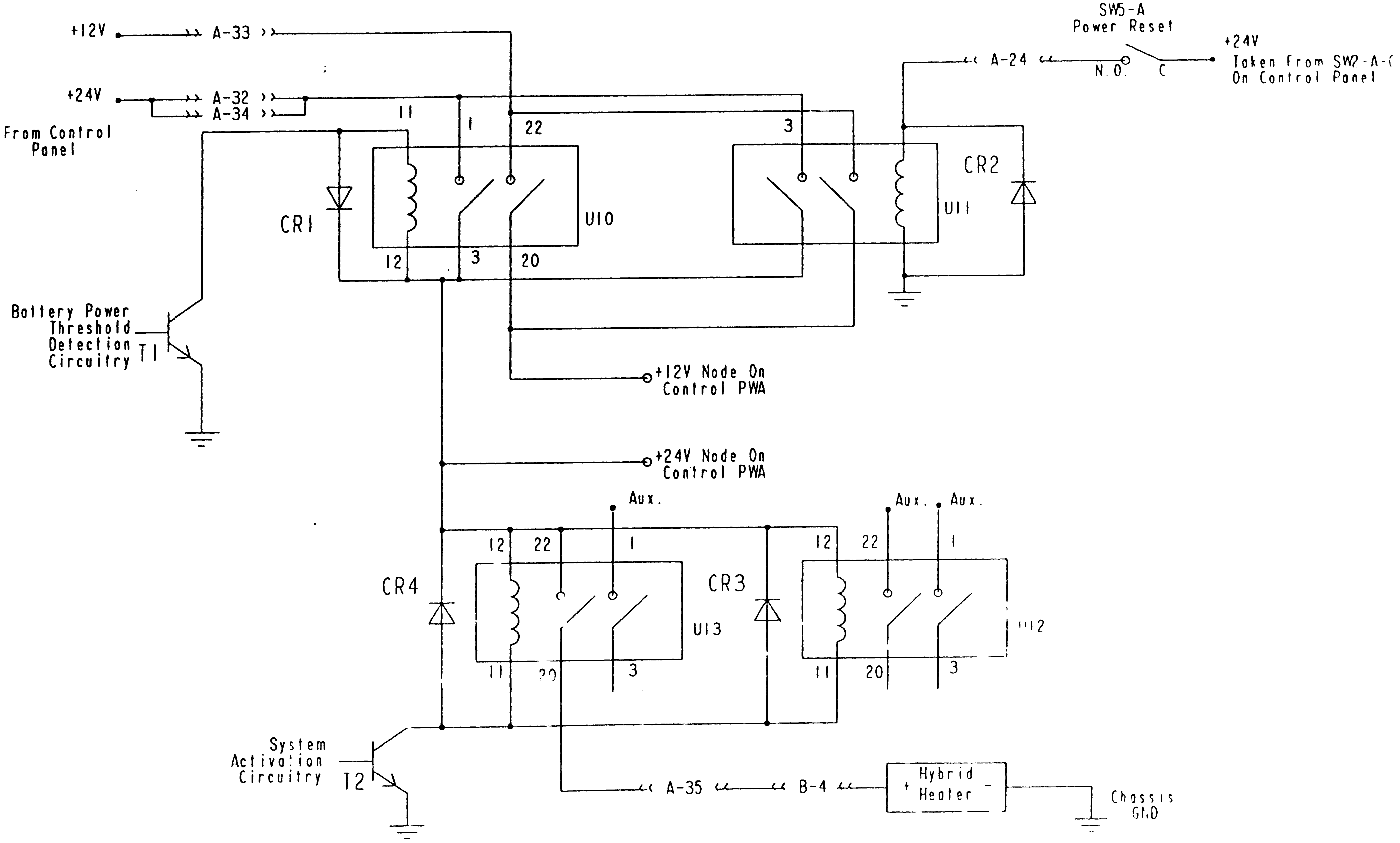
Note: SW1 (Battery Power)
Position 1: On
Position 2: Off/Recharge

SW2 (External Sources)
Position 1: Off
Position 2: On

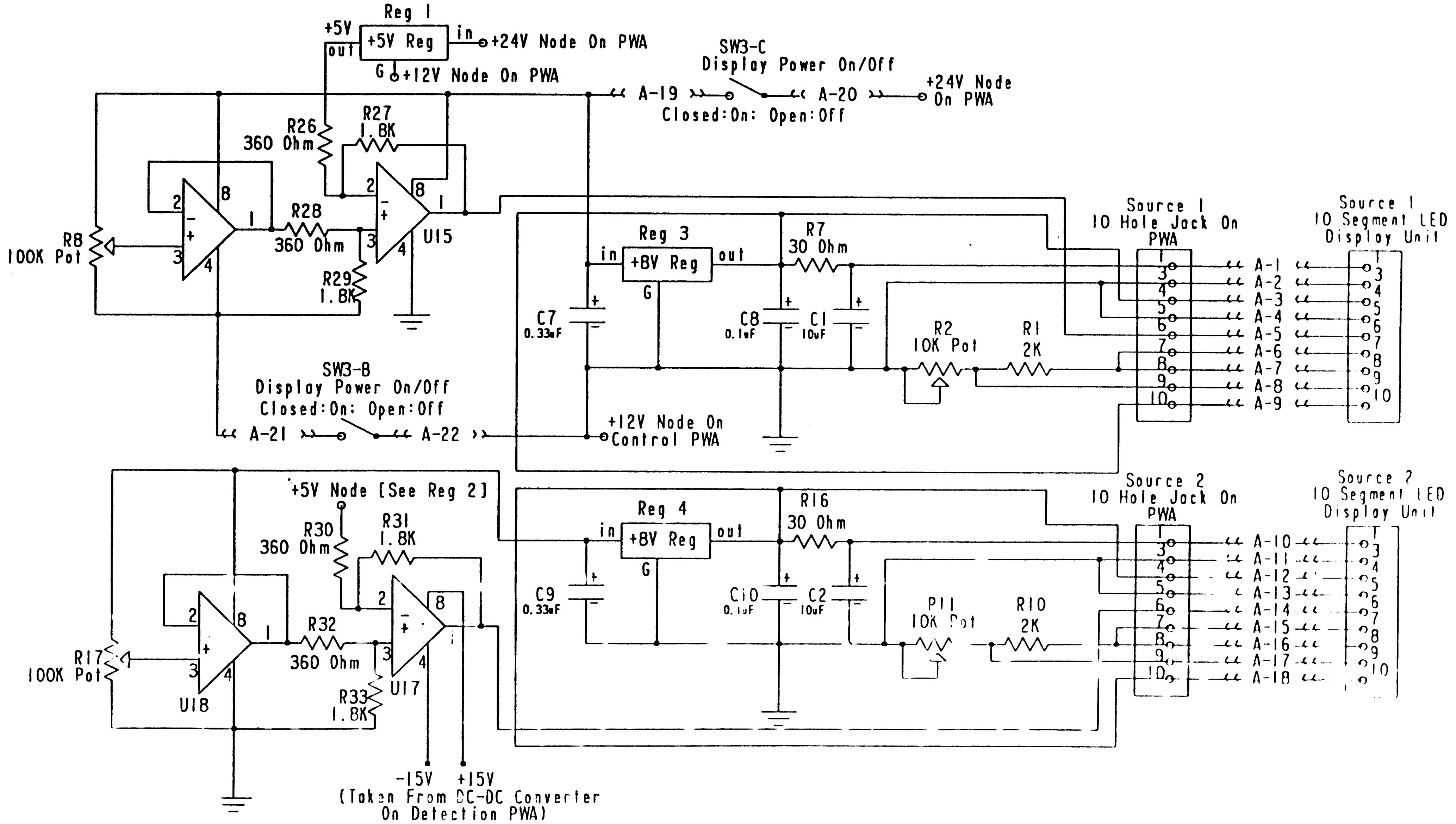
SW10 (Charging Configuration)
Open: Individual
Closed: Parallel

Connector References
A = 50 Pin Connector
B = 9 Pin Connector On Control Panel
C = 9 Pin Connector On Timing Circuit

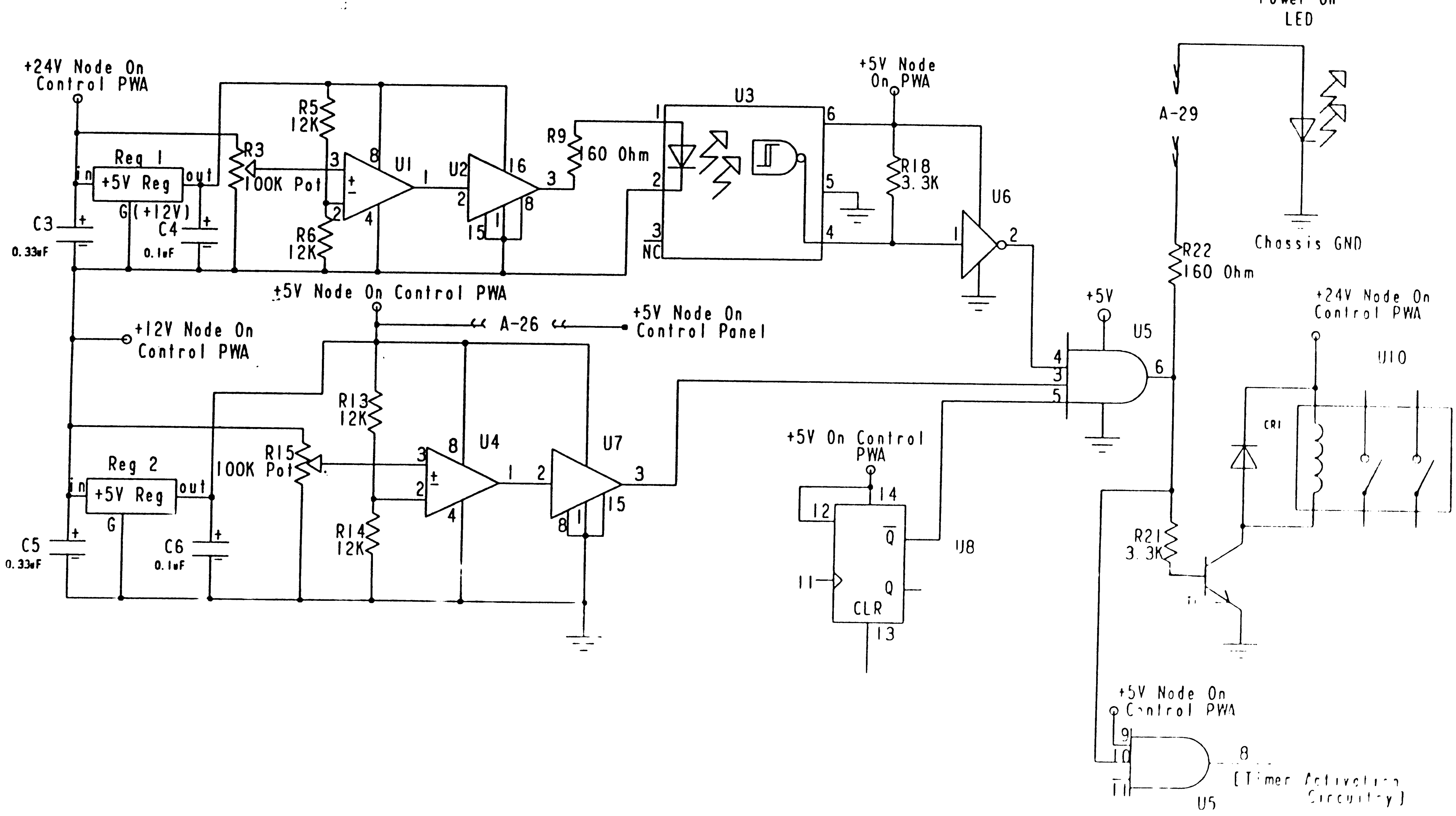
Relay Circuitry



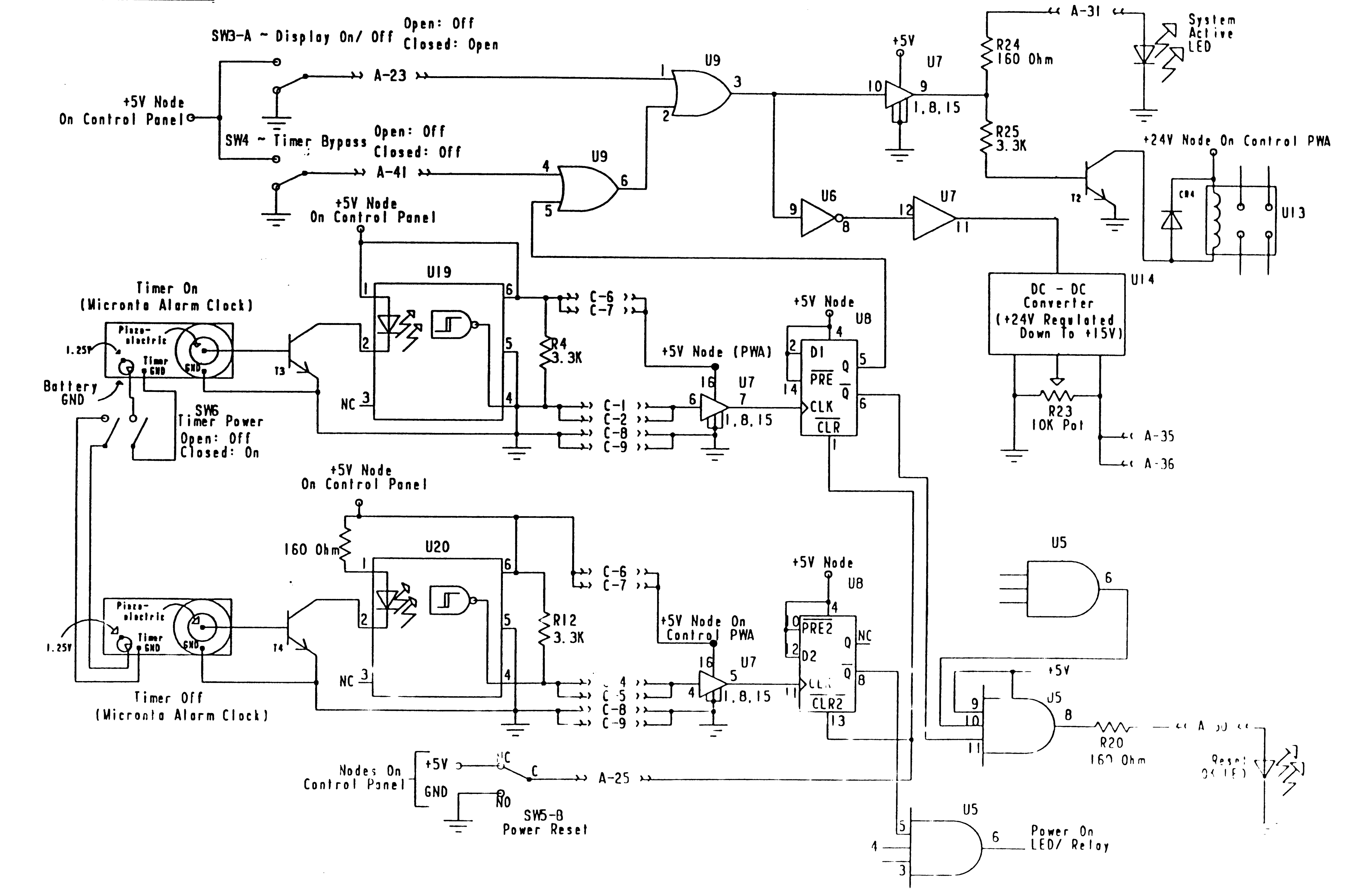
Battery Power Threshold Detection Circuitry



