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OPERATING MANUAL FOR OSU/ESL TRANSCEIVER SYSTEM

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Version 1.0

ESL Project No. 719493
Contract No. NSG 1613
February 1989

National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 22217

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No.
4. Title and Subtitle Operating Manual for OSU/ESL Transceiver System			5. Report Date February 1989 6.
7. Author(s) W.D. Burnside, T. Barnum, P. Bohley, W. Lin, M. Poirier and P. Swetnam			8. Performing Org. Rept. No. 719493 manual
9. Performing Organization Name and Address The Ohio State University ElectroScience Laboratory 1320 Kinnear Road Columbus, OH 43212			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G) NSG-1613
12. Sponsoring Organization Name and Address National Aeronautics and Space Administration Langley Research Center Hampton, VA 22217			13. Report Type/Period Covered Operating Manual 14.
15. Supplementary Notes			
16. Abstract (Limit: 200 words)			
17. Document Analysis a. Descriptors b. Identifiers/Open-Ended Terms c. COSATI Field/Group			
18. Availability Statement A. Approved for public release; Distribution is unlimited.	19. Security Class (This Report) Unclassified	20. Security Class (This Page) Unclassified	21. No. of Pages 127 22. Price

(See ANSI-Z39.18) *See Instructions on Reverse* OPTIONAL FORM 272 (4-77) Department of Commerce

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I. INTRODUCTION

Traditionally, electromagnetic measurements have been made using a far field range where the measurement zone is located a large distance from the illuminating source. Such a range is normally located outdoors and in a desert environment in order to achieve the desired isolation for the measurements. Even though a far field range provides the required results, it is limited by the weather, security, cost and access. On the other hand, a compact range is configured in an anechoic chamber which avoids weather and security problems. In addition, it can be strategically located for easy access with reduced cost. One of the major objections to the compact range has been the target size that can be measured. However it has been recently shown [1] that the compact range can be used to measure large targets; in fact, systems have already been built which can measure 40 foot targets.

Since most of the scattering measurements were previously limited to far field ranges, they had very sophisticated radar and diagnostic systems specifically designed for their use. As a result, the measurements performed outdoors were superior to those obtained in an anechoic chamber. However more recently, these systems have been modified for indoor applications. They provide a tremendous capability, but they are also very expensive. Because there are so many chambers in existence, there needed to be an inexpensive pulse radar system which was specifically designed for compact range applications. This report describes such a radar system.

In order to grasp the concepts of this system, let us review the compact range and its use for scattering measurements. A focus fed, compact range reflector system is shown in Figure 1. The signal radiated by the feed is a spherical wave which fully illuminates the main reflector. The reflected signal from the parabola is an inhomogeneous plane wave which in turn illuminates the target. The target scattered field then impinges back on the main reflector which acts as a spatial filter and focuses the far zone backscattered field onto the feed antenna. Thus, the compact range can basically measure a target which is as large as the main reflector parabolic section. In practice, the actual main reflector is normally constructed to be twice the target size in each linear dimension in order to minimize diffractions which distort the plane wave field illuminating the target.

In order to determine the radar system requirements which are inherent with compact range applications, let us examine a short pulse as it propagates through the system from the source. The first signal received by the radar, in time sequence, is the horn coupling if transmit and receive antennas are used or the horn VSWR if one antenna is used. The next major time response results from the signal propagating to the main reflector and back to the receive antenna. This term is indicated as the reflector bounce in Figure 2. The target response then appears as the next significant term, but it is much smaller than the others. Since the horn coupling and reflector bounce terms are so much larger than the target response, they would dominate the receiver if they were simultaneously measured. On the other hand, if they could be range gated out of the received response, one could obtain a greatly improved dynamic range because the target response would be the largest signal measured. Thus, a pulse radar, or some type of range gating system, is most appropriate for compact range scattering measurements.

The actual measurement procedure places additional requirements on the radar system. For example, in order to handle a large target, it is often held in the target zone by a metal ogival support structure which has a significant scattering level of its own. As shown by Lai [2], its radar

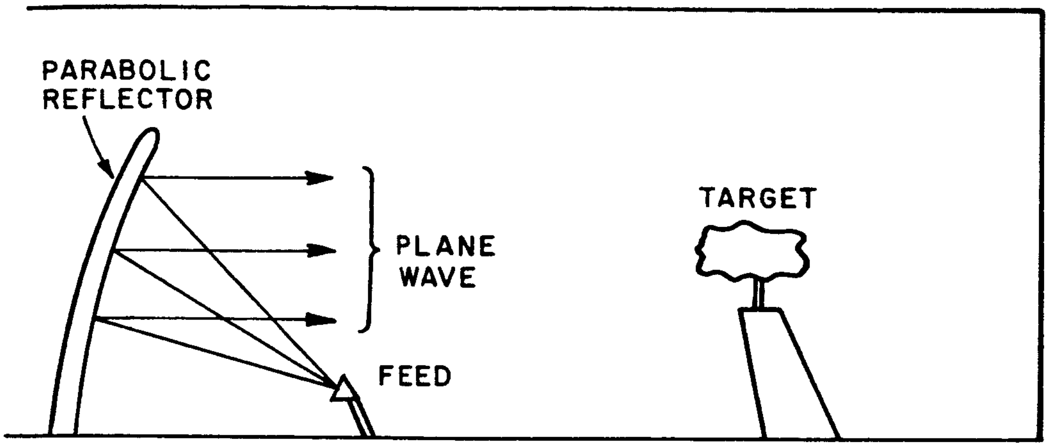


Figure 1: Compact range RCS measurement system.

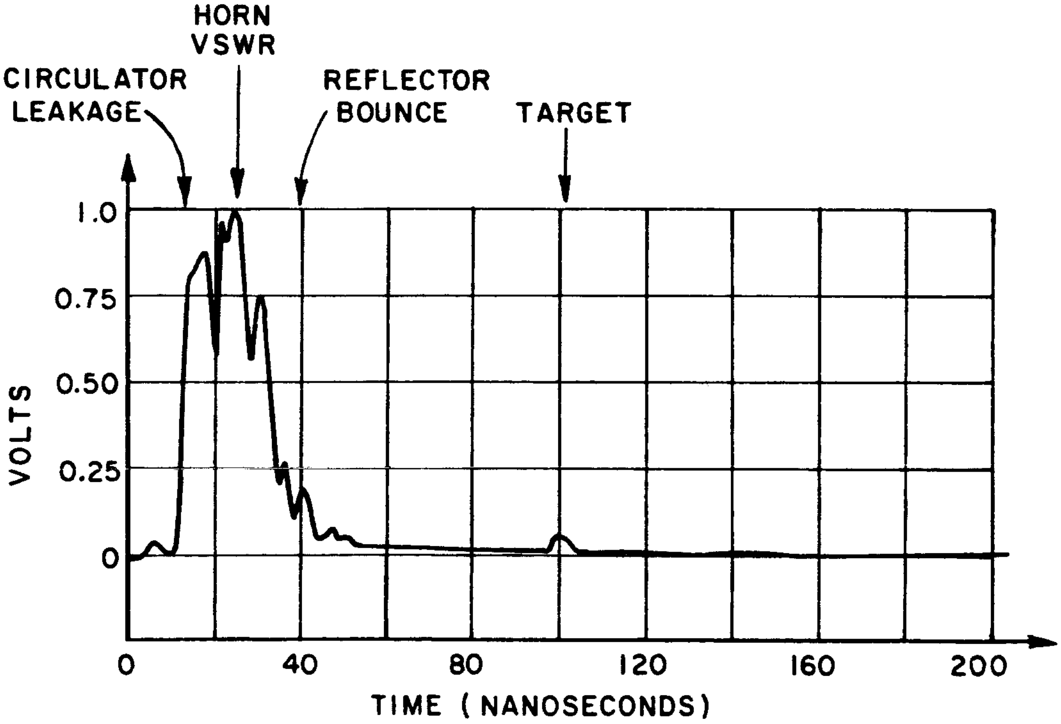


Figure 2: Time domain response of radar system in compact range.

cross-section is about 20 dB below a square a meter (dBsm) at 1 GHz. Consequently, this scattering term must be removed from the received response, but it can't be range gated out because it is in the middle of the target zone. This error term is normally removed by taking a background measurement without the target present and subtracting it from the target response. It is obviously assumed that nothing changes between these two measurements, which implies both the mount scattering and measurement systems must be stable with time. Since the metal support is so massive, it remains rather stable as the target is mounted. However, the system can potentially drift if the background is only obtained once a day. Consequently, the radar system should be very stable with time.

Another key issue associated with measuring large targets is the dynamic range needed as the target is scanned in angle. For example, a pointed object can have a radar cross-section of say -40 dBsm off its nose and +60 dBsm from its long cylindrical sides. Thus, 100 dB dynamic range for scattering measurements is certainly not out of the ordinary, and the radar system should be designed to accommodate this requirement.

In order to provide diagnostic data processing information, the radar system must accurately measure the magnitude and phase of the scattered field. This data is needed in that coherent processing is used to define the locations of various scattering centers found across the target. With this information, one can evaluate the scattering level associated with one aspect of a complex target. For instance, if one wanted to evaluate the scattering level from an antenna, it could be isolated through the data processing even though the total target return was several orders of magnitude larger than that single mechanism. Thus, one could treat the antenna scattering and see the change in its RCS level even though the total target return did not significantly change.

The pulsed/CW radar described in this report has attempted to meet all these requirements at a reasonable cost so that it can eventually be generally available to compact range users.

II. BASIC OPERATION

A. INTRODUCTION

The OSU/ESL transceiver system block diagram shown in Figure 3 is a complete pulsed/CW radar that operates from 2 to 18 GHz. In addition, it can be easily upgraded to operate from 18 to 36 GHz. The RF section is shown schematically in Figure 4. The RF signal is generated by mixing

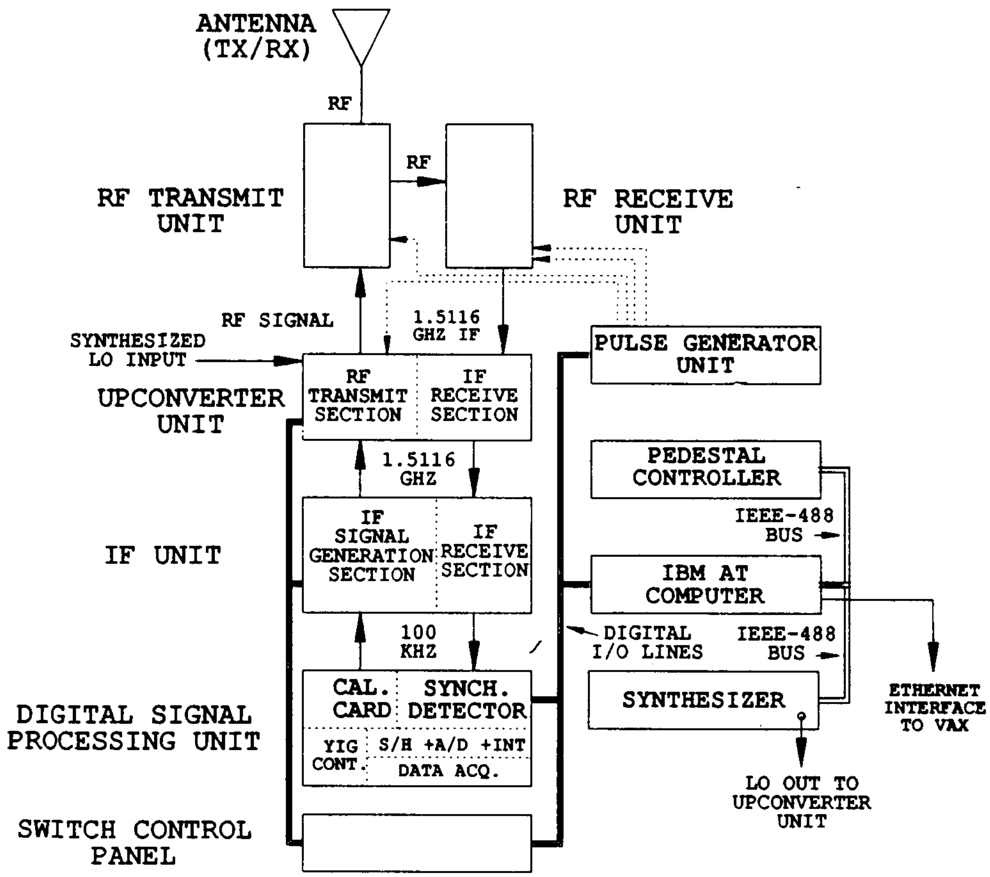


Figure 3: Transceiver System Block Diagram

the LO and IF (1.5116 GHz) and then filtered using a computer controlled yig-tuned bandpass filter. The yig filter is used to isolate the desired fundamental harmonic. The stability of the signals used in this system is insured by using crystal referenced sources.