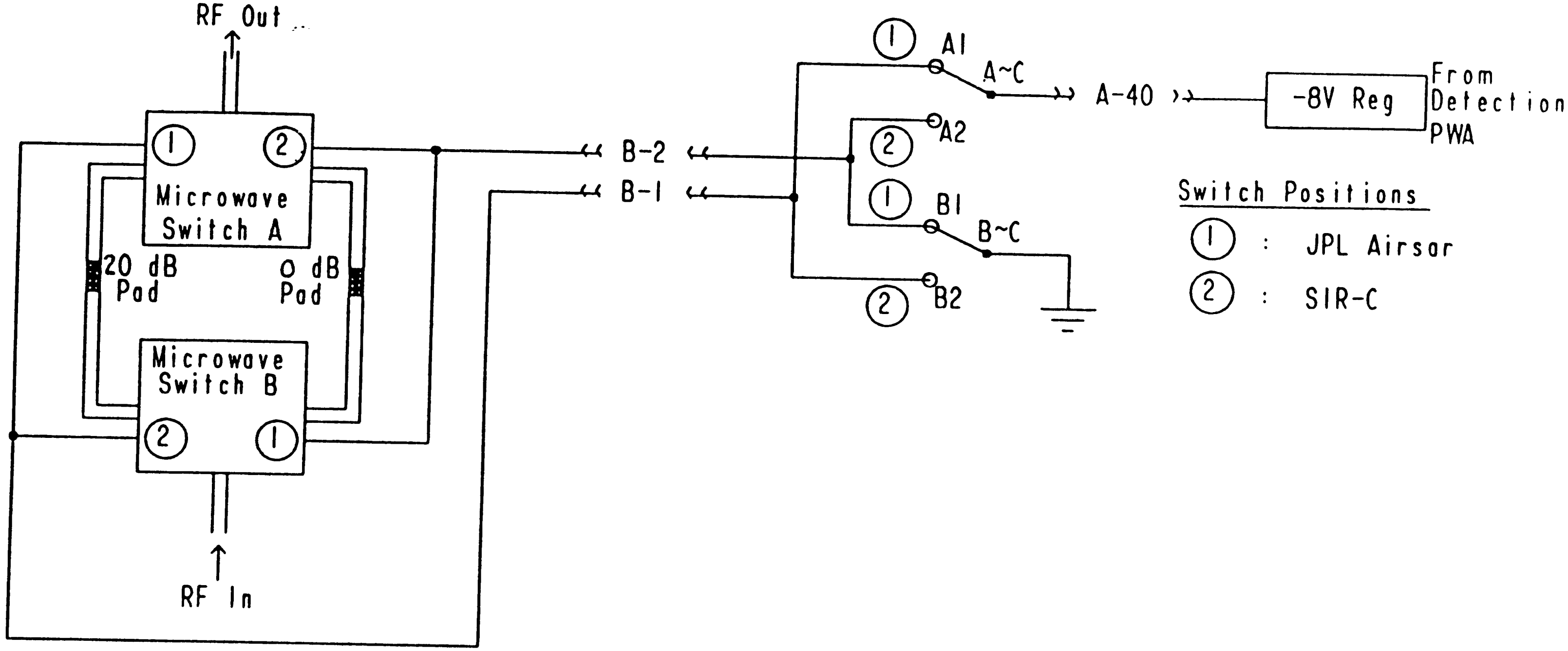
Battery Power Threshold Detection Circuitry - Part 2



Timer Activation Circuitry



Microwave Switch Connections



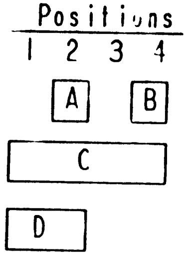
RF Amps/ Heater Connections

From PWA —— A-35 —— B-4 —— To Heater (+24V Node)

From PWA —— A-36 —— B-3 —— To Amplifiers (RF) (+15V Node)

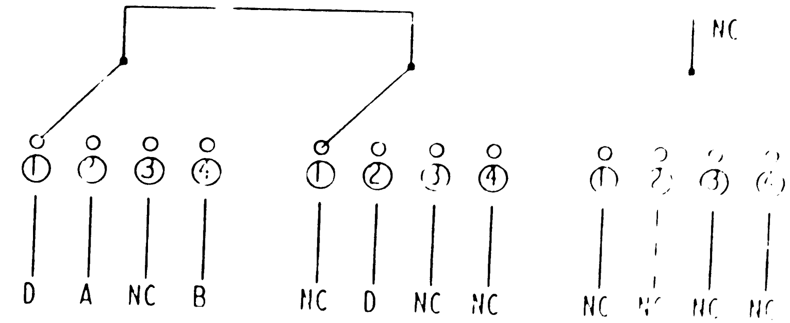
Timer Switch Replacement

Connection Pads Inside Of Timer

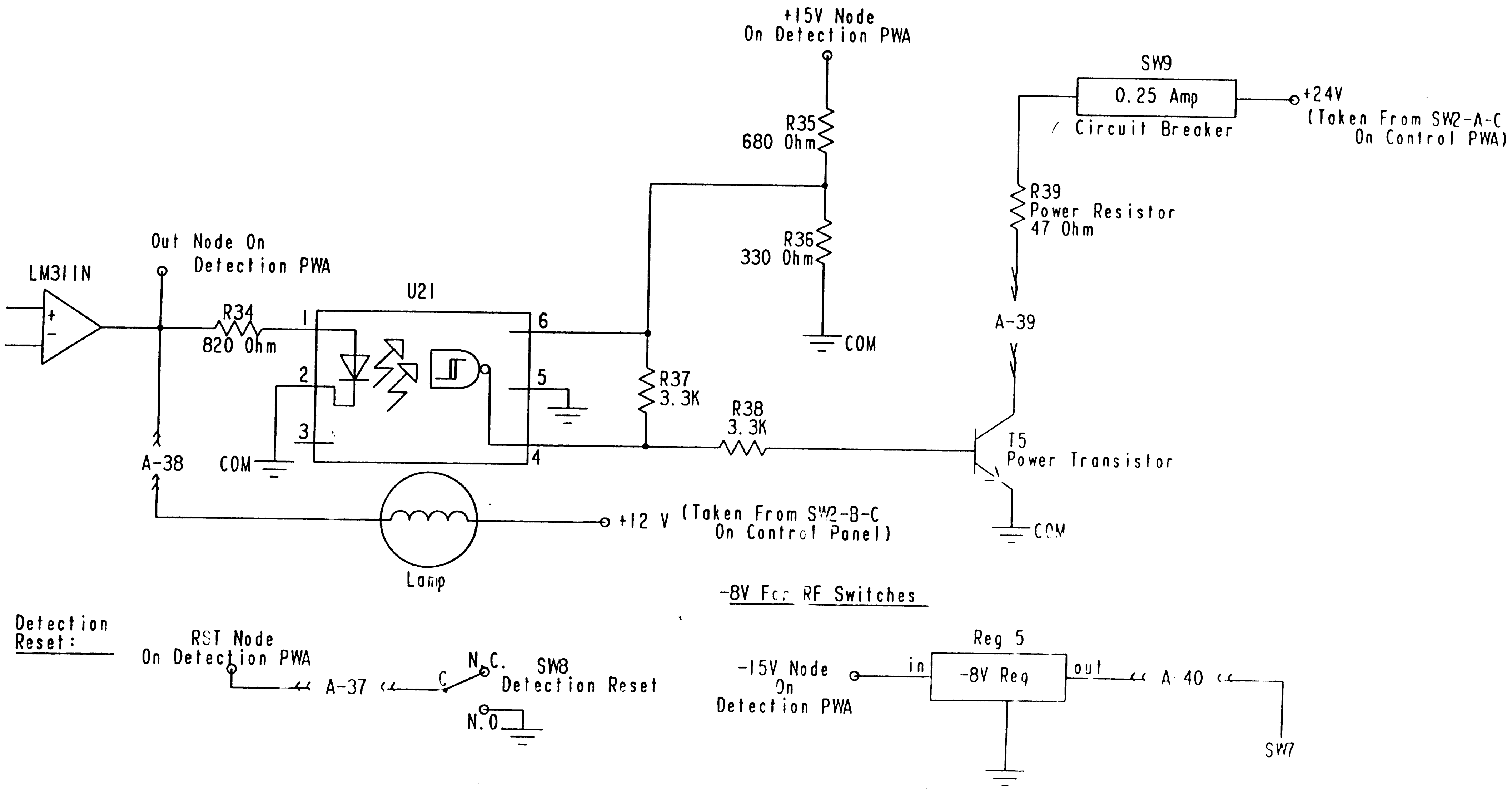


Function	Connected Pads	Position
Time Set	C, D	1
Alarm Set	A, C, D	2
Run - Alarm On	C	3
Run - Alarm Off	B, C	4

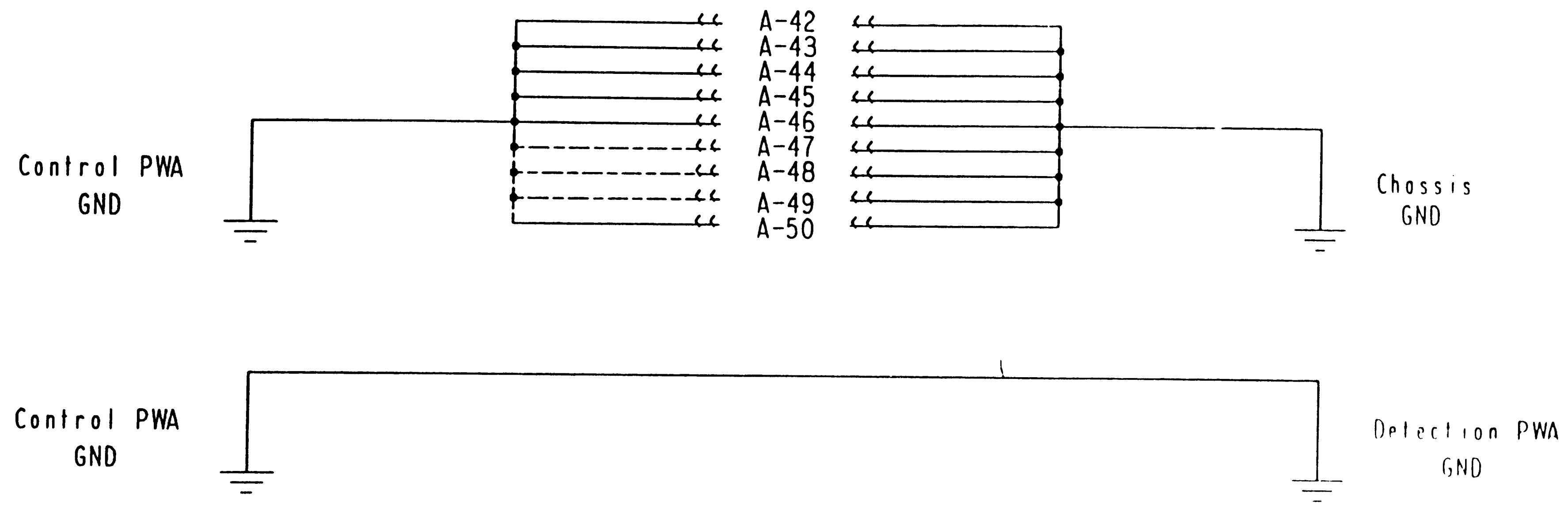
SW11 & SW12 (Timer Controls)
3 Pole - 4 Position Rotary Switch



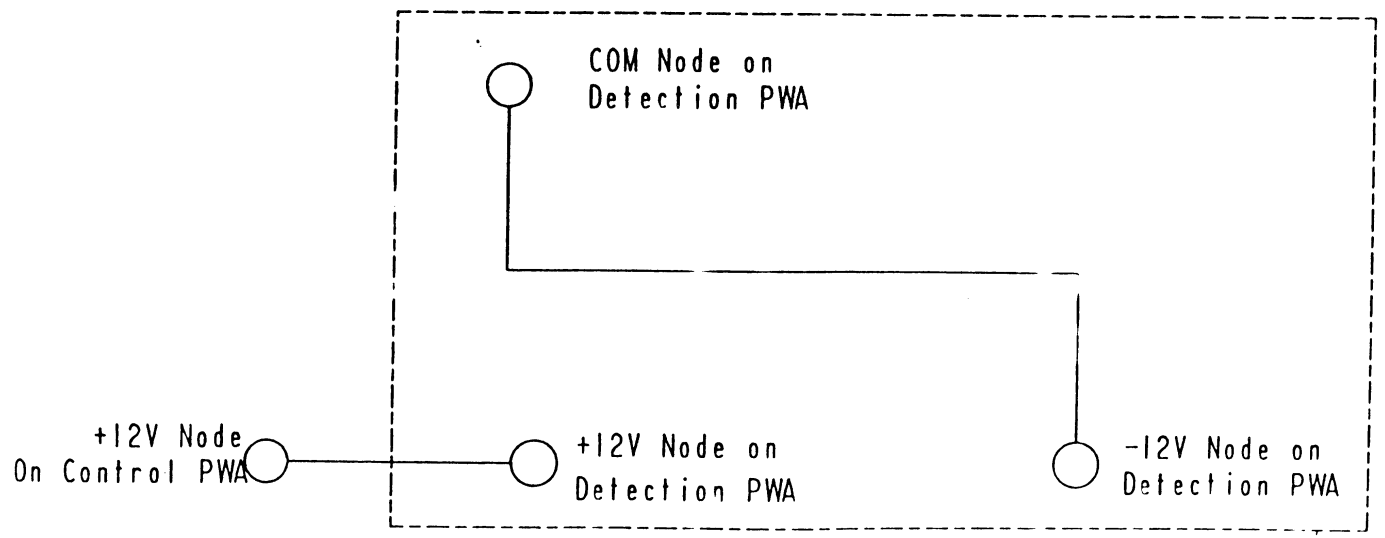
Modifications Made To Applied Microwave's Detection Circuitry



GROUND CONNECTIONS



POWER CONNECTIONS



APPENDIX D

MEASUREMENT AND CALIBRATION PROGRAMS

```
!*****************************************************************************
!
!                              Appendix D
!              Scatterometer Calibration Program (Fortran)
!
!                JPL AIRSAR / NASA SIR-C SAPARC Project
!
!                            James J. Ahne
!                        Radiation Laboratory
!       Department of Electrical Engineering and Computer Science
!            University of Michigan, Ann Arbor, MI  48109-2122
!
!*****************************************************************************
C
C   THIS PROGRAM CALIBRATES THE SCATTEROMETERS USING THE NEW METHOD.
C
        COMPLEX C,A,A11,A12,A21,A22
        COMPLEX EVV0(21),EHH0(21),EVH0(21),EHV0(21)
        COMPLEX EVVU(150,21),EHHU(150,21),EVHU(150,21),EHVU(150,21)
        COMPLEX S11(150,21),S22(150,21),S12(150,21),S21(150,21)
        complex SIG11,SIG22,SIG12,SIG21
        character*1,char
        COMPLEX S0(21)
        open(9,file='sph_14')
        open(10,file='sph14_1')
        open(13,file='lparc_2_00')
        PI=4.*ATAN(1.)
        ndata=11
        ntrace=81
c         cir=(0.6945+1.333)/(1.994+2.424)
C   READ THEORETICAL VALUE OF SPHERE
        DO I=1,ndata
        READ(9,*)DUM,S0(I)
        ENDDO
C  SPHERE DATA
       READ(10,103)
         DO I=1,ndata
         READ(10,*) evv0(I)
         ENDDO
       READ(10,103)
        DO I=1,ndata
        READ(10,*) ehh0(I)
        ENDDO
       READ(10,103)
        DO I=1,ndata
        READ(10,*) ehv0(I)
        ENDDO
       READ(10,103)
         DO I=1,ndata
         READ(10,*) evh0(I)
         ENDDO
c        do i=1,ndata
c        print *,20*alog10(cabs(evv0(i))),20*alog10(cabs(ehv0(i))),
c    &           20*alog10(cabs(evh0(i))),20*alog10(cabs(ehh0(i)))
c        enddo
c        pause
C UNKNOWN DATA
      DO ITRACE=1,ntrace
        READ(13,103)
103     FORMAT(1X)
         DO I=1,ndata
         READ(13,*) EVVU(ITRACE,I)
         ENDDO
        READ(13,103)
         DO I=1,ndata
         READ(13,*) EHHU(ITRACE,I)
         ENDDO
         READ(13,103)
         DO I=1,ndata
         READ(13,*) EHVU(ITRACE,I)
         ENDDO
         READ(13,103)
          DO I=1,ndata
          READ(13,*) EVHU(ITRACE,I)
          ENDDO
         ENDDO
c         do itrace=1,ntrace
c         print *,20*alog10(cabs(evvu(ITRACE,4))),
c     &            20*alog10(cabs(ehvu(itrace,4))),
c     &            20*alog10(cabs(evhu(itrace,4))),
c     &            20*alog10(cabs(ehhu(itrace,4)))
C         enddo
C
C this is a calibration based on c1=c2
        DO ITRACE=1,NTRACE
        DO I=1,ndata
          A=EVH0(I)*EHV0(I)/(EVV0(I)*EHH0(I))
          C=(1-CSQRT(1-A))/CSQRT(A)
          A11=(EVVU(ITRACE,I)/EVV0(I))*(1+C**2)*S0(I)
          A22=(EHHU(ITRACE,I)/EHH0(I))*(1+C**2)*S0(I)
          A12=(EVHU(ITRACE,I)/EVH0(I))*(2*C)*S0(I)
          A21=(EHVU(ITRACE,I)/EHV0(I))*(2*C)*S0(I)
          S12(ITRACE,I)=(A12+C**2*A21-C*(A11+A22))/(1-C**2)**2
          S21(ITRACE,I)=(A21+C**2*A12-C*(A11+A22))/(1-C**2)**2
          S11(ITRACE,I)=(A11+C**2*A22-C*(A12+A21))/(1-C**2)**2
          S22(ITRACE,I)=(A22+C**2*A11-C*(A12+A21))/(1-C**2)**2
        ENDDO
c         PRINT *,ITRACE
       ENDDO
c
         open(15,file='lparc2_am_00')
         open(16,file='lparc2_ph_00')

         I=6
         mt=41

  10    continue
         print*,'input psi'
         read*,psi
         psi=psi*3.1415/180.

         sig11=s11(mt,i)*cos(psi)**2-sin(psi)*cos(psi)*(s12(mt,i)
      &        +s21(mt,i)) +s22(mt,i)*sin(psi)**2
         sig22=s11(mt,i)*sin(psi)**2+sin(psi)*cos(psi)*(s12(mt,i)
      &        +s21(mt,i))+s22(mt,i)*cos(psi)**2
         sig12=sin(psi)*cos(psi)*(s11(mt,i)-s22(mt,i))-sin(psi)**2
      &        *s21(mt,i)+cos(psi)**2*s12(mt,i)
         sig21=sin(psi)*cos(psi)*(s11(mt,i)-s22(mt,i))-sin(psi)**2
      &        *s12(mt,i)+cos(psi)**2*s21(mt,i)
         print*,cabs(sig11),cabs(sig22),cabs(sig12),cabs(sig21)

         print*,'0 for renew of psi,  1 for stop'
         read*,jnk
         if(jnk .eq.0)goto 10
         DO ITR=1,NTRACE
          ANG=(ITR-int(ntrace/2)-1.)*1.
         sig11=s11(itr,i)*cos(psi)**2-sin(psi)*cos(psi)*(s12(itr,i)
      &       +s21(itr,i)) +s22(itr,i)*sin(psi)**2
```

```
      sig22=s11(itr,i)*sin(psi)**2+sin(psi)*cos(psi)*(s12(itr,i)
     &      +s21(itr,i))+s22(itr,i)*cos(psi)**2
      sig12=sin(psi)*cos(psi)*(s11(itr,i)-s22(itr,i))-sin(psi)**2
     &      *s21(itr,i)+cos(psi)**2*s12(itr,i)
      sig21=sin(psi)*cos(psi)*(s11(itr,i)-s22(itr,i))-sin(psi)**2
     &      *s12(itr,i)+cos(psi)**2*s21(itr,i)
      s11(itr,i)=sig11
      s22(itr,i)=sig22
      s12(itr,i)=sig12
      s21(itr,i)=sig21

       WRITE(15,*)ANG,10.*ALOG10(4.*PI*cabs(S11(ITR,I))**2)
     &             ,10.*ALOG10(4.*PI*cabs(S22(ITR,I))**2)
     &             ,10.*ALOG10(4.*PI*cabs(S12(ITR,I))**2)
     &             ,10.*ALOG10(4.*PI*cabs(S21(ITR,I))**2)
      WRITE(16,*)ANG,PHASE(S22(ITR,I)/S11(ITR,I))
     &              ,PHASE(S12(ITR,I)/S11(ITR,I))
     &              ,PHASE(S21(ITR,I)/S11(ITR,I))
      ENDDO
      STOP
      END
C*********************************************************************
C
      FUNCTION PHASE(Z)
C
C********************************************************************
      COMPLEX Z
      PI=4.*ATAN(1.)
      X=REAL(Z)
      Y=AIMAG(Z)
      PHASE=(180./PI)*ATAN2(Y,X)
      if(phase.lt.-150.0) phase=phase+360
      RETURN
      END
```

```
!***************************************************************************
!
!                              Appendix D
!              HP Basic Scatterometer Measurement Program
!
!                 JPL AIRSAR / NASA SIR-C SAPARC Project
!
!                             James J. Ahne
!                          Radiation Laboratory
!         Department of Electrical Engineering and Computer Science
!              University of Michigan, Ann Arbor, MI  48109-2122
!
!***************************************************************************
!
10    !**********************************************************************
20    !   L/C/X POLARIMETER MEASUREMENT PROGRAM
30    !       FILE: LPARC_2
40    !**********************************************************************
50    !   LAST EDIT: Dec 8, 1993      Change for L-Band SAPARC measurements
60    !
70    !**********************************************************************
80    OPTION BASE 1
90    COM /Paths/ @Nwa,@Nwa_data1,@Nwa_data2,Netwrk_analyzer,@Hpib,@Relay
100   COM /Constants/ Vel,Zero(3),Exec_key$[2]
110   COM /System_config/ INTEGER Printer_flag,Debug_flag,Version$[12],Mode$[10],Out_typ
e$[10],Sound$[3],Bell$[1],Target$[30],Ref_target$[30]
120   COM /Sys_1/ Freq$(3)[1],Freq_cent(3),Freq_span(3),Gate_cent(3),Gate_span(3)
130   COM /Sys_2/ Pol$(4)[2],Polsw$(3,4)[8]
140   COM /Sys_3/ INTEGER F_disp,P_disp
150   COM /Sys_4/ Drive_a$[15],Drive_b$[15],Drive_c$[15],INTEGER Preamble,Bytes
160   COM /Sys_5/ INTEGER Nskip,Ndata
170   COM /Sys_6/ Ref_angle,Angle,Angle$[10],Beam(3),INTEGER Npts,Ntrace,Average_factor
180   COM /Sys_7/ INTEGER Meas_flag(3)
190   COM /Com4/ INTEGER Rotation_state,REAL Inc_angle,Current_angle,Start_angle,Stop_an
gle,Old_home_angle,INTEGER Sets_per_pos
200   COM /Status/ INTEGER Sc,Connect_flg,E_flg,Debug_flg,Response$[80]
210   !
220   !
230   INTEGER F,I,J,P,T,Meas_flag_old(3),Exit_flag,Nt,Nst,Nskh,Npt
240   DIM Sky_cal_file$(3)[14],Old_target_name$[30]
250   DATA "L","C","X"                                     ! FREQUENCY
260   DATA "VV","HH","HV","VH"                             ! POLARIZATION
270   DATA 1.25,1.2,1.5                                    ! FREQ_CENT
280   DATA .3,.6,.5                                        ! FREQ_SPAN
290   DATA 12.5,9.0,6.2                                    ! BEAMWIDTH
300   DATA "?*B3456","?*A34B56","?*A4B356","?*A3B456"      ! L
310   DATA "?*B3456","?*A56B34","?*A6B345","?*A5B346"      ! C
320   DATA "?*A34B56","?*B3456","?*A3B456","?*A4B356"      ! X
330   DATA ":,700,0",":,700,1",":MEMORY,0,7"               ! DRIVE_A,B,C
340   DATA 200E-9,200E-9,200E-9                            ! GATE CENTERS
350   DATA 10E-9,10E-9,10E-9                               ! GATE SPANS
360   READ Freq$(*)
370   READ Pol$(*)
380   READ Freq_cent(*)
390   READ Freq_span(*)
400   READ Beam(*)
410   READ Polsw$(*)
420   READ Drive_a$,Drive_b$,Drive_c$
430   READ Gate_cent(*),Gate_span(*)
440   PRINT Meas_flag(*)
450   !
460   ! Set up error handling routine.
470   !
480   LOAD KEY "NOKEY:MEMORY,0,1"
490   MASS STORAGE IS "JIM_CPARC:,700,0"
500   !
510   !
520   ! Initialize important parameters.
530   !
540   DEG
550   Rotation_state=-1
560   Current_angle=0.
570   MAT Meas_flag= (1)
580   Mode$="FAST ACQ"
590   F_disp=1
600   P_disp=2
610   Printer_flag=0
620   !
630   Hp_bus_init
640   IF Printer_flag=1 THEN Out_type$="PRINT/DISC"
650   !
660   Vel=2.99792458E+8
670   Ntrace=81
680   Npts=401
690   Nskip=40
700   Ndata=11
710   Average_factor=4
720   Angle$="0"
730   Angle=0
740   Ref_angle=0
750   Target$=""
760   Sound$="ON "
770   Debug_flag=0
780   Bell$=CHR$(7)
790   Exec_key$=CHR$(255)&CHR$(88)
800   Version$="Version 8.0 "
810   Exit_flag=0
820   Print_banner1
830   !
840   System_memory=VAL(SYSTEM$("AVAILABLE MEMORY"))
850   IF FNAsk("INITIALIZE RAM DISK?") THEN
860      INITIALIZE Drive_c$,0
870      INITIALIZE Drive_c$,INT((System_memory)/512)
880   ELSE
890      ASSIGN @Is_it_there TO Drive_c$;RETURN Outcome
900      IF Outcome=0 THEN
910         CAT Drive_c$;NO HEADER,COUNT Entries
920         IF Entries=0 THEN INITIALIZE Drive_c$,0
930      END IF
940      ASSIGN @Is_it_there TO *
950   END IF
960   !
970   Config_and_poll
980   OUTPUT @Nwa;"TIMDTRANON;LOGM;CONT;"
990   OUTPUT @Nwa;"POIN401;"
1000 ! OUTPUT @Relay;"?*B1256A34"
1010  Series_init
1020  !
1030  !
1040 Start_loop: !
1050             !
1060     Print_banner4
1070        ON KEY 0 LABEL "                  ",FNTrap_level GOSUB Null
1080        ON KEY 1 LABEL " REFERENCE CAL",FNTrap_level GOSUB Ref_target
1090        ON KEY 2 LABEL "  TARGET RUN  ",FNTrap_level GOSUB Acq_target
1100        ON KEY 3 LABEL " SET FREQUENCY",FNTrap_level GOSUB Freq_set
1110        ON KEY 4 LABEL "    ANGLE     ",FNTrap_level GOSUB Set_angle
1120        ON KEY 5 LABEL " T[illegible]  ",FNTrap_level [illegible] Set_[illegible]
```

```
1130        ON KEY 6 LABEL " # OF TRACES  ",FNTrap_level GOSUB Set_traces
1140        ON KEY 7 LABEL " # OF POINTS  ",FNTrap_level GOSUB Set_points
1150        ON KEY 8 LABEL "# OF AVERAGES ",FNTrap_level GOSUB Set_average
1160        ON KEY 9 LABEL "     QUIT     ",FNTrap_level GOTO Quit_fast_acq
1170     GOSUB Allocate_matrix
1180     LOOP
1190        EXIT IF Exit_flag=1
1200     END LOOP
1210     GOSUB Deallocate_mtrx
1220     Exit_flag=0
1230     GOTO Start_loop
1240     !
1250 Null: RETURN
1260 !
1270 !--------------------------------------------------------------------------------
1280 !
1290 Ref_target: ! Acquire a reference target data set.
1300             !
1310     OFF KEY
1320     Clear_crt
1330     OUTPUT @Nwa;"TIMDTRANON; LOGM; GATEOFF;"
1340     OUTPUT @Nwa;"AUTO; ELED 100NS; STAR ONS; STOP 300NS;"
1350     PRINT TABXY(1,10);"Please point scatterometer assembly to reference  target."
1360     PRINT TABXY(1,12);"Press CONTINUE when ready..."
1370     PAUSE
1380     GOSUB Set_gates
1390     OUTPUT @Nwa;"TIMDTRANOFF; POLA; AVERFACT";VAL$(Average_factor);";"
1400     OUTPUT @Nwa;"AVEROON"
1410     INPUT "Enter the reference target angle: ",Ref_angle