The RF signal is pulsed using pin diode switches which are driven by computer-controlled pulse generators. The width of the transmitted signal is normally set to 20 nanoseconds (ns). The pulsed signal is then amplified to about a +20 dB relative to a milliwatt (dBm). The amplifier used for this application has a rather large noise figure so it must be isolated from the receiver. To accomplish this, a second transmit switch is used to pulse the amplifier output noise such that the input pulse waveform is not distorted by the second pin diode switch. This usually requires that the pulse width of this switch be set about 30 ns wide and centered on the transmit pulse. This means that the second switch turns on 5 ns before the first transmit pulse and turns off 5 ns after it. Thus, the second switch simply provides additional noise and signal isolation. The transmitted RF pulse is then directed to the antenna by a circulator.

The transmitted pulse which is radiated by the antenna strikes the target and returns to the antenna and then the circulator. For this signal direction the circulator (C1 or C2) as shown in Figure 4 directs the target backscattered pulse to the receive hardware.

The first receiver pin diode switch encountered is used to remove clutter terms which occur long before the target response. As a result, this switch is open during the horn coupling pulse which results from the VSWR of the antenna and leakage through the circulator. Thus, this switch has a wide pulse width, say 120 ns out of a total period of 200 ns. Note that the target pulse simply passes through this switch. The received pulse is mixed with the LO and converted to 1.5116 GHz, which is the first IF stage of the receiving system. The received pulse is then amplified by a very low noise amplifier which sets the noise level of the receiver system. Next, it

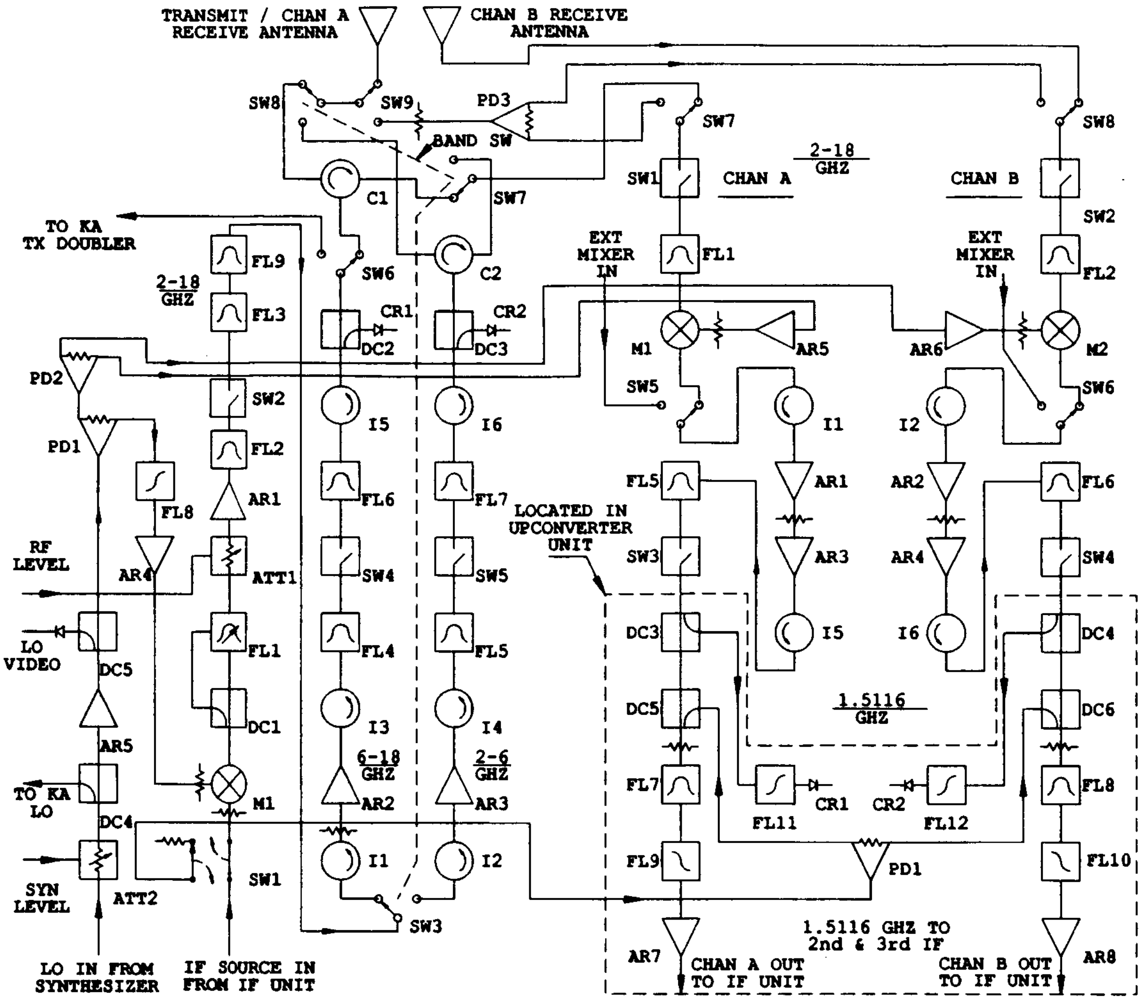


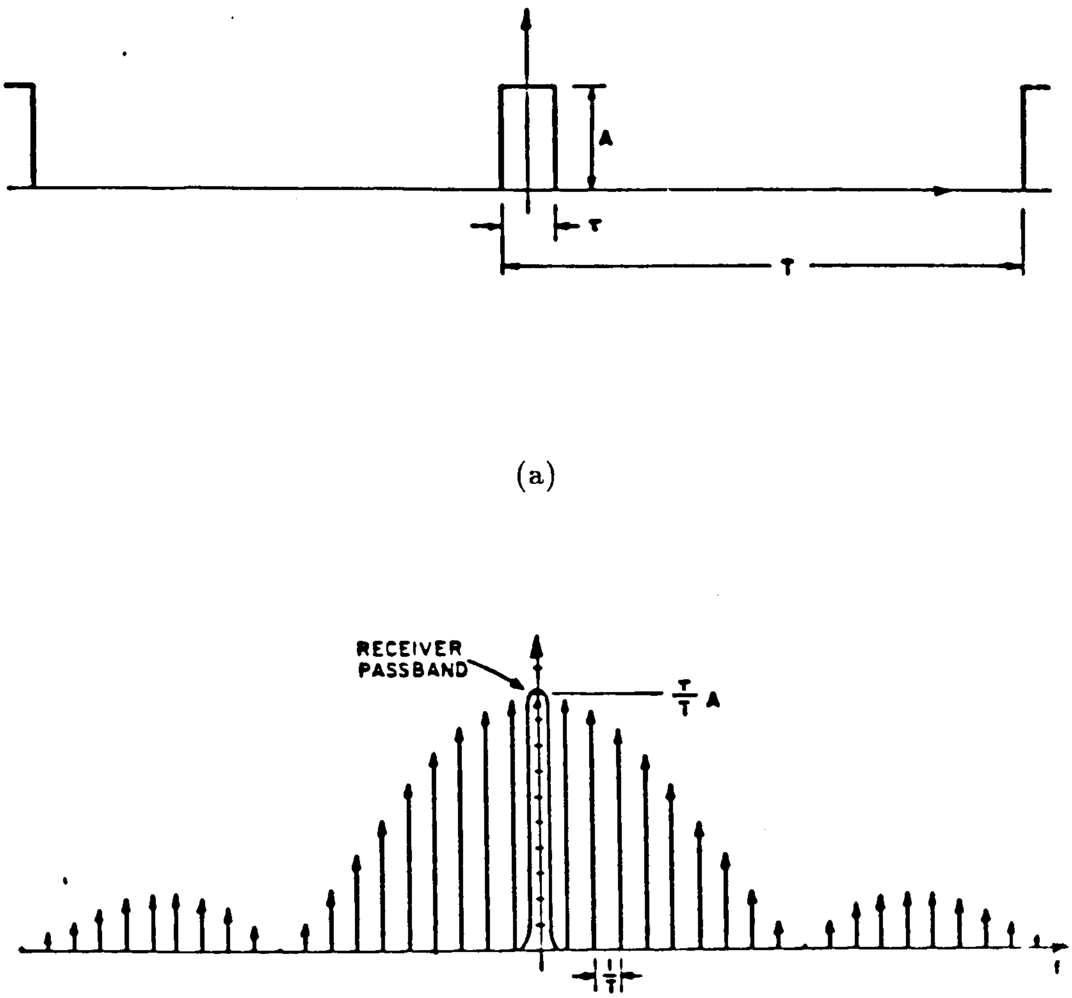
Figure 4: OSU/ESL RF transceiver system schematic.

is amplified by a limiting amplifier with a maximum output level of +10 dBm. Finally, the target pulse passes through the second pin diode switch which is normally closed for ≈ 5 ns. Its delay is set so that one obtains a uniform response as a corner reflector is moved downrange through the target zone. Note that for a 25 ns transmit gate and a 5 ns receive pulse width, one can measure a target which is 10 feet long if it is centered in the target zone. If the target under test is shorter, one can use a narrower transmit pulse width which will tend to eliminate more clutter associated with the room.

The received pulse is then filtered to remove all the pulse-related harmonics as shown in Figure 5. This is done using a very narrow bandpass filter which is about 5 MHz wide and centered at 1.5116 GHz. At this point in the circuit the pulse waveform has been reduced to a CW signal. Thus, the pulse waveforms are simply used to remove the clutter which is dominated by the horn coupling and leakage through the circulator.

The 1.5116 GHz received signal is downconverted to 11.6 MHz and finally to 100 KHz, which is the third and last IF stage. This signal is then synchronously detected, converted to a digital form, hardware integrated and sent to the IBM/AT computer.

If the reference option is selected by the operator, the system automatically shifts the receive gate between the target response and the bounce off the compact range reflector. The target response is then divided by the reflector bounce in order to correct for system drifts. Using this approach, the two signals are measured through exactly the same hardware which makes the system very stable for long periods of time. This allows one to reduce the number of background and calibration runs needed for each measurement sequence. In fact, the room stability normally becomes the



(a)

(b)

Figure 5: (a) Pulse train with amplitude A and duty cycle t/T; (b) IF spectrum and CW receiver passband.

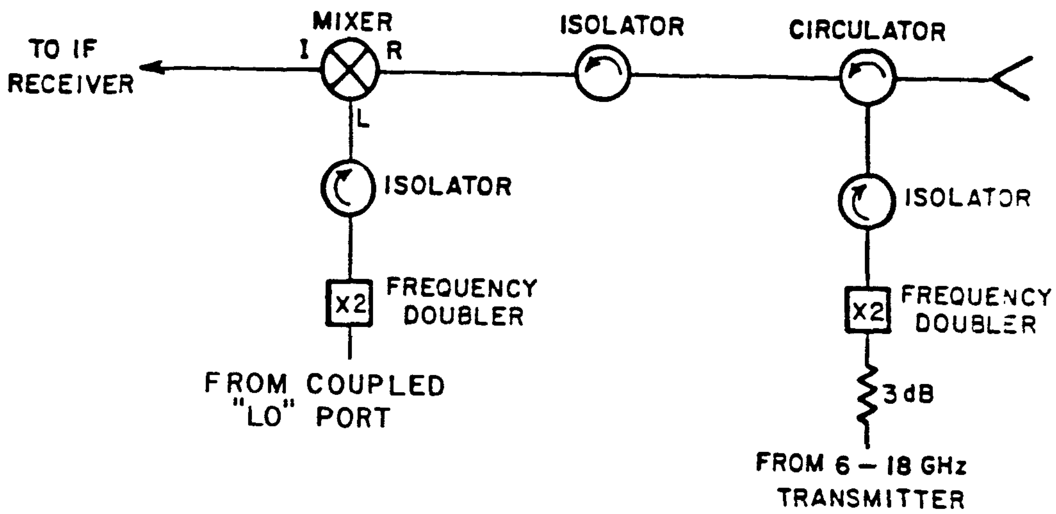


Figure 6: Ka-band system schematic.

dominant drift factor.

In order to provide frequency capability above 18 GHz, the system provides ports to double the RF and LO signals to obtain RF frequencies up to 36 GHz. Using this approach, one simply adds the components shown in Figure 6[hb] and indicates to the system that the Ka-band option has been selected. The system then activates the Ka-band ports, some of which are shown in Figure 4. This is an inexpensive way to provide RF frequencies above 18 GHz.

For some applications, it was felt that both co-polarized and cross-polarized signals needed to be measured. To satisfy this need, the radar has been designed to collect data from two receive lines. For this application, two antennas must be mounted at the focus of the reflector system, and the second receive line is simply connected directly to the cross-polarized antenna.

The radar has been interfaced to an IBM/AT personal computer through either a parallel I/O or HPIB port. All radar system functions are controlled through the IBM/AT which uses a menu driven architecture that is described in the System Software Chapter.

For a more complete description of the individual RF components and system design used for this radar, one is referred to Ref. [3].

B. IF SIGNAL GENERATION UNIT

As stated earlier, the transceiver has three IF stages (1.5116 GHz, 11.6 MHz and 100 KHz) which implies that the following frequencies must be generated:

$$
\begin{aligned}
\text{1.5 GHz and 1.5116 GHz} &\rightarrow 1^{st}\ \text{IF} \\
\text{11.6 MHz and 11.7 MHz} &\rightarrow 2^{nd}\ \text{IF} \\
\text{100 KHz} &\rightarrow 3^{rd}\ \text{IF}
\end{aligned}
$$

Because the system was designed for Ka-band operation, using frequency doubling, the IF section also had to generate a first stage IF signal at 755.8 MHz because it will be converted to 1.5116 GHz by the doubler in the RF line as will be described in the next section. In order to provide all these signals, the IF signal generator unit uses three crystal stabilized sources: one at 750 MHz, one at 5.8 MHz and one at 100 KHz. These signals can then be mixed and/or doubled to generate the other frequencies as shown in Figure 7. Note that the actual components used in this subsystem are specified in Table 1. In order to grasp the hardware approach used in this unit, let us trace the flow diagram for each signal.

1. 11.7 MHz Signal

A 5.8 MHz signal is generated by the crystal referenced oscillator (02) as shown in Figure 8. This signal is split at the power divider (PD3), doubled at (DB3), amplified by (AR4), and filtered at (FL4). Thus, the signal arriving at mixer (M2) is a pure 11.6 MHz spectral component. It is mixed at (M2) with a stable 100 KHz signal, which is filtered by a very narrow bandpass filter which selects the 11.7 MHz component. This 11.7 MHz signal is then sent to the IF receive unit and is used to downconvert the 11.6 MHz (second stage IF) signal to 100 KHz.

2. 1.5 GHz Signal

A 750 MHz signal is generated by (01) and split by (PD1) as shown in Figure 8. This signal is doubled by (DB2), amplified by (AR3) and bandpass filtered by (FL3). This 1.5 GHz signal is then sent to the IF receive unit where it will be used to mix the 1.5116 GHz (first stage IF) signal down to 11.6 MHz.

3. 755.8 MHz Signal

The 750 MHz (01) and the 5.8 MHz (02) signals are mixed by (M1) as shown in Figure 8. This signal is then bandpass-filtered (FL1) and amplified by (AR1) which is the desired 755.8 MHz component that can be switched by (SW1) and used to generate the RF signal at Ka-band. Note that the Ka-band RF signal is obtained by mixing the LO and 755.8 MHz signal and subsequently doubling them to Ka-band.

4. 1.5116 GHz Signal

Following the 755.8 MHz line from switch (SW1), the signal is doubled by (DB1), bandpass filtered by (FL2) and amplified by (AR2). The resulting signal is the desired 1.5116 GHz output. This signal is split by (DC1) with the major portion being sent to the RF source unit where it will be mixed

Amplifier	Manufacturer	Model No.	Freq. (GHz)	Gain (min) (dB)	Power Output @ 1 db Compression (dBm)	Application
AR1	Avantek	AFT-2062-1	0.5 - 2	20	20	755.8 MHz
AR2	Avantek	AFT-2061-1	0.5 - 2	10	20	1511.6 MHz
AR3	Avantek	AFT-2062-1	0.5 - 2	20	20	1500 MHz
AR4	Q-bit	QBH-9-118	3 - 125 MHz	16	13	11.6 MHz
AR5	Q-bit	QBH-9-118	3 - 125 MHz	16	13	11.6 MHz
AR6	Q-bit	QBH-9-118	3 - 125 MHz	16	13	11.6 MHz
AR7	Analog Devices	ADOP-37	100 kHz	35	16 (into 1200 Ω)	100 KHz
AR8	Analog Devices	ADOP-37	100 kHz	35	16 (into 1200 Ω)	100 KHz
AR9	Q-bit	QBH-9-118	3 - 125 MHz	16	13	11.7 MHz
AR10	Q-bit	QBH-9-118	3 - 125 MHz	16	13	11.7 MHz

Doubler	Manufacturer	Model No.	Freq. (GHz) input	Freq. (GHz) output	Conversion Loss (dB)	Application Input Freq.	Application Output Freq.
DB1	Anzac	D-6-4	0.05 - 1.3	0.1 - 2.6	13	755.8 MHz	1511.6 MHz
DB2	Anzac	D-6-4	0.05 - 1.3	0.1 - 2.6	13	750 MHz	1500 MHz
DB3	Anzac	FM-102-4	100KHz-.6GHz	200KHz-1.2GHz	13	5.8 MHz	11.6 MHz

Coupler	Manufacturer	Model No.	Freq. (GHz)	Coupling Value	Application Freq.
DC1	Narda	4012C-20	1 - 2	20 dB	1511.6 MHz

Filter	Manufacturer	Model No.	Center Freq.	Bandwidth Specs. (MHz) -3 dB	
FL1	K & L	4C40-755.8/2-0/0	755.8 MHz	5	-60 dB @ 750, 1500-1515, 2250-2275, 3000-3025
FL2	K & L	4C45-1511.6/4-0/0	1511.6 MHz	5	-60 dB @ 1500, 3000-3100, 4500, 6000
FL3	K & L	5C40-1500/4-0/0	1500 MHz	5	-60 dB @ 750, 1500, 2250, 3000
FL4	Chesterfield	22-10-1575	11.6 MHz	0.5	-60 dB Bandwidth = 6 MHz
FL5	Chesterfield	22-10-1574	11.7 MHz		-60 dB @ 11.6 MHz and >60 dB up to 60 MHz
FL6	Chesterfield	22-10-1575	11.6 MHz	0.5	-60 dB Bandwidth = 6 MHz
FL7	Chesterfield	22-10-1575	11.6 MHz	0.5	-60 dB Bandwidth = 6 MHz
FL8	Chesterfield	22-10-1522	100 KHz	50 KHz	>80 dB @ 6.25 MHz
FL9	Chesterfield	22-10-1522	100 KHz	50 KHz	>80 dB @ 6.25 MHz
FL10	K & L	5C40-1500/4-0/0	1500 MHz	5	-60 dB @ 750, 1500, 2250, 3000
FL11	K & L	5C40-1500/4-0/0	1500 MHz	5	-60 dB @ 750, 1500, 2250, 3000

Isolator	Manufacturer	Model No.	Freq. GHz	Isolation (dB)	Application Freq.
I1	Trak	20-1551			1.5 GHz
I2	Trak	20-1551			1.5 GHz
I3	Trak	20-1551			1.5116 GHz
I4	Trak	20-1551			1.5116 GHz

Table 1: IF Hardware Specifications and Manufacturers

Mixer	Manufacturer	Model No.	Freq. IF	Freq. RF,LO	Conversion Loss, (dB)	Application LO	Application RF	Application IF
M1	Anzac	MDC-154	.1 - 3000 MHz	0.3 - 5 GHz	6.5	750 MHz	755.8 MHz	5.8 MHz
M2	Watkins Johnson	MT9EC	0 - .7 GHz	0 - .7 GHz	6.5	11.6 MHz	11.7 MHz	100 KHz
M3	Anzac	MDC-154	.1 - 3000 MHz	0.3 - 5 GHz	6.5	1500 MHz	1511.6 MHz	11.6 MHz
M4	Anzac	MDC-154	.1 - 3000 MHz	0.3 - 5 GHz	6.5	1500 MHz	1511.6 MHz	11.6 MHz
M5	Watkins Johnson	MT9EC	0 - .7 GHz	0 - .7 GHz	6.5	11.7 MHz	11.6 MHz	100 KHz
M6	Watkins Johnson	MT9EC	0 - .7 GHz	0 - .7 GHz	6.5	11.7 MHz	11.6 MHz	100 KHz

Source	Manufacturer	Model No.	Freq.	Power Output (dBm)
O1	M/A Com OSW	PLO-24-04	750 MHz	+20
O2	IN HOUSE	IN HOUSE	5.8 MHz	+ 7

Power Divider (3 dB)	Manufacturer	Model No.	Freq.	Application Freq.
PD1	Narda	4321-2	0.5 - 2 GHz	750 MHz
PD2	Narda	4321-2	0.5 - 2 GHz	1500 MHz
PD3	Anzac	THV-50	2 - 200 MHz	5.8 MHz
PD4	Mini-Circuits	ZFSC-2-6	2 KHz - 60 MHz	100 KHz
PD5	Anzac	THV-50	2 - 200 MHz	11.7 MHz
PD6	Mini-Circuits	ZFSC-2-6	2 KHz - 60 MHz	100 KHz
PD7	Narda	4321-2	0.5 - 2 GHz	1511.6 MHz

Mechanical Coaxial Switches	Manufacturer	Model No.	Freq. (GHz)	Switch Type	Appl. Freq.
SW1	Peter Novak	5TLB2D	DC-2	XFER	755.8, 1511.6 MHz
SW2	Peter Novak	5TLB2D	DC-2	XFER	1511.6 MHz
SW3	Peter Novak	5TLB2D	DC-2	XFER	1511.6 MHz
SW4	Peter Novak	52LB2D	DC-2	SPDT	100 KHz
SW5	Peter Novak	52LB2D	DC-2	SPDT	100 KHz

Table 1: Continued.

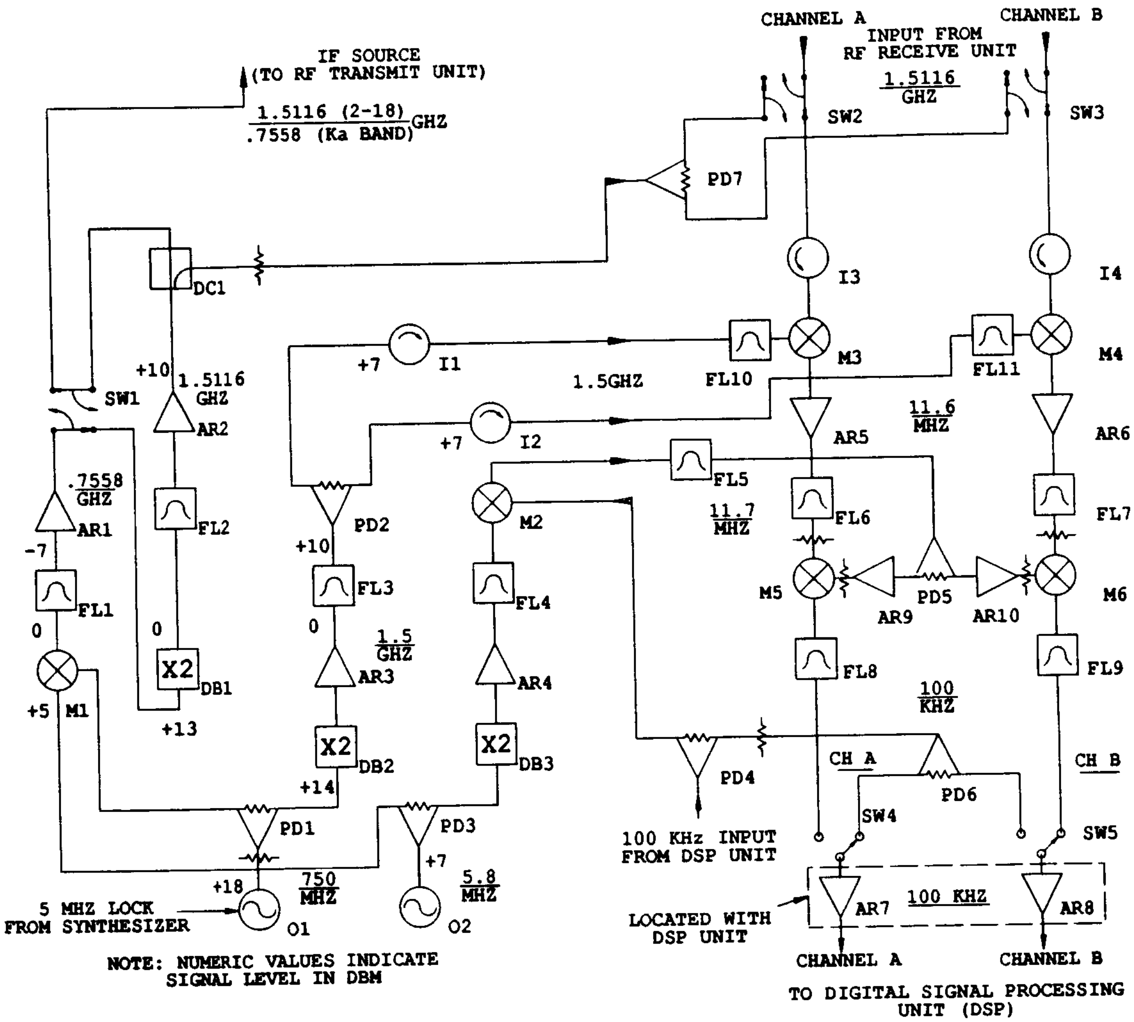


Figure 7: IF hardware unit.