1420     !
1430     ! Get the reference target response.
1440     !
1450     FOR T=1 TO Ntrace
1460     FOR F=1 TO 3
1470        IF Meas_flag(F) THEN
1480           Freq_set(F)
1490           Freq_sw(F)
1500               OUTPUT @Nwa;"GATEOFF;"
1510               OUTPUT @Nwa;"GATECENT";VAL$(Gate_cent(F));"S;"
1520               OUTPUT @Nwa;"GATESPAN";VAL$(Gate_span(F));"S;"
1530               OUTPUT @Nwa;"GATEON;"
1540               OUTPUT @Nwa;"TIMDTRANOFF;POLA;"
1550           FOR P=1 TO 4
1560               Pol_sw(F,P)
1570               OUTPUT @Nwa;"FORM3;NUMG";VAL$(Average_factor+1);";WAIT"
1580               OUTPUT @Nwa;"WAIT; OUTPFORM;"
1590               ENTER @Nwa_data1;Preamble,Bytes,Trace(*)
1600               MAT Target_response(P,*)= Trace
1610           NEXT P
1620                  Nskh=Nskip+1
1630           FOR P=1 TO 4
1640                  FOR Nt=Nskh TO Npts STEP Nskip
1650                      Nst=INT(Nt/Nskip)
1660                      Target_data(T,P,Nst)=Target_response(P,Nt)
1670                  NEXT Nt
1680           NEXT P
1690        END IF
1700     NEXT F
1710     NEXT T
1720     Store_file(Target_data(*),"REF",FNTime_stamp$,F)
1730     !
1740     ! Get the reference target mount response.
1750     !
1760     BEEP
1770     PRINT TABXY(1,10);"Please remove the reference target from its mount."
1780     PRINT TABXY(1,12);"Press CONTINUE when ready..."
1790     PAUSE
1800     Clear_crt
1810     PRINT TABXY(1,14);"Data for the mount is being collected .... "
1820     FOR T=1 TO Ntrace
1830     FOR F=1 TO 3
1840        IF Meas_flag(F) THEN
1850           Freq_set(F)
1860           Freq_sw(F)
1870               OUTPUT @Nwa;"GATEOFF;"
1880               OUTPUT @Nwa;"GATECENT";VAL$(Gate_cent(F));"S;"
1890               OUTPUT @Nwa;"GATESPAN";VAL$(Gate_span(F));"S;"
1900               OUTPUT @Nwa;"GATEON;"
1910           FOR P=1 TO 4
1920               Pol_sw(F,P)
1930               OUTPUT @Nwa;"FORM3;NUMG";VAL$(Average_factor+1);";WAIT"
1940               OUTPUT @Nwa;"WAIT; OUTPFORM;"
1950               ENTER @Nwa_data1;Preamble,Bytes,Trace(*)
1960               MAT Target_response(P,*)= Trace
1970           NEXT P
1980                  Nskh=Nskip+1
1990           FOR P=1 TO 4
2000                  FOR Nt=Nskh TO Npts STEP Nskip
2010                      Nst=INT(Nt/Nskip)
2020                      Target_data(T,P,Nst)=Target_response(P,Nt)
2030                  NEXT Nt
2040           NEXT P
2050        END IF
2060     NEXT F
2070     NEXT T
2080     Store_file(Target_data(*),"MNT",FNTime_stamp$,F)
2090     Pol_sw(F_disp,P_disp)
2100     DISP "Reference target mount response saved."
2110     Exit_flag=1
2120 RETURN
2130 !
2140 !
2150 !
2160 Acq_target: !
2170             !
2180     OFF KEY
2190     Clear_crt
2200     OUTPUT @Nwa;"TIMDTRANON; LOGM; GATEOFF;"
2210     OUTPUT @Nwa;"ELED 100NS; STAR ONS; STOP 300NS;"
2220     PRINT TABXY(1,10);"Please point scatterometer assembly at surface target."
2230     PRINT TABXY(1,12);"Press CONTINUE when ready..."
2240     PAUSE
2250     GOSUB Set_gates
2260     OUTPUT @Nwa;"TIMDTRANOFF; POLA; AVERFACT";VAL$(Average_factor);";"
2270     OUTPUT @Nwa;"GATEOFF;AVEROON;"
2280     !
2290     ! Get the target response.
2300     !
2310     FOR T=1 TO Ntrace
2320     !
2330     ! Get angles
2340     !
2350     IF T=1 THEN
2360        Rotation_state=-1
2370     ELSE
2380        Rotation_state=2
2390     END IF
2400     SELECT Rotation_state
```

```
2410       CASE =0
2420            Clear_crt
2430            PRINT TABXY(1,4);"When ready for measurement, press CONTINUE."
2440            BEEP
2450            PAUSE
2460            Clear_crt(3,16)
2470            PRINT TABXY(1,4);"Collecting data... "
2480       CASE ELSE
2490            PRINT TABXY(1,4);"Current angle is ";Current_angle;" degrees."
2500            Rotate_target    !
2510            WAIT 1
2520            Clear_crt(3,16)
2530            PRINT TABXY(1,4);"Collecting data ..."
2540       END SELECT
2550           FOR F=1 TO 3
2560            IF Meas_flag(F) THEN
2570              Freq_set(F)
2580              Freq_sw(F)
2590              OUTPUT @Nwa;"GATEOFF;"
2600              OUTPUT @Nwa;"GATECENT";VAL$(Gate_cent(F));"S;"
2610              OUTPUT @Nwa;"GATESPAN";VAL$(Gate_span(F));"S;"
2620              OUTPUT @Nwa;"GATEON; WAIT;"
2630        PRINT Npts,Ntrace,Ndata,Nskip
2640              FOR P=1 TO 4
2650                Pol_sw(F,P)
2660                OUTPUT @Nwa;"NUMG";VAL$(Average_factor);";WAIT; FORM3; OUTPFORM;"
2670                ENTER @Nwa_data1;Preamble,Bytes,Trace(*)
2680                MAT Target_response(P,*)= Trace
2690              NEXT P
2700              Nskh=Nskip+1
2710              FOR P=1 TO 4
2720                FOR Nt=Nskh TO Npts STEP Nskip
2730                  Nst=INT(Nt/Nskip)
2740                  Target_data(T,P,Nst)=Target_response(P,Nt)
2750                NEXT Nt
2760              NEXT P
2770            END IF
2780          NEXT F
2790          PRINT "# OF TRACES LEFT=",Ntrace-T
2800       NEXT T
2810       Store_file(Target_data(*),"GND",FNTime_stamp$,F)
2820       DISP "Surface target data saved."
2830       BEEP
2840         Rotation_state=4
2850         Rotate_target
2860       WAIT 5
2870       BEEP
2880       OUTPUT @Nwa;"CONT;"
2890       Exit_flag=1
2900 RETURN
2910 !
2920 !-------------------------------------------------------------------------
2930 !
2940 Freq_set: GOSUB Deallocate_mtrx
2950            OFF KEY
2960          MAT Meas_flag_old= Meas_flag
2970          MAT Meas_flag= (0)
2980 !        Exit_flag=0
2990 !           ON KEY 0 LABEL "    L BAND    ",FNTrap_level GOSUB Set_l
3000 !           ON KEY 1 LABEL "    C BAND    ",FNTrap_level GOSUB Set_c
3010 !           ON KEY 2 LABEL "    X BAND    ",FNTrap_level GOSUB Set_x
3020 !           ON KEY 4 LABEL "    STORE     ",FNTrap_level GOTO Store_band
3030 !           ON KEY 5 LABEL "              ",FNTrap_level GOSUB Null
3040 !           ON KEY 6 LABEL "              ",FNTrap_level GOSUB Null
```

```
3050 !           ON KEY 7 LABEL "              ",FNTrap_level GOSUB Null
3060 !           ON KEY 8 LABEL "              ",FNTrap_level GOSUB Null
3070 !           ON KEY 9 LABEL "    CANCEL    ",FNTrap_level GOTO Cancel_band
3080 !        LOOP
3090 !           EXIT IF Exit_flag=1
3100 !        END LOOP
3110          GOSUB Set_c
3120          GOTO Store_band
3130 RETURN
3140 Set_l:     OFF KEY 0
3150            Meas_flag(1)=1
3160            F_disp=1
3170 RETURN
3180 Set_c:     OFF KEY 1
3190            Meas_flag(2)=1
3200            F_disp=2
3210 RETURN
3220 Set_x:     OFF KEY 2
3230            Meas_flag(3)=1
3240            F_disp=3
3250 RETURN
3260 Store_band: Print_banner4
3270               Exit_flag=1
3280               GOSUB Allocate_matrix
3290 RETURN
3300 Cancel_band: !
3310                MAT Meas_flag= Meas_flag_old
3320                Exit_flag=1
3330                GOSUB Allocate_matrix
3340 RETURN
3350 !
3360 !------------------------------------------------------------------------
3370 !
3380 Set_angle:  !
3390               INPUT "Enter measurement angle: ",Angle
3400               Angle$=VAL$(Angle)&CHR$(179)&"    "    ! Degree sign.
3410               Print_banner4
3420 RETURN
3430 !
3440 !------------------------------------------------------------------------
3450 !
3460 Set_target: !
3470               LINPUT "Enter target type or name: ",Target$
3480               Target$=TRIM$(Target$)
3490               Target$=Target$&RPT$(" ",30-LEN(Target$))
3500               Print_banner4
3510 RETURN
3520 !
3530 !------------------------------------------------------------------------
3540 !
3550 Set_traces: !
3560               INPUT "Enter the number of traces( or angles) desired( >=3 ): ",Ntrace
3570               GOSUB Deallocate_mtrx
3580               GOSUB Allocate_matrix
3590               Print_banner4
3600 RETURN
3610 !
3620 !------------------------------------------------------------------------
3630 Set_points: !
3640               INPUT "Enter the number of sample points (Npts,201): ",Npts
3650               OUTPUT @Nwa;"POIN "&VAL$(Npts)&";"
3660               INPUT "Enter the data points to be stored (Ndata,10):",Ndata
3670               Nskip=INT(Npts/Ndata)
3680               Bytes=16*Ndata
```

```
3690             Print_banner4
3700             GOSUB Deallocate_mtrx
3710             GOSUB Allocate_matrix
3720 RETURN
3730 !
3740 !------------------------------------------------------------------------
3750 !
3760 Set_average: !
3770              INPUT "Enter averaging factor: ",Average_factor
3780              Print_banner4
3790 RETURN
3800 !
3810 !------------------------------------------------------------------------
3820 !
3830 Allocate_matrix: ! Allocate storage space for data.
3840                  !
3850      System_memory=VAL(SYSTEM$("AVAILABLE MEMORY"))
3860      Avail_traces=MIN(Ntrace,INT(System_memory-50000-3*4*16.*Npts)/(3*4*16.*Ndata))
3870      IF Avail_traces<Ntrace THEN
3880         BEEP
3890         PRINT TABXY(1,16);"Memory has capacity for only ";Avail_traces;" traces."
3900         PRINT "Press CONTINUE key to continue"
3910         PAUSE
3920         Ntrace=Avail_traces
3930      END IF
3940      ALLOCATE COMPLEX Trace(Npts),Target_response(4,Npts)
3950      ALLOCATE COMPLEX Target_data(Ntrace,4,Ndata)
3960   RETURN
3970 Deallocate_mtrx: ! Return to main program.
3980                  !
3990      DEALLOCATE Target_response(*),Trace(*)
4000      DEALLOCATE Target_data(*)
4010   RETURN
4020 !
4030 !------------------------------------------------------------------------
4040 !
4050 Set_gates: ! Set gate centers and spans.
4060            !
4070    FOR F=1 TO 3
4080        IF Meas_flag(F) THEN
4090           Freq_set(F)
4100           Freq_sw(F)
4110           P=3
4120               Pol_sw(F,P)
4130               OUTPUT @Nwa;"TIMDTRANON; LOGM;"
4140               OUTPUT @Nwa;"ELED 100NS; STAR 0NS; STOP 300NS; WAIT;"
4150               OUTPUT @Nwa;"FORM3; OUTPACTI;"
4160               ENTER @Nwa;Gate_cent(F)
4170               OUTPUT @Nwa;"MARKOFF;"
4180               OUTPUT @Nwa;"CONT;"
4190               OUTPUT @Nwa;"GATESPAN";VAL$(Gate_span(F));"S;"
4200               OUTPUT @Nwa;"GATECENT";VAL$(Gate_cent(F));"S;"
4210               OUTPUT @Nwa;"KEY41; KEY59; KEY58; KEY59;"
4220               LOCAL @Nwa
4230               DISP "Adjust gate center to suit, and press CONTINUE."
4240               PAUSE
4250               OUTPUT @Nwa;"OUTPACTI;"
4260               ENTER @Nwa;Gate_cent(F)
4270               OUTPUT @Nwa;"GATESPAN";VAL$(Gate_span(F));";"
4280               OUTPUT @Nwa;"KEY41; KEY59; KEY58; KEY4;"
4290               LOCAL @Nwa
4300               DISP "Adjust gate span to suit, and press CONTINUE."
4310               PAUSE
4320               OUTPUT @Nwa;"OUTPACTI;"
4330               ENTER @Nwa;Gate_span(F)
4340        END IF
4350    NEXT F
4360    RETURN
4370    !
4380    !------------------------------------------------------------------------
4390    !
4400 Quit_fast_acq: ! End of program
4410  DISP "PROGRAM EXIT"
4420  GOSUB Deallocate_mtrx
4430  LOAD KEY "EDITKEY:MEMORY,0,1"
4440  STOP
4450  END
4460  !
4470  !*************************************************************************
4480  !
4490  DEF FNAsk(Prompt$)
4500    OFF KEY
4510    DISP Prompt$;
4520    INPUT "",Yn$
4530    Yn$=UPC$(Yn$[1,1])
4540    SELECT Yn$
4550           CASE ="Y"
4560                RETURN 1
4570           CASE ="N",=""
4580                RETURN 0
4590           CASE ELSE
4600                RETURN 0
4610    END SELECT
4620  FNEND
4630  !
4640  !*************************************************************************
4650  !
4660  DEF FNFileloc$(File$,Dir$)
4670    INTEGER C  ! for the location of the ':' in Dir$ (minus 1)
4680    LET C=POS(Dir$,":")-1
4690    IF C<=0 THEN
4700      RETURN TRIM$(File$&Dir$)
4710    ELSE
4720      RETURN Dir$[1,C]&RPT$("/",Dir$[C,C]<>"/")&File$&Dir$[C+1,LEN(Dir$)]
4730    END IF
4740  FNEND ! Fileloc
4750  !
4760  !************************************************************************
4770  !
4780   DEF FNTime_stamp$(OPTIONAL Time_format)
4790       !
4800       DIM Time_digits$[4],Year_digits$[6]
4810       DIM Machine_time$[8],Machine_date$[11]
4820       REAL Timedate_now
4830       !
4840       Timedate_now=TIMEDATE
4850       Machine_date$=DATE$(Timedate_now)
4860       Machine_time$=TIME$(Timedate_now)
4870       Time_digits$=Machine_time$[1,2]&Machine_time$[4,5]
4880       Year_digits$[1,2]=Machine_date$[10,11]
4890       IF Machine_date$[1,1]=" " THEN Machine_date$[1,1]="0"
4900       !
4910       SELECT Machine_date$[4,6]
4920       CASE ="Jan"
4930            Year_digits$[3,4]="01"
4940       CASE ="Feb"
4950            Year_digits$[3,4]="02"
4960       CASE ="Mar"
```

```
4970            Year_digits$[3,4]="03"
4980       CASE ="Apr"
4990            Year_digits$[3,4]="04"
5000       CASE ="May"
5010            Year_digits$[3,4]="05"
5020       CASE ="Jun"
5030            Year_digits$[3,4]="06"
5040       CASE ="Jul"
5050            Year_digits$[3,4]="07"
5060       CASE ="Aug"
5070            Year_digits$[3,4]="08"
5080       CASE ="Sep"
5090            Year_digits$[3,4]="09"
5100       CASE ="Oct"
5110            Year_digits$[3,4]="10"
5120       CASE ="Nov"
5130            Year_digits$[3,4]="11"
5140       CASE ="Dec"
5150            Year_digits$[3,4]="12"
5160       END SELECT
5170       !
5180       Year_digits$[5,6]=Machine_date$[1,2]
5190       SELECT NPAR
5200       CASE =0
5210            RETURN Year_digits$[5,6]&Time_digits$
5220       CASE =1
5230            IF Time_format=1 THEN
5240               RETURN Year_digits$&Time_digits$
5250            END IF
5260            IF Time_format=2 THEN
5270               RETURN Year_digits$[3,6]&Time_digits$
5280            END IF
5290       END SELECT
5300   FNEND
5310   !
5320   !**********************************************************************
5330   !
5340   DEF FNTrap_level
5350       RETURN VAL(SYSTEM$("SYSTEM PRIORITY"))+1
5360   FNEND
5370   !
5380   !**********************************************************************
5390   !
5400  SUB Config_and_poll
5410      COM /Paths/ @Nwa,@Nwa_data1,@Nwa_data2,Netwrk_analyzer,@Hpib,@Relay
5420      COM /System/ System_memory
5430  !
5440  ! Find out what's out there.
5450  !
5460      ALLOCATE Device_list$(0:31)[20]
5470      ALPHA PEN 4
5480      KBD LINE PEN 3
5490      KEY LABELS PEN 5
5500      Clear_crt
5510      Netwrk_analyzer=0
5520      ALLOCATE Na_ident$[80]
5530      System_memory=VAL(SYSTEM$("AVAILABLE MEMORY")) ! How much memory for RAM-DISK
5540      PRINT "AVAILABLE MEMORY: ";System_memory;" BYTES"
5550      ON TIMEOUT 7,4 GOTO No_na       ! In case there is no network analyzer
5560 Is_na:  OUTPUT @Nwa;"FORM4; OUTPIDEN;"
5570         ENTER @Nwa_data2;Na_ident$
5580         IF POS(Na_ident$,"8510A") THEN Netwrk_analyzer=1
5590         IF POS(Na_ident$,"8510B") THEN Netwrk_analyzer=2
5600         IF POS(Na_ident$,"8720A") THEN Netwrk_analyzer=3
5610         IF POS(Na_ident$,"8720B") THEN Netwrk_analyzer=4
5620         IF POS(Na_ident$,"8753A") THEN Netwrk_analyzer=5
5630         IF POS(Na_ident$,"8753B") THEN Netwrk_analyzer=6
5640         LOCAL @Nwa
5650         PRINT
5660         PRINT Na_ident$
5670         PRINT Netwrk_analyzer
5680       !  Clear_crt
5690       PRINT
5700       PRINT
5710         IF Netwrk_analyzer=0 THEN
5720            !
5730            !
5740 No_na:     BEEP
5750            OFF CYCLE
5760            PRINT TABXY(1,5);"There is no active network analyzer on the HPIB bus."
5770            PRINT TABXY(1,6);"Please check connections, and press the RUN key."
5780            PRINT
5790            PRINT TABXY(1,7);"If you DO NOT want to use a network analyzer, press th
CONTINUE key."
5800            PAUSE
5810         END IF
5820         !
5830         !
5840 Check_hpib:  ! Check the rest of the bus
5850       ON TIMEOUT 7,.01 GOTO Nothing
5860       !
5870       FOR Device=700 TO 731
5880          DISP "Checking for device at address: ";Device
5890          Device_list$(Device-700)="NOTHING"
5900          ASSIGN @What_is_it TO Device
5910          Outcome=SPOLL(@What_is_it)
5920          Device_list$(Device-700)="SOMETHING"
5930          PRINT Device,"SOMETHING HERE","spoll: ";Outcome
5940          ASSIGN @What_is_it TO *
5950 Nothing: ! Skip to next device
5960       NEXT Device
5970       !
5980       OFF TIMEOUT 7
5990       ASSIGN @What_is_it TO *
6000       IF Device_list$(1)="SOMETHING" THEN
6010          DISP "Position the printer to Top-Of-Form and press CONTINUE..."
6020          PAUSE
6030          PRINTER IS PRT
6040          PRINT CHR$(27)&"&l1L"; ! Set Page Breaks
6050          Printer_flag=1
6060          PRINTER IS CRT
6070       END IF
6080       DEALLOCATE Na_ident$
6090       DEALLOCATE Device_list$(*)
6100       ABORT @Hpib
6110  SUBEXIT
6120  SUBEND
6130  !
6140  ! ****************************************************************
6150  !
6160  SUB Hp_bus_init
6170    COM /Paths/ @Nwa,@Nwa_data1,@Nwa_data2,Netwrk_analyzer,@Hpib,@Relay
6180    COM /Sys_1/ Freq$(*),Freq_cent(*),Freq_span(*),Gate_cent(*),Gate_span(*)
6190    COM /Sys_2/ Pol$(*),Polsw$(*)
6200    COM /System_config/ INTEGER Printer_flag,Debug_flag,Version$,Mode$,Out_type$,So
d$,Bell$,Target$,Ref_target$
6210    !
6220    !  This subroutine configures the HP-[illegible] and presets the [illegible]
```

```
6230    !
6240    ASSIGN @Hpib TO 7
6250    ASSIGN @Nwa TO 716
6260    ASSIGN @Nwa_data1 TO 716;FORMAT OFF
6270    ASSIGN @Nwa_data2 TO 716;FORMAT ON
6280    ASSIGN @Relay TO 710
6290    REMOTE @Hpib
6300    ABORT @Hpib
6310    CLEAR @Nwa
6320    IF Debug_flag=1 THEN OUTPUT @Nwa;"DEBUON;"
6330    IF Debug_flag=0 THEN
6340      OUTPUT @Nwa;"DEBUOFF;"
6350      OUTPUT @Nwa;"TITL """&Freq$(2)&" BAND   """
6360    END IF
6370  SUBEND
6380  !
6390  !***********************************************************************
6400  !
6410  SUB Series_init
6420  COM /System_config/ INTEGER Printer_flag,Debug_flag,Version$,Mode$,Out_type$,Sound
$,Bell$,Target$,Ref_target$
6430    DIM Input$[80]
6440    !
6450    !  This subroutine prints a header for the printout and sets the system
6460    !  date and time.
6470    !
6480    IF Printer_flag=1 THEN PRINTER IS PRT
6490    PRINT CHR$(12)
6500    Set_clock
6510 !  LINPUT "ENTER MEASUREMENT SERIES TITLE",Input$
6520 !  Preface$="*"&RPT$(" ",9)
6530 !  PRINT RPT$("*",70)
6540 !  PRINT Preface$&Input$
6550 !  LINPUT "ENTER OPERATOR NAME",Input$
6560 !  PRINT Preface$&Input$
6570    PRINTER IS CRT
6580    PRINT
6590    PRINT
6600    PRINT Preface$&"MEASUREMENT SERIES STARTED AT "&TIME$(TIMEDATE)
6610    PRINTER IS CRT
6620  SUBEND
6630  !
6640  !***********************************************************************
6650  !
6660  SUB Set_clock
6670      OPTION BASE 1
6680      INTEGER I
6690      DIM Chrono$[12],Month$(12)[3]
6700      Exec_key$=CHR$(255)&CHR$(88)
6710      READ Month$(*)
6720      DATA "JAN","FEB","MAR","APR","MAY","JUN","JUL","AUG","SEP","OCT","NOV","DEC"
6730      OUTPUT KBD;"SCRATCH KEY "&Exec_key$;
6740      Clear_crt
6750      PRINT "                              Current system date: ";DATE$(TIMEDATE)
6760      PRINT "                              Current system time: ";TIME$(TIMEDATE)
6770      PRINT
6780 Ask: LINPUT "Enter date and time (YYMMDDHHMMss) :",Chrono$
6790      IF Chrono$="" AND DATE$(TIMEDATE)<>" 1 Mar 1900" THEN
6800         Clear_crt
6810         SUBEXIT
6820      END IF
6830      Year$=VAL$(1900+VAL(Chrono$[1,2]))
6840      IF (VAL(Chrono$[3,4])<=0 OR VAL(Chrono$[3,4])>12) THEN
6850         BEEP
6860         PRINT "Incorrect month value."
6870         GOTO Ask
6880      END IF
6890      Year$=Month$(VAL(Chrono$[3,4]))&" "&Year$
6900      Year$=Chrono$[5,6]&" "&Year$
6910      SET TIMEDATE (DATE(Year$))
6920      IF (VAL(Chrono$[7,8]))>23 THEN
6930         BEEP
6940         PRINT "Incorrect hour value."
6950         GOTO Ask
6960      END IF
6970      Day$=Chrono$[7,8]&":"
6980      IF VAL(Chrono$[9,10])>59 THEN
6990         BEEP
7000         PRINT "Incorrect minute value."
7010         GOTO Ask
7020      END IF
7030      Day$=Day$&Chrono$[9,10]&":"
7040      IF (LEN(Chrono$)>10 AND LEN(Chrono$)=12) THEN
7050         IF VAL(Chrono$[11,12])>59 THEN
7060            BEEP
7070            PRINT "Incorrect seconds value."
7080            GOTO Ask
7090         END IF
7100         Day$=Day$&Chrono$[11,12]
7110      ELSE
7120         Day$=Day$&"00"
7130      END IF
7140      SET TIME TIME(Day$)
7150      Clear_crt
7160   SUBEXIT
7170   SUBEND
7180   !
7190   !***********************************************************************
7200   !
7210   SUB Fix_error
7220   SELECT ERRN
7230   CASE ELSE
7240        PRINTER IS CRT
7250        PRINT "ERROR ";ERRN
7260        PRINT ERRM$
7270        PRINT " PROGRAM IS PAUSED.  FIX ERROR, IF POSSIBLE, AND CONTINUE."
7280        PAUSE
7290   END SELECT
7300   SUBEND
7310   !
7320   !***********************************************************************
7330   !
7340  SUB Clear_crt(OPTIONAL INTEGER Start_line,Num_of_lines)
7350      !
7360      INTEGER I
7370      DIM Clear_line$[80]
7380      Clear_line$=""
7390      IF NPAR=0 THEN
7400         OUTPUT KBD;CHR$(255)&CHR$(75);
7410      ELSE
7420         PRINT TABXY(1,Start_line);"";RPT$(Clear_line$,Num_of_lines)
7430         PRINT TABXY(1,Start_line);"";
7440         SUBEXIT
7450      END IF
7460  SUBEND
7470  !
7480  !***********************************************************************
7490  !
```

```
7500 SUB Print_banner1
7510    Clear_crt
7520    PRINT
7530    PRINT
7540    PRINT TABXY(3,16);"**********************************************************"
7550    PRINT TABXY(4,16);"*                                                        *"
7560    PRINT TABXY(5,16);"*                        LCX                             *"
7570    PRINT TABXY(6,16);"*      UNIVERSITY OF MICHIGAN RADIATION LAB              *"
7580    PRINT TABXY(7,16);"*           L/C/X MEASUREMENT PROGRAM                    *"
7590    PRINT TABXY(8,16);"*                 (VERSION 8.0)                          *"
7600    PRINT TABXY(9,16);"*                                                        *"
7610    PRINT TABXY(10,16);"*               May 21, 1990                           *"
7620    PRINT TABXY(11,16);"*                                                       *"
7630    PRINT TABXY(12,16);"*********************************************************"
7640 SUBEXIT
7650 SUBEND
7660 !
7670 !*************************************************************************
7680 !
7690  SUB Print_banner2
7700  PRINT "Don't use Print_banner2."
7710  SUBEND
7720  !
7730  !************************************************************************
7740  !
7750  SUB Print_banner3
7760  PRINT "Don't use Print_banner3."
7770  SUBEND
7780 !
7790 !*************************************************************************
7800 !
7810  SUB Print_banner4