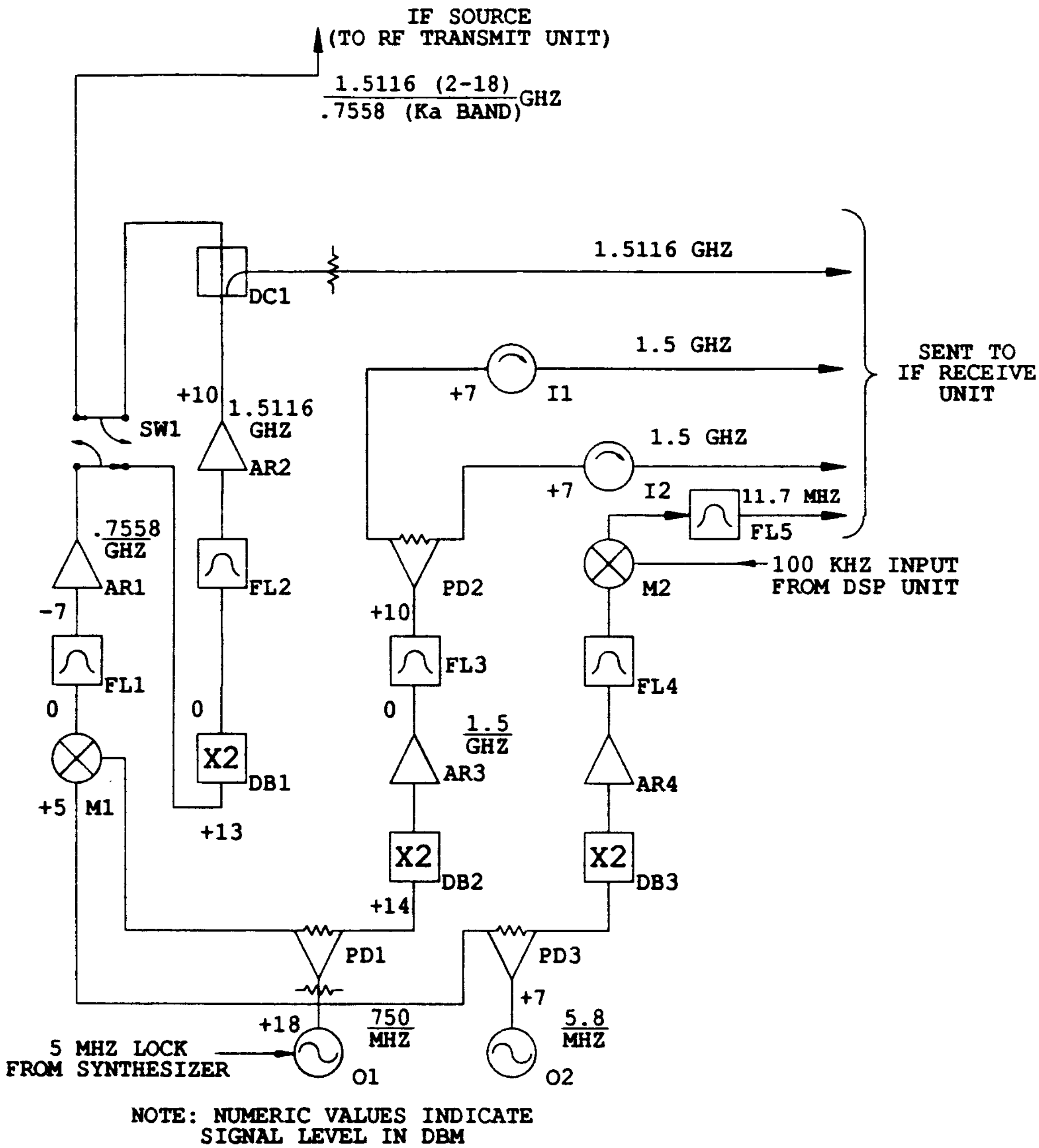


Figure 8: IF signal generation unit schematic.

with the LO to generate the desired RF. The minor signal from (DC1) is sent to the IF receive unit to be used as a loop mode to test the system hardware if a potential problem is suspected.

C. RF SIGNAL GENERATION UNIT

There are two input signals to the RF signal generator unit shown in Figure 9. They are the IF input provided by the IF signal generator unit and the LO signal produced by a synthesized source. This unit uses the specific hardware components listed in Table 2 and provides the RF radiated signal from 2-18 GHz which consists of two bands, 2 to 6 GHz and 6 to 18 GHz. These two bands are needed because isolators are presently limited to 3 to 1 bandwidths. As seen in Figure 9, each pin diode switch (SW2, SW4 and SW5) is surrounded by a bandpass filter to remove transient signals and isolators to eliminate reverberations. The RF circuit description is examined next.

The LO signal is sent to the computer-controlled attenuator (ATT2) and then the signal is split at (DC4) with the minor portion going to the Ka-band LO port. The major part of the LO is then amplified by (AR5). After the amplifier, the signal strength is sensed by (DC5) and sent to the computer through the data acquisition card. The computer can then use this data to adjust the LO power which is used as an LO leveler. The LO leveled signal is then split by (PD1) with a half being sent to the RF receiver unit and will be used to mix the RF backscattered signal down to 1.5116 GHz. The other half is high pass filtered by (FL8) to remove any IF signal which could couple through M1 and PD1 and be introduced into the RF receive section. Finally, this signal is amplified by (AR4) and input to the mixer (M1) to generate the desired RF component.

The IF (1.5116 GHz) signal is input to switch (SW1) which is used to

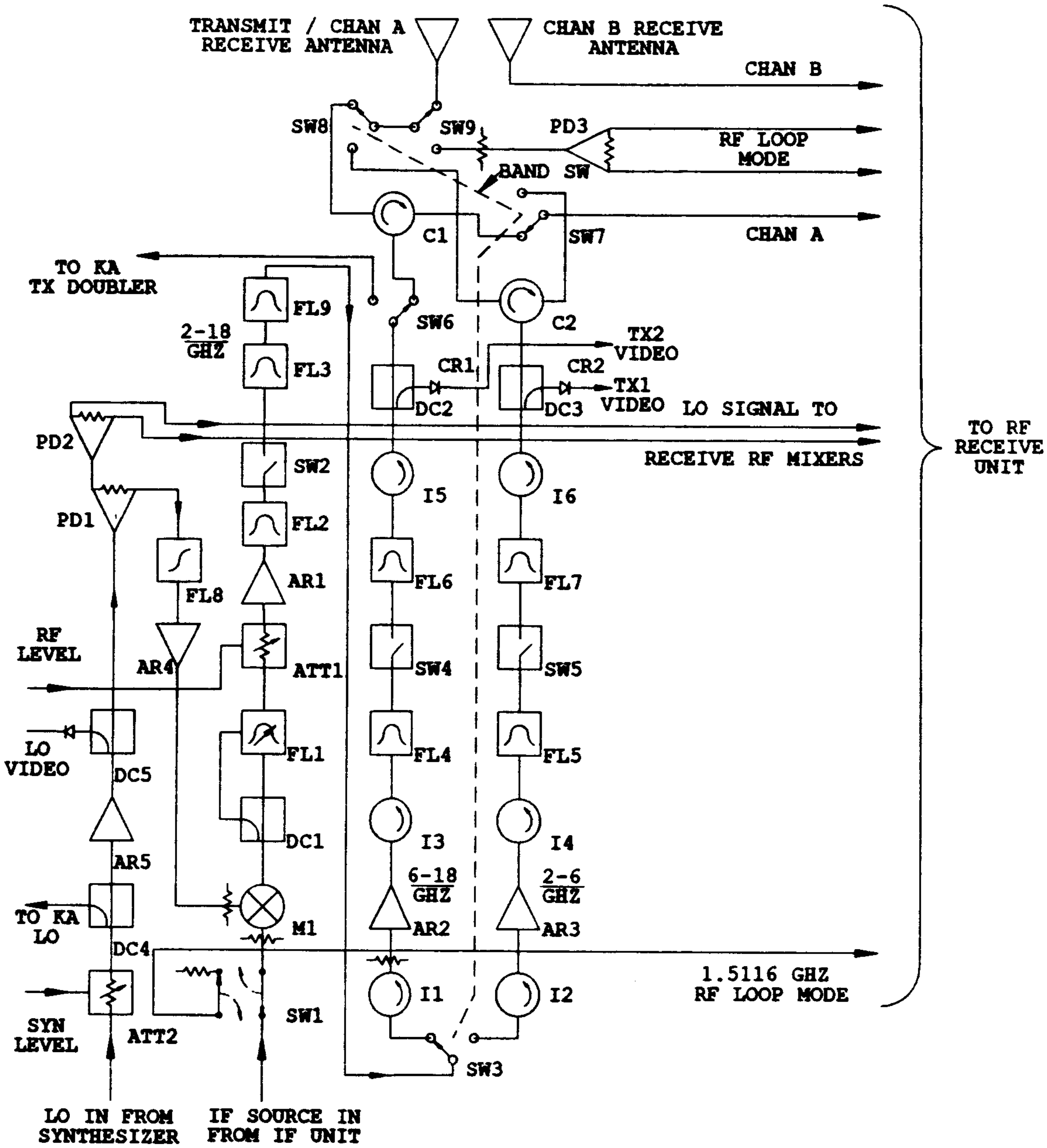


Figure 9: RF transmit unit schematic.

transfer the IF signal to the RF receiver unit (under computer control) as a loop mode for system testing. In the normal operation mode, the LO and IF signals are mixed by (M1) to produce the RF. The RF is then split by (DC1) with a small portion being sent to the reference input port of the yig-tuned filter (FL1). The yig-tuned filter is coarsely tuned by the computer and locks onto the reference signal for fine tuning. Once the yig filter is locked, the RF signal passes through the filter (FL1). The amplitude of the RF is set by the computer controlled attenuator (ATT1), amplified by (AR1), and filtered by (FL2). The RF pulse width is then set by the pin diode switch (SW2). It is normally set between 20 ns and 25 ns. This RF pulse is then filtered by (FL3) and (FL9) and sent to (SW3) which switches the RF between the two bands (2 to 6 GHz and 6 to 18 GHz). The reverberations from the first pin diode switch are then eliminated by the isolators (I1 or I2). The RF signal is then amplified to about +20 dBm by (AR2 or AR3). The second pin diode switch (SW4 or SW5) is used to pulse the output noise of the power amplifiers and provide more isolation between the transmit and receive sections. These switches normally have a 30 ns pulse width which turns on 5 ns before the narrow RF pulse and off 5 ns after it. This will be discussed more in the Pulse Timing Chapter. The filters (FL4, FL5, FL6 and FL7) are used to remove switch transients, and the isolators (I3, I4, I5 and I6) are needed to eliminate reverberations. The resulting RF component is split by (DC2 or DC3), and the minor portion is sensed by a diode detector which sends the signal strength to the computer through the data acquisition card. The major RF component is sent to the circulator (C1 or C2) which directs the RF to the antenna after it is band switched by (SW8). The signal received by the antenna again passes through the band switch (SW8) to the circulator (C1 or C2) where it is