7820  COM /Paths/ @Nwa,@Nwa_data1,@Nwa_data2,Netwrk_analyzer,@Hpib,@Relay
7830  COM /Constants/ Vel,Zero(*),Exec_key$
7840  COM /System_config/ INTEGER Printer_flag,Debug_flag,Version$,Mode$,Out_type$,Soun
d$,Bell$,Target$,Ref_target$
7850  COM /Sys_1/ Freq$(*),Freq_cent(*),Freq_span(*),Gate_cent(*),Gate_span(*)
7860  COM /Sys_2/ Pol$(*),Polsw$(*)
7870  COM /Sys_3/ INTEGER F_disp,P_disp
7880  COM /Sys_4/ Drive_a$,Drive_b$,Drive_c$,INTEGER Preamble,Bytes
7890  COM /Sys_5/ INTEGER Nskip,Ndata
7900  COM /Sys_6/ Ref_angle,Angle,Angle$,Beam(*),INTEGER Npts,Ntrace,Average_factor
7910  COM /Sys_7/ INTEGER Meas_flag(*)
7920      !
7930      !
7940   OFF KEY
7950   Clear_crt
7960   PRINT
7970   PRINT
7980   PRINT "          PARAMETER                        CURRENT VALUE"
7990   PRINT
8000   PRINT "                    FREQUENCY              ";
8010   FOR F=1 TO 3
8020     IF Meas_flag(F) THEN PRINT Freq$(F)&" ";
8030   NEXT F
8040   PRINT "     "
8050   PRINT "       "
8060   PRINT "                    ANTENNA ANGLE          "&Angle$
8070   PRINT "                    TARGET TYPE            "&Target$
8080   PRINT "                    MEASUREMENT MODE       "&Mode$&"      "
8090 !  PRINT "                    CURRENT DISPLAY       "&Freq$(F_disp)&" "&Pol$(P_d
isp);
8100   PRINT "       "
8110   PRINT "                    # OF TRACES/SET        ";Ntrace
8120   PRINT "                    # OF SAMPLE POINTS     ";Npts
8130   PRINT "                    # OF DATA POINTS       ";Ndata
8140   PRINT "                     (to be stored)        "
8150   PRINT "                    # OF AVERAGES          ";Average_factor
8160 SUBEXIT
8170 SUBEND
8180 !
8190 !*************************************************************************
8200 !
8210 SUB Store_file(COMPLEX Matrix(*),File_type$,Filename$,INTEGER F)
8220     !
8230     COM /Sys_1/ Freq$(*),Freq_cent(*),Freq_span(*),Gate_cent(*),Gate_span(*)
8240     COM /Sys_2/ Pol$(*),Polsw$(*)
8250     COM /Sys_5/ INTEGER Nskip,Ndata
8260     COM /Sys_6/ Ref_angle,Angle,Angle$,Beam(*),INTEGER Npts,Ntrace,Average_factor
8270     COM /Sys_7/ INTEGER Meas_flag(*)
8280     COM /System_config/ INTEGER Printer_flag,Debug_flag,Version$,Mode$,Out_type$,S
und$,Bell$,Target$,Ref_target$
8290     !
8300     !
8310     INTEGER Records_per_set,T
8320     REAL Bytes_per_set
8330     DIM Suffix$[2]
8340     ALLOCATE COMPLEX Trace(Ndata)
8350     !
8360     !
8370     DISP "Saving file."
8380     SELECT File_type$
8390     CASE ="SKY"  ! Sky data.
8400             Bytes_per_set=16*Ndata
8410             Records_per_set=4*SUM(Meas_flag)*Ntrace
8420           IF SUM(Meas_flag)=3 THEN
8430             Suffix$="SA"
8440           ELSE
8450            FOR F=1 TO 3
8460              IF Meas_flag(F)=1 THEN
8470                Mf=F
8480              END IF
8490            NEXT F
8500            Suffix$="S"&Freq$(Mf)
8510           END IF
8520             GOSUB Save_hpux
8530 !           GOSUB Save_traces
8540           !
8550           !
8560     CASE ="REF"
8570           Bytes_per_set=16*Ndata
8580           Records_per_set=4*SUM(Meas_flag)*Ntrace
8590            IF SUM(Meas_flag)=3 THEN
8600             Suffix$="RA"
8610           ELSE
8620            FOR F=1 TO 3
8630              IF Meas_flag(F)=1 THEN
8640                Mf=F
8650              END IF
8660            NEXT F
8670            Suffix$="R"&Freq$(Mf)
8680           END IF
8690             GOSUB Save_hpux
8700 !           GOSUB Save_traces
8710           !
8720           !
8730     CASE ="MNT"
8740           Bytes_per_set=16*Ndata
```

```
8750          Records_per_set=4*SUM(Meas_flag)*Ntrace
8760           IF SUM(Meas_flag)=3 THEN
8770             Suffix$="MA"
8780           ELSE
8790            FOR F=1 TO 3
8800              IF Meas_flag(F)=1 THEN
8810                Mf=F
8820              END IF
8830            NEXT F
8840            Suffix$="M"&Freq$(Mf)
8850           END IF
8860             GOSUB Save_hpux
8870 !           GOSUB Save_traces
8880          !
8890          !
8900     CASE ="GND"
8910          Bytes_per_set=16*Ndata
8920          Records_per_set=Ntrace*4*SUM(Meas_flag)
8930           IF SUM(Meas_flag)=3 THEN
8940             Suffix$="GA"
8950           ELSE
8960            FOR F=1 TO 3
8970              IF Meas_flag(F)=1 THEN
8980                Mf=F
8990              END IF
9000            NEXT F
9010            Suffix$="G"&Freq$(Mf)
9020           END IF
9030             GOSUB Save_hpux
9040  !          GOSUB Save_traces
9050     END SELECT
9060     DEALLOCATE Trace(*)
9070     SUBEXIT
9080          !
9090          !
9100 Save_averaged: !
9110               ! Save the reference data file.
9120               !
9130    IF NOT Debug_flag THEN
9140       CREATE BDAT Filename$&Suffix$&Drive_c$,Records_per_set,Bytes_per_set
9150    END IF
9160    Base_record=0
9170    FOR F=1 TO 3
9180    IF Meas_flag(F)=1 THEN
9190    IF Debug_flag THEN
9200       ASSIGN @Disc TO PRT
9210       OUTPUT @Disc;"FILE: ",Filename$,Suffix$
9220       OUTPUT @Disc USING Image_1;Version$,Freq_cent(F),Freq_span(F)
9230       OUTPUT @Disc USING Image_2;Ndata,Average_factor
9240       OUTPUT @Disc USING Image_3;Ref_target$,T
9250       FOR P=1 TO 4
9260           OUTPUT @Disc USING Image_4;Pol$(P),Gate_cent(F),Gate_span(F)
9270           MAT Trace= Matrix(1,P,*)
9280           OUTPUT @Disc;Trace(*)
9290       NEXT P
9300     ELSE
9310       ASSIGN @Disc TO Filename$&Suffix$&Drive_c$;FORMAT OFF
9320       OUTPUT @Disc,Base_record+1;Version$,Freq_cent(F),Freq_span(F)
9330       OUTPUT @Disc,Base_record+1;Ndata,Average_factor
9340       OUTPUT @Disc,Base_record+1;Ref_target$,T
9350       FOR P=1 TO 4
9360           OUTPUT @Disc,Base_record+P;Pol$(P),Gate_cent(F),Gate_span(F)
9370           MAT Trace= Matrix(1,P,*)
9380           OUTPUT @Disc,Base_record+P;Trace(*)
9390           NEXT P
9400           Base_record=Base_record+4
9410       END IF
9420       END IF
9430       NEXT F
9440       ASSIGN @Disc TO *
9450 RETURN
9460  !
9470  !-----------------------------------------------------------------
9480  !
9490 Save_hpux: !
9500               ! Save data in HP-UX format.
9510               !
9520    IF NOT Debug_flag THEN
9530       CREATE Filename$&Suffix$&Drive_c$,240000
9540    END IF
9550    IF Debug_flag THEN
9560       ASSIGN @Disc TO PRT
9570       FOR T=1 TO Ntrace
9580         FOR F=1 TO 3
9590          IF Meas_flag(F)=1 THEN
9600           FOR P=1 TO 4
9610               MAT Trace= Matrix(T,P,*)
9620               OUTPUT @Disc;Trace(*)
9630           NEXT P
9640          END IF
9650         NEXT F
9660        NEXT T
9670    ELSE
9680       ASSIGN @Disc TO Filename$&Suffix$&Drive_c$;FORMAT ON
9690       FOR T=1 TO Ntrace
9700         FOR F=1 TO 3
9710         IF Meas_flag(F)=1 THEN
9720           FOR P=1 TO 4
9730               MAT Trace= Matrix(T,P,*)
9740                OUTPUT @Disc;Trace(*)
9750            NEXT P
9760          END IF
9770         NEXT F
9780       NEXT T
9790    END IF
9800    ASSIGN @Disc TO *
9810  RETURN
9820  !
9830  !-----------------------------------------------------------------
9840  !
9850 Save_traces: !
9860               ! Save the ground target data file.
9870               !
9880    IF NOT Debug_flag THEN
9890       CREATE BDAT Filename$&Suffix$&Drive_c$,Records_per_set,Bytes_per_set
9900       Base_record=0
9910    END IF
9920    IF Debug_flag THEN
9930       ASSIGN @Disc TO PRT
9940       OUTPUT @Disc;"FILE: ";Filename$;Suffix$
9950       OUTPUT @Disc USING Image_5;Ndata,Ntrace
9960       OUTPUT @Disc USING Image_3;Target$
9970       FOR T=1 TO Ntrace
9980         FOR F=1 TO 3
9990          IF Meas_flag(F)=1 THEN
10000          OUTPUT @Disc USING Image_1;Version$,Freq_cent(F),Freq_span(F)
10010          FOR P=1 TO 4
10020              OUTPUT @Disc USING Image_4;Pol$(P),Gate_cent(F),Gate_span(F),T
```

```
10030             MAT Trace= Matrix(T,P,*)
10040             OUTPUT @Disc;Trace(*)
10050           NEXT P
10060          END IF
10070         NEXT F
10080        NEXT T
10090    ELSE
10100       ASSIGN @Disc TO Filename$&Suffix$&Drive_c$;FORMAT OFF
10110 !      OUTPUT @Disc,1;Ndata,Ntrace
10120 !      OUTPUT @Disc,1;Target$
10130       FOR T=1 TO Ntrace
10140         FOR F=1 TO 3
10150         IF Meas_flag(F)=1 THEN
10160 !         OUTPUT @Disc,Base_record+1;Version$,Freq_cent(F),Freq_span(F)
10170           FOR P=1 TO 4
10180 !              OUTPUT @Disc,Base_record+P;Pol$(P),Gate_cent(F),Gate_span(F),T
10190             MAT Trace= Matrix(T,P,*)
10200              OUTPUT @Disc,Base_record+P;Trace(*)
10210            NEXT P
10220           Base_record=Base_record+4
10230          END IF
10240         NEXT F
10250       NEXT T
10260    END IF
10270    ASSIGN @Disc TO *
10280 RETURN
10290 !
10300 !------------------------------------------------------------------------
10310 !
10320 Image_1:IMAGE (1X,12A,5X,"FREQ CENTER: ",2D.4D,5X,"FREQ SPAN: ",2D.4D)
10330 Image_2:IMAGE ("NUMBER OF POINTS: ",5D,5X,"NUMBER OF AVERAGES: ",5D)
10340 Image_3:IMAGE ("TARGET: ",30A,"GATING TARGET TYPE: ",2D)
10350 Image_4:IMAGE ("POLARIZATION: ",2A,5X,"GATE CENTER: ",SD.14DE,/,5X,"GATE SPAN: ",S
D.14DE,"TRACE: ",3D)
10360 Image_5:IMAGE ("NUMBER OF POINTS: ",5D,5X,"NUMBER OF TRACES: ",5D)
10370 Image_6:IMAGE (5X,SD.14DE,5X,SD.14DE)
10380 SUBEND
10390 !
10400 !*********************************************************************
10410 !
10420 SUB Freq_set(INTEGER Ifreq)
10430 COM /Paths/ @Nwa,@Nwa_data1,@Nwa_data2,Netwrk_analyzer,@Hpib,@Relay
10440 COM /Sys_1/ Freq$(*),Freq_cent(*),Freq_span(*),Gate_cent(*),Gate_span(*)
10450   !
10460   !  This subroutine sets the transmit frequency for the HP8753.
10470   !
10480   IF Ifreq=1 THEN
10490       OUTPUT @Nwa;"POWE0"
10500   ELSE
10510       OUTPUT @Nwa;"POWE-10"
10520   END IF
10530   SELECT Netwrk_analyzer
10540   CASE =3,=4,=5,=6
10550        OUTPUT @Nwa;"TIMDTRANOFF;"
10560   CASE =1,=2
10570        OUTPUT @Nwa;"FREQ;"
10580   END SELECT
10590   OUTPUT @Nwa;"CENT "&VAL$(Freq_cent(Ifreq))&" GHZ;"
10600   OUTPUT @Nwa;"SPAN "&VAL$(Freq_span(Ifreq))&" GHZ;"
10610 SUBEND
10620 !
10630 !*********************************************************************
10640 !
10650 SUB Freq_sw(INTEGER Ifreq)
10660 COM /Paths/ @Nwa,@Nwa_data1,@Nwa_data2,Netwrk_analyzer,@Hpib,@Relay
10670   SELECT Ifreq
10680   CASE 1
10690     OUTPUT @Relay;"?*A2B1"
10700   CASE 2
10710     OUTPUT @Relay;"?*A1B2"
10720   CASE 3
10730     OUTPUT @Relay;"?*B12"
10740   END SELECT
10750   WAIT .1
10760 SUBEND
10770 !
10780 !*********************************************************************
10790 !
10800 SUB Pol_sw(INTEGER Ifreq,Ipol)
10810     COM /Paths/ @Nwa,@Nwa_data1,@Nwa_data2,Netwrk_analyzer,@Hpib,@Relay
10820     COM /Sys_1/ Freq$(*),Freq_cent(*),Freq_span(*),Gate_cent(*),Gate_span(*)
10830     COM /Sys_2/ Pol$(*),Polsw$(*)
10840   !
10850   !  This subroutine sets the transmit and receive polarization by
10860   !  sending the proper command over the HPIB to the polarization
10870   !  relays.
10880   !
10890   OUTPUT @Relay;Polsw$(Ifreq,Ipol)
10900   OUTPUT @Nwa;"TITL "" "&Freq$(Ifreq)&" BAND - "&Pol$(Ipol)&""""
10910   WAIT .1
10920 SUBEND
10930 !
10940 !*********************************************************************
10950 !
10960 SUB Rotate_target
10970 OPTION BASE 1
10980 COM /Com4/ INTEGER Rotation_state,REAL Inc_angle,Current_angle,Start_angle,Stop_an
le,Old_home_angle,INTEGER Sets_per_pos
10990 COM /Status/ INTEGER Sc,Connect_flg,E_flg,Debug_flg,Response$[80]
11000 INTEGER Fs_flag,Ss_flag,Speed,Imc_status,Confirm_answer
11010    !
11020    !
11030    Confirm_answer=1
11040    Imc_status=0
11050    Debug_flg=0
11060    Fs_flag=-1
11070    Ss_flag=-1
11080    Clear_crt(3,16)
11090    !
11100    !
11110    SELECT Rotation_state
11120    CASE =-1
11130         IF FNAsk("Do you wish to use the rotator?") THEN
11140            Connect_flg=0
11150            GOSUB Init_imc
11160            GOSUB Init_graph_pos
11170            GOSUB Manual_loop
11180            PRINT "Set Auto Mode Please....."
11190         ELSE
11200            Rotation_state=0
11210            GCLEAR
11220            GRAPHICS OFF
11230         END IF
11240    CASE =0
11250         SUBEXIT
11260    CASE =1
11270         GOSUB Check_position
11280         GOSUB Print_angles
```

```
11290         GOSUB Manual_loop
11300     CASE =2
11310         GOSUB Check_position
11320         GOSUB Auto
11330     CASE =3
11340         GOSUB Check_position
11350         GOSUB Manual_loop
11360         GOSUB Auto
11370     CASE =4
11380         GOSUB Check_position
11390         GOSUB Go_home
11400     CASE =5
11410         GOSUB Check_position
11420         Rotation_state=1  ! Switch to manual mode.
11430     END SELECT
11440     SUBEXIT
11450     !
11460     !
11470 Init_imc: ! Initialize the IMC unit.
11480     GOSUB Check_4_fault
11490     PRINT TABXY(1,3);"INITIALIZING IMC"
11500     Clear_crt(4,15)
11510     Comm("4WB")           ! Set warm boot (clear flags).
11520     PRINT TABXY(1,4);"WB"
11530     Comm("4EB")           ! Clear IMC buffer.
11540     PRINT TABXY(1,4);"EB"
11550     Encoder_ratio=4096  ! 32000
11560     Comm("4ER"&VAL$(Encoder_ratio))        ! Load encoder ratio.
11570     PRINT TABXY(1,4);"ER"&VAL$(Encoder_ratio)
11580     IF FNAsk("Do you wish to set home at the current position?") THEN
11590        Comm("4RS",Confirm_answer)
11600        ENTER Response$;Old_home_angle
11610        Old_home_angle=Old_home_angle/93.3
11620        Comm("4PIZ0")          ! Set IMC at 0.
11630        PRINT TABXY(1,4);"PIZ"&RPT$(" ",LEN(VAL$(Encoder_ratio)))
11640        Comm("4PIA0")          ! Set IMC at 0.
11650        PRINT TABXY(1,4);"PIA"
11660        Current_angle=0
11670     END IF
11680     Comm("4SP100")        ! Set speed to (50pps).
11690     PRINT TABXY(1,4);"SP "&RPT$(" ",LEN(VAL$(Encoder_ratio)))
11700     Comm("4AC500")        ! Set acceleration (500pps^2).
11710     PRINT TABXY(1,4);"AC "
11720     Comm("4DC500")        ! Set deceleration (500pps^2).
11730     PRINT TABXY(1,4);"DC "
11740     GOSUB Check_position
11750     Rotation_state=1
11760     Clear_crt
11770 !
11780 !
11790     PRINT TABXY(1,4);"DONE INITIALIZING IMC"
11800     PRINT TABXY(1,5);"Turntable currently in manual mode."
11810     PRINT TABXY(1,6)
11820 Print_angles:!
11830     PRINT TABXY(1,7);"Current  angle is: ";Current_angle;" degrees."
11840     PRINT TABXY(1,8);"Starting angle is: ";Start_angle;" degrees."
11850     PRINT TABXY(1,9);"Stopping angle is: ";Stop_angle;" degrees."
11860 RETURN
11870 !
11880 !
11890 Manual_loop:! Main activation loop.
11900     LOOP
11910       ON KEY 0 LABEL "FAST SLEW CW  ",FNTrap_level GOSUB Fs_cw
11920       ON KEY 1 LABEL "FAST SLEW CCW ",FNTrap_level GOSUB Fs_ccw
11930       ON KEY 5 LABEL "SLOW SLEW CW  ",FNTrap_level GOSUB Ss_cw
11940       ON KEY 6 LABEL "SLOW SLEW CCW ",FNTrap_level GOSUB Ss_ccw
11950       ON KEY 2 LABEL "MANUAL CONTROL",FNTrap_level GOSUB Manual
11960       ON KEY 3 LABEL "TARGET GO HOME",FNTrap_level GOSUB Go_home
11970       ON KEY 4 LABEL "STOP ROTATION ",FNTrap_level GOSUB Stop_turn
11980       ON KEY 7 LABEL "SET AUTO MODE ",FNTrap_level GOSUB Set_auto
11990       ON KEY 8 LABEL "SET TARGET HOME",FNTrap_level GOSUB Set_position
12000       ON KEY 9 LABEL "RETURN         ",FNTrap_level GOTO Quit
12010       GOSUB Check_position
12020     END LOOP
12030 !
12040 !------------------------------------------------------------------------
12050 !
12060 Fs_cw:! Fast slew clockwise.
12070       IF Fs_flag<0 THEN
12080          Comm("4SP500")
12090          Comm("4SFN")
12100          Fs_flag=-1*Fs_flag
12110          Clear_crt(3,15)
12120          PRINT TABXY(1,15);"ROTATING CW (FAST)"
12130       ELSE
12140          Comm("4ST")
12150          Fs_flag=-1*Fs_flag
12160          Clear_crt(3,15)
12170          PRINT TABXY(1,15);"ROTATION STOPPED"
12180          GOSUB Check_position
12190       END IF
12200 RETURN
12210 !
12220 !------------------------------------------------------------------------
12230 !
12240 Fs_ccw:! Fast slew counterclockwise.
12250       IF Fs_flag<0 THEN
12260          Comm("4ST")
12270          Comm("4SP500")
12280          Comm("4SRN")
12290          Fs_flag=-1*Fs_flag
12300          Clear_crt(3,10)
12310          PRINT TABXY(1,15);"ROTATING CCW (FAST)"
12320       ELSE
12330          Comm("4ST")
12340          Fs_flag=-1*Fs_flag
12350          Clear_crt(3,15)
12360          PRINT TABXY(1,15);"ROTATION STOPPED"
12370          GOSUB Check_position
12380       END IF
12390 RETURN
12400 !
12410 !------------------------------------------------------------------------
12420 !
12430 Ss_cw:! Slow slew clockwise.
12440       IF Ss_flag<0 THEN
12450          Comm("4ST")
12460          INPUT "Speed?",Sp
12470          Comm("4SP"&VAL$(INT(Sp)))
12480          Comm("4SFN")
12490          Ss_flag=-1*Ss_flag
12500          Clear_crt(3,15)
12510          PRINT TABXY(1,15);"ROTATING CW (SLOW)"
12520       ELSE
12530          Comm("4ST")
12540          Ss_flag=-1*Ss_flag
12550          Clear_crt(3,15)
12560          PRINT TABXY(1,15);"ROTATION STOPPED"
```

```
12570       GOSUB Check_position
12580    END IF
12590 RETURN
12600 !
12610 !-------------------------------------------------------------------------
12620 !
12630 Ss_ccw:! Slow slew counterclockwise.
12640    IF Ss_flag<0 THEN
12650    INPUT "Speed?",Sp
12660       Comm("4SP"&VAL$(INT(Sp)))
12670       Comm("4SRN")
12680       Ss_flag=-1*Ss_flag
12690       Clear_crt(3,15)
12700       PRINT TABXY(1,15);"ROTATING CCW (SLOW)"
12710    ELSE
12720       Comm("4ST")
12730       Ss_flag=-1*Ss_flag
12740       Clear_crt(3,15)
12750       PRINT TABXY(1,15);"ROTATION STOPPED"
12760       GOSUB Check_position
12770    END IF
12780 RETURN
12790 !
12800 !-------------------------------------------------------------------------
12810 !
12820 Manual: INPUT "ANGLE (IN DEGREES)=?",Inc_angle
12830         INPUT "SPEED? (~100-~500 RECOMMENDED)",Speed
12840         Comm("4SP"&VAL$(Speed))
12850 Auto:   SELECT Rotation_state
12860         CASE =4
12870              GOSUB Go_home
12880              Rotation_state=2
12890              GOTO Auto
12900         CASE ELSE
12910              Angl2=Inc_angle*93.3
12920              Angl1=INT(Angl2)
12930              IF Angl2-Angl1>=.5 THEN Angl1=Angl1+1
12940         !    Current_angle=Current_angle+Inc_angle
12950              Inc_angle$=VAL$(Angl1)
12960              Comm("4IM"&Inc_angle$)
12970              Comm("4RFI")
12980         END SELECT
12990         Imc_status=0
13000         Clear_crt(3,7)
13010         PRINT TABXY(1,14);"ROTATING TARGET, PLEASE WAIT."
13020         !
13030         !
13040         WHILE NOT BIT(Imc_status,0)            ! Wait for motor to stop.
13050               Comm("4RS",Confirm_answer)
13060               ENTER Response$;Imc_status
13070               PRINT TABXY(1,15);DVAL$(Imc_status,2)
13080               GOSUB Check_position
13090               WAIT 1
13100         END WHILE
13110         Imc_status=0
13120         !
13130         !
13140         Clear_crt(3,16)
13150         PRINT TABXY(1,16);"CURRENT TARGET POSITION IS ";Current_angle;" DEGREES.
              "
13160         WAIT 2  ! Wait for target settling.
13170 RETURN
13180 !
13190 !-------------------------------------------------------------------------
13200 !
13210 Stop_turn:Comm("4ST")
13220          WHILE NOT BIT(Imc_status,0)           ! Wait for motor to stop.
13230                Comm("4RS",Confirm_answer)
13240                ENTER Response$;Imc_status
13250                WAIT .1
13260          END WHILE
13270          Clear_crt(3,16)
13280          PRINT TABXY(1,15);"ROTATION STOPPED"
13290          GOSUB Check_position
13300          Imc_status=0
13310 RETURN
13320 !
13330 !-------------------------------------------------------------------------
13340 !
13350 Set_auto: Comm("4SP500")
13360          GOSUB Check_position
13370          Clear_crt(3,16)
13380          PRINT TABXY(1,3);"Current starting  angle: ";Start_angle;" degrees"
13390          PRINT TABXY(1,4);"Current increment angle: ";Inc_angle;" degrees"
13400          PRINT TABXY(1,5);"Current stopping  angle: ";Stop_angle;" degrees"
13410          PRINT TABXY(1,6);"Current rotation  speed: ";Speed
13420          PRINT TABXY(1,7);RPT$(" ",80)
13430          PRINT TABXY(1,8);"Rotator  positioned  at: ";Current_angle;" degrees"
13440          INPUT "Enter starting angle value (degrees): ",Start_angle
13450          INPUT "Enter increment angle (degrees): ",Inc_angle
13460          INPUT "Enter stopping angle (degrees): ",Stop_angle
13470          INPUT "Enter rotation speed of target (~500 recommended): ",Speed
13480          Speed=INT(Speed)
13490          Comm("4SP"&VAL$(Speed))
13500          IF ABS(Start_angle-Current_angle)>.1 THEN
13510             PRINT TABXY(1,9);RPT$(" ",80)
13520             PRINT TABXY(1,10);"Rotating target to starting angle..."
13530             Temp_angle=Inc_angle
13540             Inc_angle=Start_angle-Current_angle
13550             GOSUB Auto
13560             Inc_angle=Temp_angle
13570          END IF
13580          Rotation_state=2
13590          Clear_crt
13600          PRINT TABXY(1,20);"Turntable is in automatic mode. (press the RETURN sof
key)"
13610 RETURN
13620 !
13630 !-------------------------------------------------------------------------
13640 !
13650 Set_position:INPUT "LOCK IN CURRENT TARGET POSITION AS REFERENCE POSITION?",Yn$
13660              IF Yn$="Y" OR Yn$="y" THEN
13670                 Comm("4RS",Confirm_answer)
13680                 ENTER Response$;Old_home_angle
13690                 Old_home_angle=Old_home_angle/93.3
13700                 Comm("4PIA0") ! Set absolute position to zero.
13710                 Comm("4PIZ0") ! Set incremental postition to zero.
13720                 Current_angle=0
13730              ELSE
13740                 PRINT "POSITION WAS NOT SET."
13750              END IF
13760 RETURN
13770 !
13780 !-------------------------------------------------------------------------
13790 !
13800 Go_home: IF Speed<200 THEN Speed=200
13810          Comm("4SP"&VAL$(Speed))
13820          Comm("4AM0") ! Move to zero absolute position.
```

```
13830          Comm("4RAN") ! Initiate movement.
13840          Comm("4MW")  ! Make sure the move is completed.
13850          Imc_status=0
13860          Clear_crt(3,15)
13870          PRINT TABXY(1,14);"ROTATING TARGET TO HOME POSITION, PLEASE WAIT."
13880          WHILE NOT (BIT(Imc_status,0) AND BIT(Imc_status,5))
13890               GOSUB Check_status
13900               PRINT TABXY(1,15);"CURRENT STATUS: ";DVAL$(Imc_status,2)
13910               GOSUB Check_position
13920               WAIT .1
13930          END WHILE
13940          Clear_crt(3,16)
13950          PRINT TABXY(1,15);"TARGET AT HOME POSITION."
13960          GOSUB Check_position
13970          Imc_status=0
13980 RETURN
13990 !
14000 !-------------------------------------------------------------------------
14010 !
14020 Check_status:! Keep an eye on the Whedco controller status.