Amplifier	Manufacturer	Model No.	Freq. (GHz)	Gain (dB)	Power Output @ 1 db Gain Compression, (dBm)	Application Notes
AR1	Avantek	APT-18232	2-18 GHz	9	+10	2-18 Xmit Preamp
AR2	Avantek	APT-18649	6-18 GHz	35	+23	6-18 Xmit Power Amp
AR3	Avantek	AWT-6054	2-6 GHz	36	+23	2-6 Xmit Power Amp
AR4	Avantek	APT-18232	2-18 GHz	9	+10	LO Amp
AR5	Avantek	APT-18232	2-18 GHz	9	+10	LO Amp

PIN Diode Attenuator	Manufacturer	Model No.	Freq. (GHz)	Attenuation Range (dB)	Application
ATT1	General Micro	M190-311	0.2 - 18	65	Part of RF leveler
ATT2	General Micro	M190-311	0.2 - 18	65	Part of LO leveler

Circulator	Manufacturer	Model No.	Freq. (GHz)	Isolation (dB)
C1	Trak	50A2601	6-18	11
C2	Trak	50A3401	2-6	12

Detector	Manufacturer	Model No.	Freq. (GHz)	Application Note
CR1	Virtech	VTP-2018	2 - 18	6 - 18 GHz Xmit Video Detector
CR2	Virtech	VTP-2018	2 - 18	2 - 6 GHz Xmit Video Detector

Directional Coupler	Manufacturer	Model No.	Freq. (GHz)	Coupling (dB)	Application Note
DC1	Narda	4203-6	2 - 18	6	
DC2	Narda	4203-16	2 - 18	16	
DC3	Narda	4203-16	2 - 18	16	
DC4	Narda	4203-16	2 - 18	16	
DC5	Virtech	VC-123	2 - 18		directional detector / used in LO leveler

Filter	Manufacturer	Model No.	Type	Freq. (GHz)
FL1	Ferretec	FT-1755	Tracking BP	2 - 18
FL2	Cir-Q-Tel	FHR-2G-5/50	BP	2 - 18
FL3	Cir-Q-Tel	FHR-2G-5/50	BP	2 - 18
FL4	Cir-Q-Tel	FHR-2G-5/50	BP	2 - 18
FL5	Cir-Q-Tel	FHR-2G-5/50	BP	2 - 18
FL6	Cir-Q-Tel	FHR-2G-5/50	BP	2 - 18
FL7	Cir-Q-Tel	FHR-2G-5/50	BP	2 - 18
FL8	Cir-Q-Tel	FHR-3G-5/50	HP	f_c = 3
FL9	Sierra Microwave Tech.	SM31019	BP / Gain Equalizer	2 - 18

Table 2: RF Transmit Hardware Specifications and Manufacturers

Isolator	Manufacturer	Model No.	Freq. GHz	Isolation (dB)
I1	Trak	60A2601	6 - 18	12
I2	Trak	60A3401	2 - 6	12
I3	Trak	60A2601	6 - 18	12
I4	Trak	60A3401	2 - 6	12
I5	Trak	60A2601	6 - 18	12
I6	Trak	60A3401	2 - 6	12

Mixer	Manufacturer	Model No.	Freq. IF	Freq. RF,LO	Conversion Loss, (dB)	Application LO	Application RF	Application IF
M1	Watkins Johnson	MY50HC	1 - 12 GHz	2 - 26 GHz	9.5	3.5-16.5 GHz	2-18 GHz	1.5116 GHz

Power Divider (3 dB)	Manufacturer	Model No.	Freq. (GHz)	Application Freq. (GHz)
PD1	Narda	4456-2	2 - 18	3.5 - 16.5
PD2	Narda	4456-2	2 - 18	3.5 - 16.5

Switch	Manufacturer	Model No.	Freq. (GHz)	Switch Type	Appl. Freq. (GHz)
SW1	Dynatech/UZ	T2-416E30L	DC - 18	Mechanical XFER	1.5116
SW2	General Micro	F-192A	0.2 - 18	High Speed PIN	2 - 18
SW3	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SP2T	2 - 18
SW4	General Micro	F-192A	0.2 - 18	High Speed PIN	6 - 18
SW5	General Micro	F-192A	0.2 - 18	High Speed PIN	2 - 6
SW6	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SP2T	6 - 18
SW7	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SP2T	2 - 18
SW8	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SP2T	2 - 18
SW9	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SP2T	2 - 18

Table 2: Continued.

directed to the Channel A receive line band switch (SW7). This switch then connects the 2 to 6 GHz and 6 to 18 GHz circulator output to the RF channel A receive unit.

The 6 to 18 GHz band RF line can be switched by (SW6) to provide the necessary RF signal for the Ka-band doubler. In addition, switch (SW9) is used to provide an RF loop mode by connecting the antenna transmit line to the RF receive unit. This loop mode is used to insure that the RF system is functioning properly.

D. RF RECEIVE UNIT

The RF receive unit is divided into two channels (A and B) which use identical hardware as shown in Figure 10 with the actual components listed in Table 3. Channel A is normally connected to the transmit antenna which means that it is used to measure the co-polarized, scattered signal; whereas, Channel B is used to measure the cross- polarized response. Thus, channel B is connected to a second antenna which is oriented orthogonal to the transmit one.

The RF receive unit also has two loop mode inputs. One loop mode is a 1.5116 GHz signal which is used to test lines to and from the RF head located at the feed mount. The second loop mode uses the RF signal which is switched via (SW9) to either the transmit antenna or the loop mode. In the loop mode, the signal is input into a splitter (PD3) as shown in Fig. 9 and injected into the receive line by a mechanical switch (SW7 or SW8) as shown in Fig. 10.

The pulsed RF signal is input to (SW1 and SW2) where it is pulsed to eliminate the horn coupling and circulator leakage terms which arrive at the switch long before the target response. Thus, these switches are open initially but are closed after these early responses die out. They normally

Amplifier	Manufacturer	Model No.	Freq. (GHz)	Gain (min) (dB)	Power Output @ 1 db Compression (dBm)	Application
AR1	Miteq	AFD2-0120175-11	1.2 - 1.75	20	+10	LNA, 1.5116 GHz
AR2	Miteq	AFD2-0120175-11	1.2 - 1.75	20	+10	LNA, 1.5116 GHz
AR3	Miteq	AFD2-0120175LN	1.2 - 1.75	30	+20	LIMITING, 1.5116 GHz
AR4	Miteq	AFD2-0120175LN	1.2 - 1.75	30	+20	LIMITING, 1.5116 GHz
AR5	Avantek	AFT-18232	2 - 18	9	+10	3.5 - 16.5 GHZ
AR6	Avantek	AFT-18232	2 - 18	9	+10	3.5 - 16.5 GHZ

Detector	Manufacturer	Model No.	Freq. (GHz)	Application Note
CR1	Virtech	VTP-2018	2 - 18	RCV Channel A Video Detector
CR2	Virtech	VTP-2018	2 - 18	RCV Channel B Video Detector

Directional Coupler	Manufacturer	Model No.	Freq. (GHz)	Coupling (dB)	Application Note
DC3	Omni-Spectra	2020-6605-10	1 - 2	10	RCV Chan. A IF Detector Coupler
DC4	Omni-Spectra	2020-6605-10	1 - 2	10	RCV Chan. B IF Detector Coupler
DC5	Narda	4012C-20	1 - 2	20	RCV Chan. A IF Loop Injection
DC6	Narda	4012C-20	1 - 2	20	RCV Chan. A IF Loop Injection

Filter	Manufacturer	Model No.	Type	Freq. (GHz) Fc	BW
FL1	Cir-Q-Tel	FHR-2G--5/50	BAND PASS	2 - 18	
FL2	Cir-Q-Tel	FHR-2G--5/50	BAND PASS	2 - 18	
FL5	K & L	4B120-1500/600	BAND PASS	1.2 - 1.8	
FL6	K & L	4B120-1500/600	BAND PASS	1.2 - 1.8	
FL7	K & L	4C45-1511.6/4-0/0	BAND PASS	1.5116	4 MHz
FL8	K & L	4C45-1511.6/4-0/0	BAND PASS	1.5116	4 MHz
FL9	K & L	5L120-2000-0/0	LOW PASS	2.0	
FL10	K & L	5L120-2000-0/0	LOW PASS	2.0	
FL11	RLC	F100-1200-3-R	HIGH PASS	1.2	
FL12	RLC	F100-1200-3-R	HIGH PASS	1.2	

Table 3: RF Receive Hardware Specifications and Manufacturers

Isolator	Manufacturer	Model No.	Freq. GHz	Isolation (dB)	Application Freq.
I1	Western Micro	2JC-3018	1.35 - 1.85	18	1.5116 GHz
I2	Western Micro	2JC-3018	1.35 - 1.85	18	1.5116 GHz
I5	Western Micro	2JC-3018	1.35 - 1.85	18	1.5116 GHz
I6	Western Micro	2JC-3018	1.35 - 1.85	18	1.5116 GHz

Mixer	Manufacturer	Model No.	Freq. IF	Freq. RF,LO	Conversion Loss, (dB)	Application (GHz) LO	RF	IF
M1	Avantek	DBX-1824M	.005 - 4 GHz	2 - 18 GHz	7.0	3.5-16.5	2-18	1.5116
M2	Avantek	DBX-1824M	.005 - 4 GHz	2 - 18 GHz	7.0	3.5-16.5	2-18	1.5116

Power Divider (3 dB)	Manufacturer	Model No.	Freq. (GHz)	Application Freq. (GHz)
PD1	Narda	4321-2	1 - 2	1.5116

Switch	Manufacturer	Model No.	Freq. (GHz)	Switch Type	Freq./Application (GHz)
SW1	General Micro	F-192A	0.2 - 18	High Speed PIN	1.5116 GHz Pre-RCV, Chan. A
SW2	General Micro	F-192A	0.2 - 18	High Speed PIN	1.5116 GHz Pre-RCV, Chan. B
SW3	General Micro	F-192A	0.2 - 18	High Speed PIN	1.5116 GHz Pre-RCV, Chan. A
SW4	General Micro	F-192A	0.2 - 18	High Speed PIN	1.5116 GHz Pre-RCV, Chan. B
SW5	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SPDT	1.5116 Ext. mixer in
SW6	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SPDT	1.5116 Ext. mixer in
SW7	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SPDT	2 - 18 RF LOOP mode
SW8	Dynatech/UZ	D1-416E30L	DC - 18	Mechanical SPDT	2 - 18 RF LOOP mode

Table 3: Continued.