14030         Comm("4RS",Confirm_answer)
14040         ENTER Response$;Imc_status
14050 RETURN
14060 !
14070 !-------------------------------------------------------------------------
14080 !
14090 Check_position:! Get the current turnstile position in degrees.
14100         Comm("4RP",Confirm_answer)
14110         ENTER Response$;Motor_position
14120         Current_angle=Motor_position/93.3
14130    !    Current_angle=Current_angle+Inc_angle
14140         PRINT TABXY(1,16);"CURRENT TARGET POSITION IS ";Current_angle;" DEGREES.
      "
14150         GOSUB Draw_positions
14160 RETURN
14170 !
14180 !-------------------------------------------------------------------------
14190 !
14200 Check_4_fault: ! Check the IMC for a fault condition and correct or
14210                ! notify the user if necessary.
14220                !
14230      Comm("4FC",Confirm_answer)
14240      ENTER Response$;Fault$
14250      SELECT Fault$
14260      CASE ="Power failure" ! Loss of power
14270           RETURN
14280      CASE ="Force DAC" ! Force DAC command was given
14290           BEEP
14300           PRINT "Force DAC command was given..."
14310           DISP "Press CONTINUE to resume..."
14320           PAUSE
14330      RETURN
14340      CASE ="Over-current" ! Over-current condition exists.
14350           BEEP
14360           PRINT "An over-current condition has been detected on the IMC."
14370           PRINT
14380           PRINT "Cycle the power to the IMC until the OV-CUR LED goes out"
14390           DISP "Press CONTINUE to reinitialize the IMC"
14400           PAUSE
14410           GOSUB Init_imc
14420      RETURN
14430      END SELECT
14440      RETURN
14450 !
14460 !-------------------------------------------------------------------------
14470 !
14480 Init_graph_pos: ! Creates a graphical depiction of where the target is.
14490                 !
14500     GINIT
14510     GCLEAR
14520     GRAPHICS ON
14530     SHOW 0,100,0,100
14540     PENUP
14550     MOVE 90,70
14560     PEN 1       ! Draw circle
14570     POLYGON 12,360,360
14580     PENUP
14590     MOVE 90,70  ! Draw old home orientation.
14600     PEN 2
14610     DRAW 90+11*COS(Old_home_angle),70-11*SIN(Old_home_angle)
14620     PENUP
14630     MOVE 90,70  ! Draw current home orientation.
14640     PEN 4
14650     DRAW 90,58
14660     PENUP
14670     MOVE 90,70  ! Draw current target orienation.
14680     PEN 3
14690     X_pos=90+11*COS(Current_angle)
14700     Y_pos=70-11*SIN(Current_angle)
14710     DRAW X_pos,Y_pos
14720 RETURN
14730 !
14740 !-------------------------------------------------------------------------
14750 !
14760 Draw_positions:  ! Draws out the angular orienations.
14770     MOVE 90,70   ! Draw old home orientation.
14780     PEN 2
14790     DRAW 90-11*SIN(Old_home_angle),70-11*COS(Old_home_angle)
14800     PENUP
14810     MOVE 90,70  ! Draw current home orientation.
14820     PEN 4
14830     DRAW 90,58
14840     PENUP
14850     DISABLE
14860     MOVE 90,70  ! Draw current target orienation.
14870     PEN -3
14880     DRAW X_pos,Y_pos
14890     MOVE 90,70
14900     PEN 3
14910     X_pos=90-11*SIN(Current_angle)
14920     Y_pos=70-11*COS(Current_angle)
14930     DRAW X_pos,Y_pos
14940     PENUP
14950     ENABLE
14960 RETURN
14970 !
14980 !-------------------------------------------------------------------------
14990 !
15000 Quit: !
15010       SUBEXIT
15020 SUBEND
15030 !
15040 !*************************************************************************
15050 !
15060 SUB Comm(C$,OPTIONAL INTEGER Confirm_answer)
15070 !
15080 !  PROGRAM MODULE:  Comm
15090 !
```

```
15100 !  PURPOSE:         Modified version of the Comm module to be used
15110 !                   for direct two way communication with the WHEDCO
15120 !                   IMC stepping motor controller.
15130 !
15140 !  UPDATE:  3.0     Version 3.0 checks to see if the card being used
15150 !                   is the HP98628A (Datacomm) or the HP98626A (Serial).
15160 !                   Depending on which card is used, the appropriate
15170 !                   registers are selected.
15180 !
15190     OPTION BASE 1
15200     COM /Status/ INTEGER Sc,Connect_flg,E_flg,Debug_flg,Response$
15210     INTEGER Baud_rate,B,Num_chars,Response_flg,Index1
15220     DIM Input$[256],Term$[256],In$[256] BUFFER,From_232$[256]
15230     DIM Num_chars$[6],Num_ltrs$[6],Out$[256] BUFFER
15240     DIM White_print$[1],Crlf$[2]
15250     IF Debug_flg THEN PRINT TABXY(1,1);"ENTERING Comm "
15260     ON ERROR GOSUB Error
15270     !
15280     !
15290     !
15300     IF Connect_flg THEN After_init
15310     Sc=30
15320     ASSIGN @Find_it TO Sc;RETURN Outcome
15330     IF Outcome=0 THEN
15340        ASSIGN @Find_it TO *
15350        CONTROL Sc,0;1                 ! Reset RS-232 interface.
15360        CONTROL Sc,3;1                 ! Async link protocol.
15370        CONTROL Sc,0;1                 ! Set Async toggle.
15380        CONTROL Sc,8;1+2               ! Set RTS and DTR lines.
15390        CONTROL Sc,16;0                ! Disable connection timeout.
15400        CONTROL Sc,17;0                ! Disable no activity timeout.
15410        CONTROL Sc,18;0                ! Disable NO CARRIER timeout.
15420        CONTROL Sc,19;0                ! Disable transmit timeout.
15430        CONTROL Sc,20;14               ! TX baud speed = 9600
15440        CONTROL Sc,21;14               ! RX baud speed = 9600
15450        CONTROL Sc,22;0                ! No handshake with Whedco.
15460        CONTROL Sc,23;0                ! No hardwired handshake.
15470        CONTROL Sc,34;2                ! 7 bits/character.
15480        CONTROL Sc,35;0                ! 1 stop bit.
15490        CONTROL Sc,36;1                ! ODD parity.
15500        Connect_flg=1
15510     ELSE
15520        Sc=8
15530        ASSIGN @Find_it TO *
15540        ASSIGN @Find_it TO Sc;RETURN Outcome
15550        IF Outcome<>0 THEN
15560           PRINT "RS-232 card not installed. Please install and reboot."
15570           ASSIGN @Find_it TO *
15580           STOP
15590        END IF
15600        ASSIGN @Find_it TO *
15610        RESET Sc
15620        CONTROL Sc,0;1                ! Reset the RS-232 interface.
15630        CONTROL Sc,3;Baud_rate        ! Set the baud rate.
15640        CONTROL Sc,4;8+2              ! UART 8 bits/char.  ODD parity.
15650        CONTROL Sc,5;3                ! UART DTR line active.
15660        CONTROL Sc,12;128+32+16       ! Disable CD,DSR,CTS
15670        STATUS Sc,3;B                 ! Confirm speed to user.
15680        Connect_flg=1
15690     END IF
15700 After_init:!
15710     White_print$=CHR$(136)
15720     Crlf$=CHR$(13)&CHR$(10)
15730     PRINT CHR$(128)&CHR$(136);     ! Set up the screen.
15740     ASSIGN @Screen TO CRT
15750     ASSIGN @Kbd TO KBD
15760     ASSIGN @Rx TO BUFFER In$
15770     ASSIGN @Tx TO BUFFER Out$
15780     ASSIGN @Uart_out TO Sc
15790     ASSIGN @Uart_in TO Sc
15800     Response_flg=0                 ! Reset command acknowledge flag.
15810     Response$=""                   ! Null out response string.
15820     !
15830     !
15840        ENABLE INTR Sc                  ! Enable interrupt on card.
15850        TRANSFER @Tx TO @Uart_out;CONT ! Enable transfer buffers.
15860        TRANSFER @Uart_in TO @Rx
15870        ON INTR Sc,FNTrap_level GOSUB Read_loop ! Process card interrupts.
15880        IF C$<>"" THEN
15890           GOSUB Send_com               ! Send command out to controller.
15900        ELSE
15910           GOTO Quit                    ! If null command, exit quick.
15920        END IF
15930        !
15940        !
15950        !
15960 Wait_for_it:WHILE NOT Response_flg      ! Waiting for acknowledgement.
15970              GOSUB Read_loop
15980              IF NPAR=2 THEN             ! We are waiting for data to be
15990                                         ! sent by the Whedco controller.
16000                 LOOP
16010                       GOSUB Read_loop
16020                       IF (POS(Response$,"*")) THEN
16030                          Response$=Response$[POS(Response$,"*"),LEN(Response
)]
16040                          Response_flg=1
16050                       END IF
16060                 EXIT IF ((Response_flg=1) AND (POS(Response$,Crlf$)))
16070                 END LOOP
16080              ELSE
16090                 WHILE NOT ((POS(Response$,"*")) OR (POS(Response$,"?")))
16100                       GOSUB Read_loop
16110                 END WHILE
16120                 Index1=POS(Response$,"*")
16130                 IF Index1=0 THEN ! Must be a "?" (Whedco command error).
16140                    ! Must be a "?" (Whedco command error).
16150                    E_flg=1       ! Notify via error flag.
16160                    Response_flg=1
16170                 ELSE
16180                    ! Normal command interpretation.
16190                    E_flg=0
16200                    Response_flg=1
16210                 END IF
16220              END IF
16230           END WHILE
16240        GOTO Quit
16250     !
16260     !
16270 Read_loop:! Read in serial data from Whedco.
16280           !
16290     STATUS @Rx,4;Num_chars                ! Number of characters to
16300     IF Num_chars=0 THEN RETURN            ! receive, if 0 try again.
16310     Num_chars$="#,"&VAL$(Num_chars)&"A"   ! Set up the IMAGE for ENTER.
16320     ENTER @Rx USING Num_chars$;From_232$         ! Transfer contents.
16330     Response$=Response$&From_232$                ! Build up dialogue.
16340     RETURN                                       ! Update pointers.
16350 !
16360 !
```

```
16370 Send_com:Term$=Crlf$[1,1]&C$&Crlf$
16380          Num_ltrs$="#,"&VAL$(LEN(Term$))&"A"
16390          OUTPUT @Tx USING Num_ltrs$;Term$
16400          Term$=""
16410          RETURN
16420 !
16430 !
16440 Quit:  OFF ERROR
16450        STATUS @Tx,10;Stat
16460        STATUS @Rx,4;Num_bytes
16470        ABORTIO @Uart_out
16480        ASSIGN @Tx TO *
16490        CONTROL @Rx,8;0
16500        STATUS @Rx,10;Stat
16510        STATUS @Rx,4;Num_bytes
16520        ABORTIO @Uart_in
16530        ASSIGN @Rx TO *
16540        DISABLE INTR Sc
16550        SUBEXIT
16560 !
16570 !
16580 Error:PRINT "HANDLING Comm ERROR"
16590        IF ERRN<>167 THEN Other_error
16600        IF Sc=8 THEN ! Process the simple card.
16610           STATUS Sc,10;Uart_error
16620           IF BIT(Uart_error,1) THEN Overrun
16630           IF BIT(Uart_error,2) THEN Parity
16640           IF BIT(Uart_error,4) THEN Break1
16650           IF BIT(Uart_error,3) THEN Framing
16660           E_flg=1
16670           PAUSE
16680           RETURN
16690         ELSE
16700           PRINT ERRM$
16710           E_flg=1
16720           PAUSE
16730           RETURN
16740         END IF
16750 !
16760 !
16770 Other:  PRINT "UART error status: ";Uart_error
16780         E_flg=1
16790         RETURN
16800 !
16810 !
16820 Overrun:PRINT "Overrun"
16830         E_flg=1
16840         RETURN
16850 !
16860 !
16870 Parity: PRINT "Parity"
16880         E_flg=1
16890         RETURN
16900 !
16910 !
16920 Break1: PRINT "Break"
16930         E_flg=1
16940         RETURN
16950 !
16960 !
16970 Framing:PRINT "Framing"
16980         E_flg=1
16990         RETURN
17000 !
17010 !
17020 Other_error:PRINT "Error message: ";ERRM$
17030             PAUSE
17040             E_flg=1
17050             SUBEXIT
17060 !
17070 !
17080 SUBEND
17090 !
17100 !**********************************************************************
17110 !
```