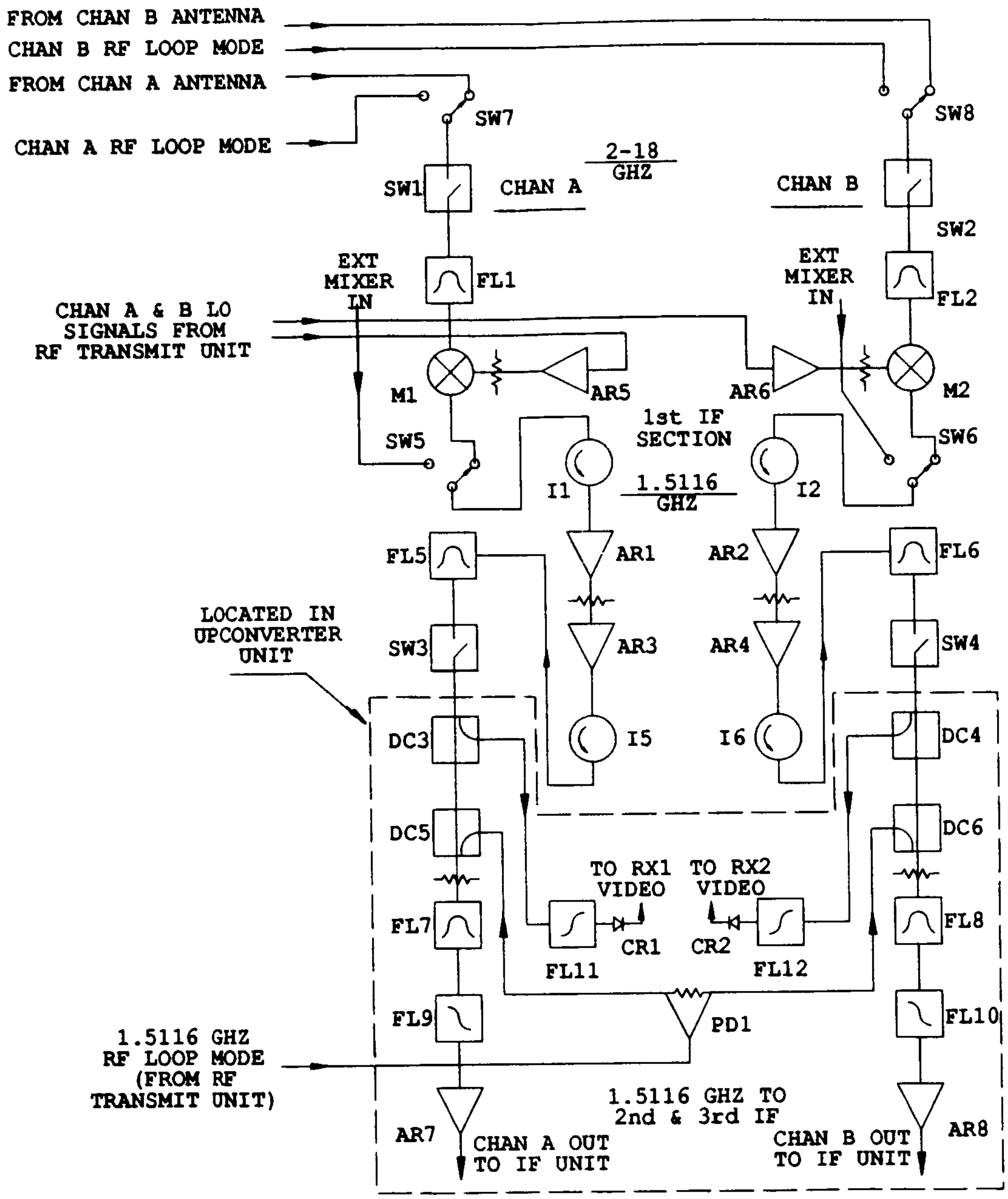


Figure 10: RF receive unit schematic.

have a pulse width of 120 ns which encompasses the reflector bounce and target responses. Note the reflector bounce is used as the reference term so it must pass through this switch to get to the receiver.

The pulsed RF signal is then filtered to remove video transients and input to (M1 and M2) where it is mixed with the LO to generate the first IF (1.5116 GHz). Note that the mechanical switches (SW5 and SW6) allow the IF input to come from the Ka-band system. In either case, these pulsed IF signals are sent to isolators (I1 and I2). This rather narrow band signal is then amplified by an LNA (AR1 and AR2) which ultimately sets the system noise floor. The signal is then amplified by a limiting amplifier (AR3 and AR4). This amplifier limits its output to +10 dBm which insures that the system will not be over driven if too large a signal is input to the receiver.

Next the usual isolators and filters surround the second receive switch (SW3 or SW4). This switch defines the receive gate width which for the target response is normally 5 to 10 ns wide. The receive pulse width for the reference response is normally set at 5 ns and positioned on the reflector bounce. After this switch, the clutter has been removed such that the complete pulse spectrum is not needed any longer. Thus, the signal is filtered which eliminates the pulse spectral lines as shown in Figure 5. These spectral lines occur at the PRF, and their amplitude is defined by the pulse width. This filtering occurs at FL7 and FL8. Thus, the output from this filter is basically a CW signal at 1.5116 MHz which results directly from the original RF frequency and can be thought of as the carrier that is modulated by the pin diode switches. This CW output is then sent to the IF receive unit. If the system is built as a dual-channel receiver, then channels (A and B) are output as separate signals.

E. IF RECEIVE UNIT

The IF receive unit has two basic inputs from channels A and B at 1.5116 GHz as shown in Figure 11. In addition, there are two loop mode signals which can be used to evaluate the operation of the IF components. Note that the hardware components and specifications are defined in Table 1. First, there is a loop mode at 1.5116 MHz which can be injected into the IF receive line by switches (SW2 and SW3). The second (100 KHz) loop mode is input at the end of the IF receive line. Between these two loops, one can ascertain whether or not this IF subsystem is operational.

The normal signal route is input first to an isolator (I3 and I4) to eliminate mismatches. It is then mixed by (M3 and M4) with the 1.5 GHz signal to generate the second IF at 11.6 MHz. This signal is subsequently amplified (AR5 and AR6), filtered (FL6 and FL7) and mixed by (M5 and M6) to produce the third IF. This 100 KHz is bandpass-filtered by (FL8 and FL9) and amplified by AR7 and AR8 to provide the desired fundamental harmonic. These stable 100 KHz signals from channels A and B are then sent to our synchronous detector unit which is described in the next section.

F. DIGITAL SIGNAL PROCESSING (DSP) UNIT

The digital signal processing (DSP) unit is used to determine the real and imaginary parts of the 100 KHz signal, convert the analog result to 16 bit digital numbers which are hardware integrated, and then transferred to the IBM/AT computer. An overview of its basic structure is illustrated in Figure 12. Note that this subsystem is all mounted in a PC card rack and is composed of both digital and analog components.

Figure 13 shows the physical orientation of the cards in the DSP chassis.

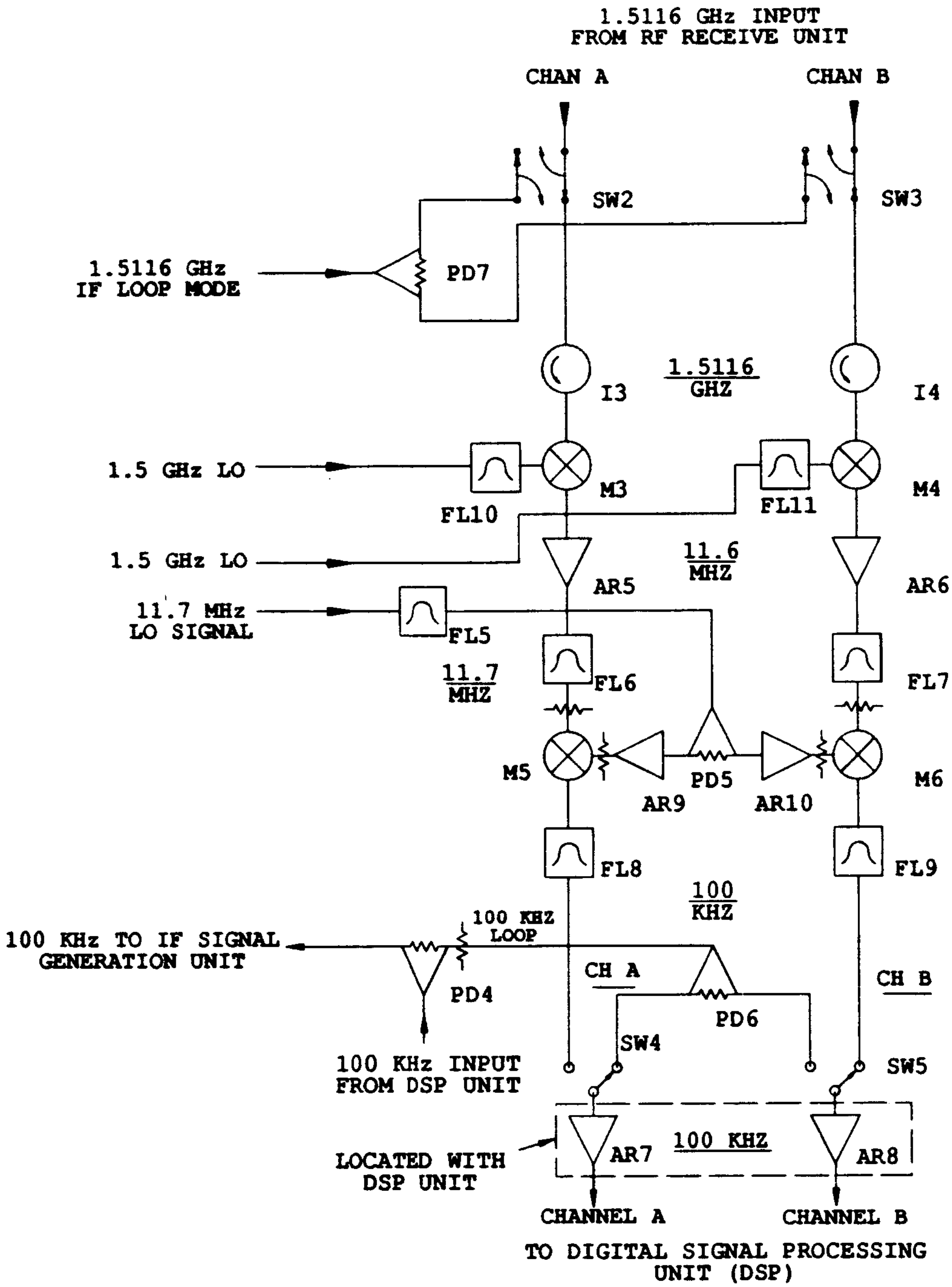


Figure 11: IF receive unit schematic.

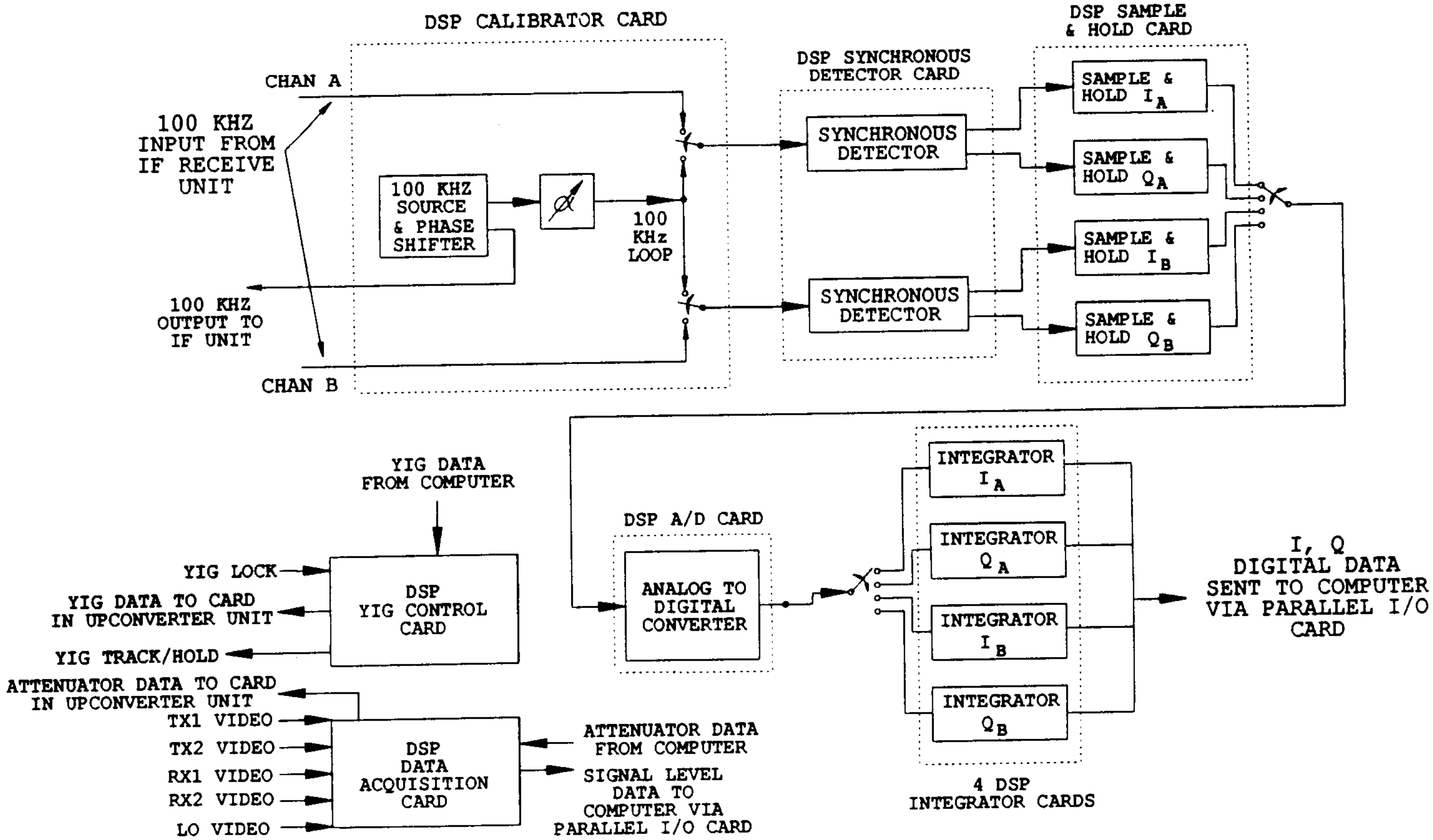


Figure 12: Complete Digital signal processing (DSP) unit schematic.

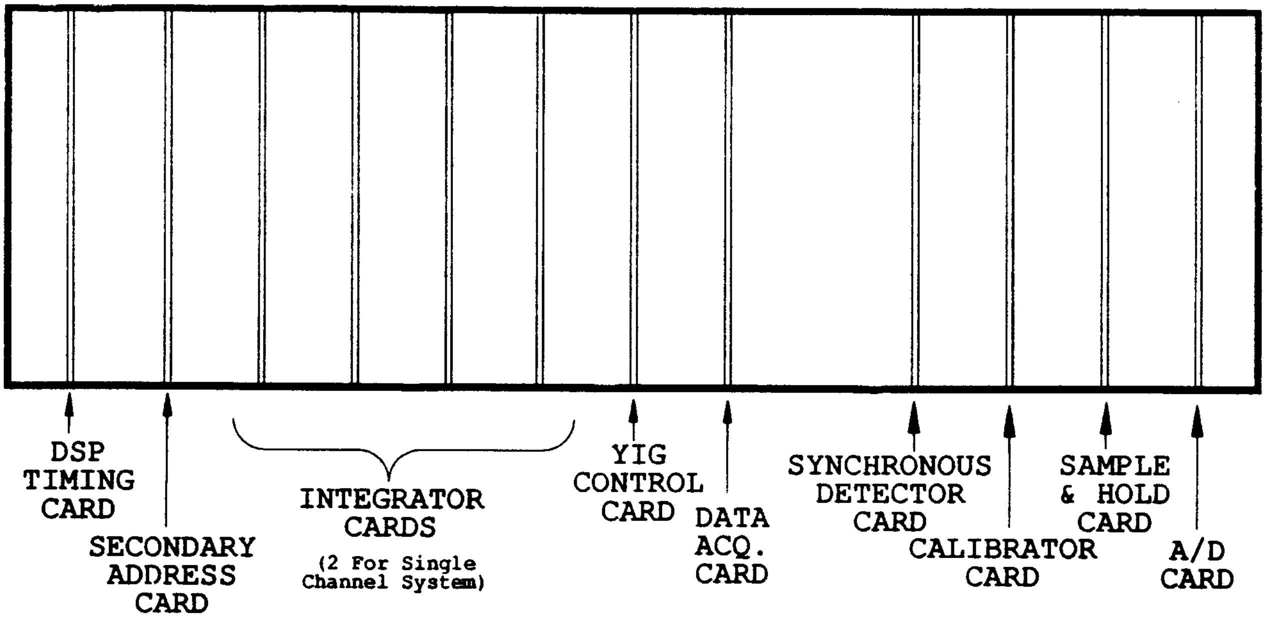


Figure 13: Placement of DSP Cards

The cards are arranged so that the analog processing cards are on the right hand side and the digital processing cards are on the left. However, all the DSP bus slots are identical, so the cards could be arranged in any order and still function properly.

The cards in the chassis are as follows: one calibrator card, one synchronous detector card, one sample and hold card, four integrator cards (two for a single channel system), one yig control card, one data acquisition card, one timing card and one secondary address card. The function of each of these cards is now described.

1. Synchronous Detector Card

In the synchronous detector card, the 100 KHz signal is split into two components each of which is input to the reference port of a D to A converter chip as shown in Figure 14. The digital input is obtained from a memory chip which outputs the digital equivalent of a sine or cosine waveform. This digital data is clocked into the D to A converter at a 4 MHz rate so that the 100 KHz sine and cosine waveforms are represented by 40 samples (this represents sinusoidal samples every 9 degrees). In fact, the cosine waveform is simply a shifted set of samples relative to the sine waveform. The output of these two D to A converters represents a multiplication of the 100 KHz signal by a very accurate sine and cosine signal which forms the integrand of the Fourier integral for the 100 KHz harmonic. Note that the real (I) and imaginary (Q) parts of the 100 KHz signal can be found using the following:

$$I + jQ = \frac{1}{T}\int_{-T/2}^{T/2} f(t)e^{jwt}dt$$

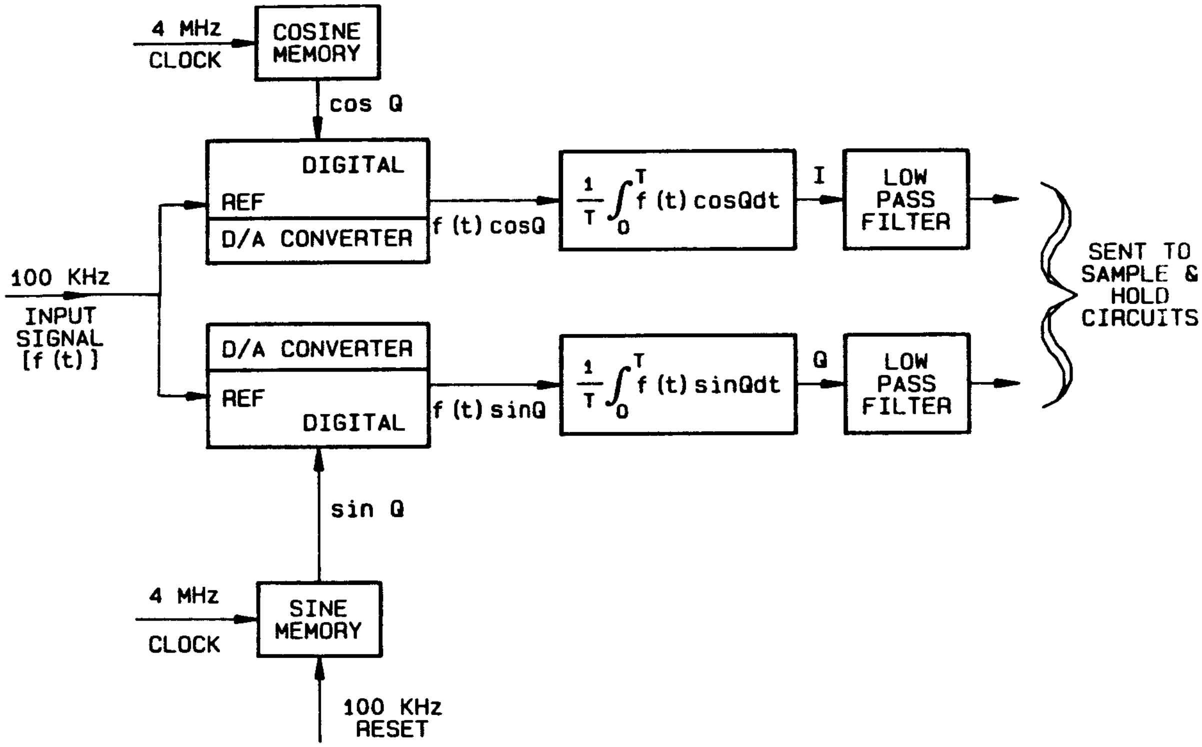


Figure 14: Synchronous detector overview.

$$I + jQ = \frac{1}{T}\int_{-T/2}^{t/2} f(t)\cos wt dt + j\frac{1}{T}\int_{-T/2}^{T/2} f(t)\sin wt dt$$

or

$$I = \frac{1}{T}\int_{-T/2}^{T/2} f(t)\cos wt dt$$

and

$$Q = \frac{1}{T}\int_{-T/2}^{T/2} f(t)\sin wt dt$$

where $T = 10^{-5}$ seconds, $w = 2\pi$ (100 KHz) and $f(t)$ represents the 100 KHz signal. Since the integrands have been generated by the D to A converters, the integrals are performed using an analog integrator circuit. The integrator outputs are then stored by sample and hold circuits shown in Figure 12.

2. Sample and Hold Card

The sample and hold card consists of 4 sample and hold circuits which are clocked to obtain the results at exactly the same time and are updated every 100 μs or at a 10 KHz rate. The timing is very important here in that one must obtain the real (I) and imaginary (Q) parts at precisely the same instant; otherwise, the signal phase will change if the data is collected at different instants, and the I and Q results will be for different time references which results in errors.

Since there are two channels (A and B) input to the synchronous detection unit and an I and Q result is obtained for each channel, there are 4 results stored by the 4 separate sample and hold circuits.

3. The A/D Card

The 4 sample and hold results are then sequentially multiplexed into a single 16-bit A to D converter on the A/D card which in turn outputs the digital data to the appropriate integrator card.

4. The Integrator Cards

There are 4 integrators, one for each of the results stored in the sample and hold circuits; i.e., 2 integrator cards for the I_A and Q_A of channel A and 2 integrator cards for the I_B and Q_B of channel B. The timing is all synchronized so that the sample and hold data is loaded into the A to D, converted to a 16-bit number, and transferred to the integrator cards in 20 μs. This whole process is started after the sample and holds settle down for 12 μs. The total (settling and conversion) time is then 100 μs which is used as the update rate for the sample and holds. Thus, everything is pushed to the timing limit in the hardware to obtain maximum efficiency.

The flow diagram for an integrator card is illustrated in Figure 15. The 16 bit digital data from the A to D converter is multiplexed by a timing sequence to the appropriate integrator card. The data is stored in a latch and then loaded into a 24 bit adder. Starting with a 16 bit input, the adder will then be saturated after 256 additions.

The number of additions, 1 to 256, is input to the integrator card through the computer. Once the integrator card sums the defined amount, the digital data is loaded into an output buffer latch and a data ready line is activated so that the information can be sent to the computer.

Each integrator card has a selection switch which identifies the appropriate input digital data (whether it is I_A, Q_A, I_B or Q_B) and a second switch which specifies the appropriate output address that defines the sequence that the data from the integrator cards is read into the computer. Since there are 4 integrator cards for each dual- channel receiver, one can interchange these cards if a problem is suspected. Note that the integra-

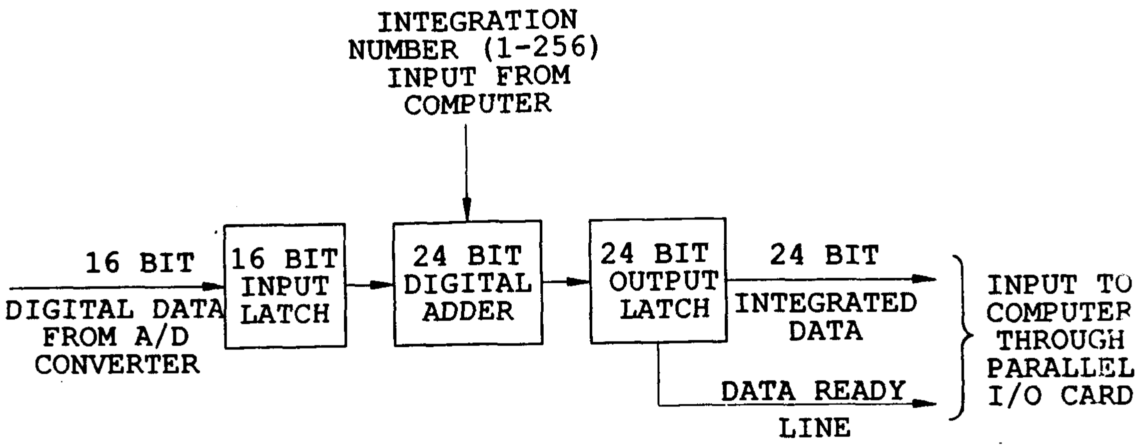


Figure 15: Integrator card overview.

tor cards are interfaced to the computer through the parallel I/O port. The appropriate integrator card is selected by using a secondary address scheme which appears on the parallel I/O address lines. One is referred to the Digital Hardware Schematic Appendix, for more details.

5. Calibrator Card

The calibrator card performs two functions. First, it provides the 100 KHz signal used in the IF unit. This signal is generated by a read-only-memory and D/A configuration similar to that used on the synchronous detector card. In addition, this signal can be switched into the synchronous detector input, which provides the first 100 KHz loop mode as shown in Figure 13. A phase shifter and attenuator are also present so that both magnitude and phase response of the system can be checked by this loop mode.

6. Yig control card

The yig control card in the DSP unit passes digital data between the computer and yig D/A card located in the upconverter unit. A twelve bit latch takes data from the computer and sends it to the D/A converter to tune the yig filter to the proper frequency. A one bit latch provides control over the yig filter's track and hold modes. Another 1 bit line can be monitored to determine whether the yig filter is locked when it is used in the hold mode. Presently only the track mode is used.

7. Data acquisition card

This card converts the detected RX1, RX2, TX1, TX2, and LO video signals into digital data for the computer to read. Also on this card are two 8 bit latches which send data from the computer to the attenuator control card in the upconverter unit to control the LO and RF attenuators.

8. Timing card

As discussed above, precise timing is essential for the proper operation of the calibrator, synchronous detector, sample and hold, A/D, and integrator cards. The timing card provides the necessary timing signals to these cards.

9. Secondary address card

This card interfaces the DSP box with the computer so that the computer can send data to or receive data from the proper card in the DSP box.

G. PULSE GENERATOR UNIT

The pulse generator unit is used to produce the appropriate drive signals for the pin diode switches used in the RF hardware. These switches are controlled either using TTL or ECL logic levels which are generated simultaneously by the pulse generator unit. In order to achieve the desired performance, the pulse generator cards had to be capable of desired delays and pulse width to a resolution of 1 ns. In addition, the pulse has to be stable in time to about 100 picoseconds so that the pulses don't generate additional system noise.

With a dual channel receiver, there are 6 pin diode switches that need to be controlled by the pulse generator unit. Since each pulse generator uses the same concept, it is constructed on an individual printed circuit card with each card being the same. The cards are interfaced to the computer through the parallel I/O card with the appropriate card being specified by a secondary address. Since the secondary address is specified by a switch setting on each card, one can interchange these cards if he suspects an error. Note that the TTL or ECL output signals are sent to the pin diode switches by connecting the appropriate cable to the appropriate output port on the card.

The timing unit is a general purpose pulse generator capable of generating six independent pulse signals. All six pulses are at the same pulse repetition frequency (PRF), but are separately adjustable in delay and width. The common PRF is adjustable from 33.33 MHz to 390.6 KHz or the inter-pulse period is adjustable from 30 ns in 10 ns steps. The pulse cards generate pulses in widths of 0 ns to 21 ns less than the inter-pulse period. The pulses may be placed anywhere in the inter- pulse period except for the first 30 ns, and may extend beyond the inter-pulse period by 9 ns. The PRF generator and all pulse generator cards all have four outputs available simultaneously, positive true and a negative true TTL compatible outputs, and positive true and negative true ECL compatible outputs, all capable of driving 50 ohm coaxial cables. Normally, only two signals are brought off the cards, depending on the requirements of the switch being driven. One signal goes to the switch, and the other is provided to monitor the timing pulses without interrupting the switch drive.

The timing unit is made up of nine printed circuit cards, on 100 MHz basic clock generator, one PRF generator, one 4 MHz clock generator (provides clock signal to the synchronous detection unit), and six pulse generator cards as shown in Figure 16. All cards are housed in a 5.25 inch high by 19 inch wide chassis for rack mounting. A back plane is used for interconnection of all nine cards such that all signals that pass between cards pass through the back plane. The computer is interfaced to the cards through a latch circuit whose purpose it is to correct for dispersion of computer generated pulse edges caused by the ribbon cable. The computer signals are then distributed to the cards through the back plane.

The computer interface circuits are all TTL compatible, and are translated to ECL signals on the cards. All high speed counting circuits are ECL to give better jitter performance, a final output translator chip is used to convert the ECL level pulses to TTL levels, if TTL compatible RF switches are used.

1. 100 MHz Generator Description

The 100 MHz generator card provides the basic clock signal to all other cards in the chassis as shown in Figure 17. It uses either an external 100 MHz signal if one is available or has a 100 MHz oscillator on the board, with moderate stability; i.e., 10 PPM. The 100 MHz is output as a differential signal to the back plane, which is used to improve the stability of the pulses generated by the pulse cards.

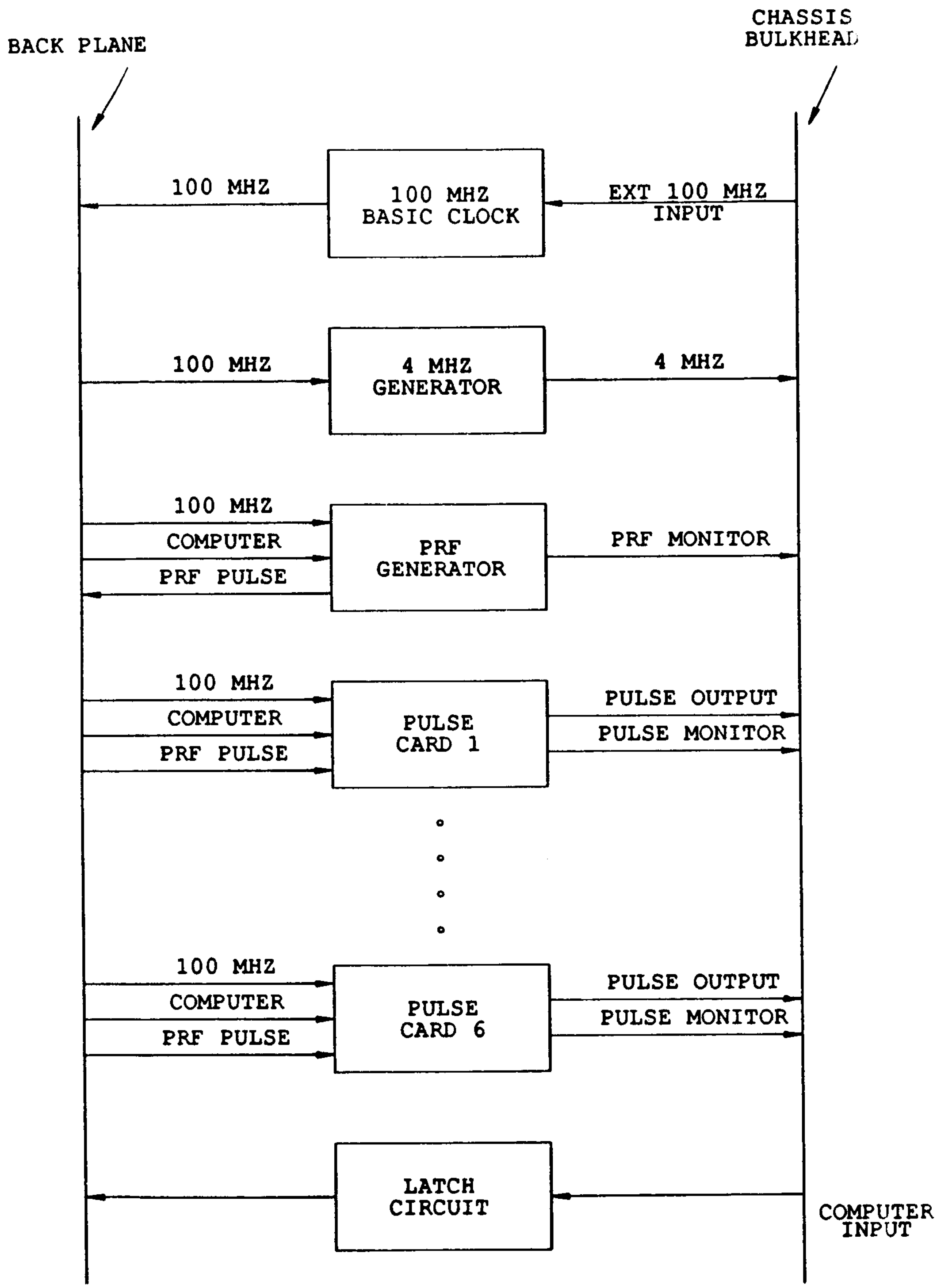


Figure 16: Timing unit block diagram.

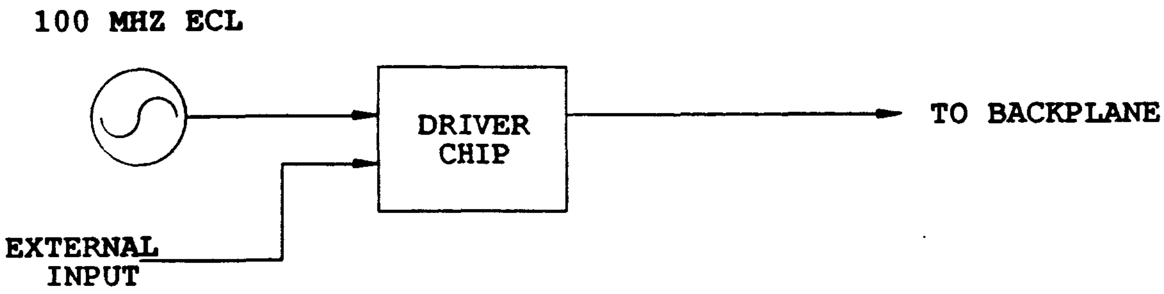


Figure 17: 100 MHz generator card.

2. 4 MHz Generator Description

The 4 MHz generator card uses the 100 MHz signal from the back plane and utilizes a counter circuit to generate the 4 MHz signal required by the synchronous detection unit as shown in Figure 18. The output from the card is a TTL level signal only, with a 20% duty cycle.

3. PRF Generator Description

The PRF generator card has a programmable counter circuit used to generate the inter-pulse period as shown in Figure 19. The card has inputs from the computer to set the counters, which count the 100 MHz basic clock pulses to generate a 10 ns wide pulse to be output as the PRF and input to the pulse cards. The PRF pulse that goes to the back plane is ECL, but both ECL and TTL signals are available to be output for monitoring. The computer input is asynchronous. After the correct address is sent to the card by the computer, the data is clocked into the first latch by the falling edge of PC7 computer line, which is the MSB of the address byte. At the end of the next PRF pulse, the data byte is clocked into the second buffer

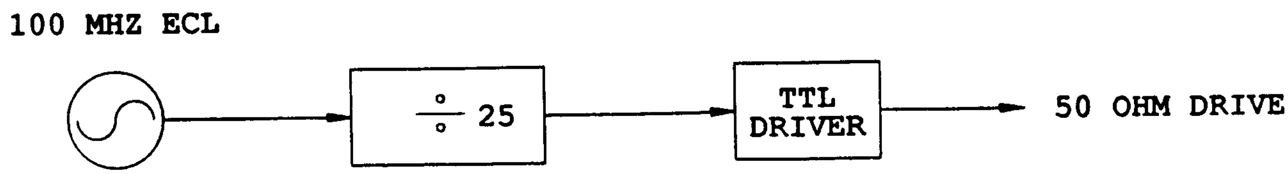


Figure 18: 4 MHz generator card.

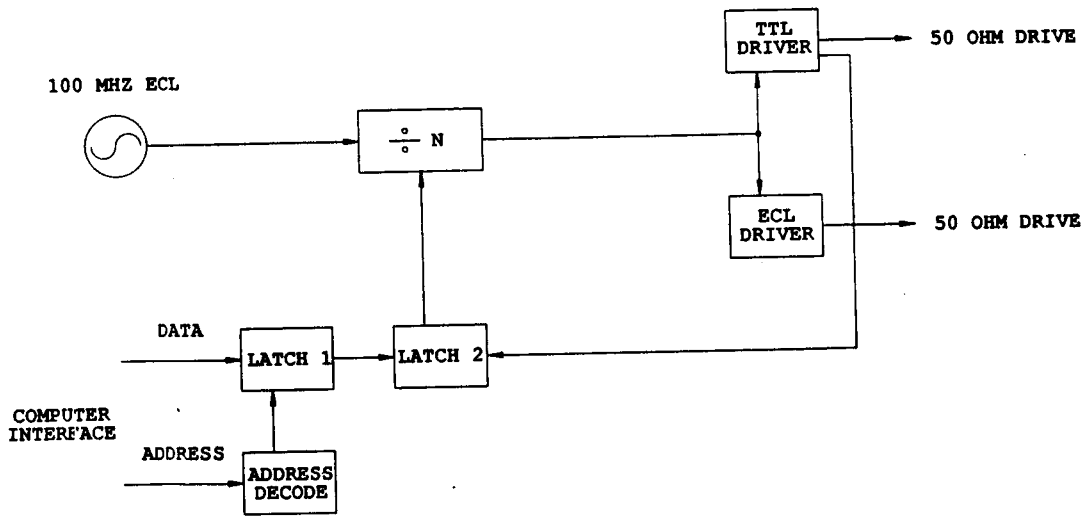


Figure 19: PRF generator card.

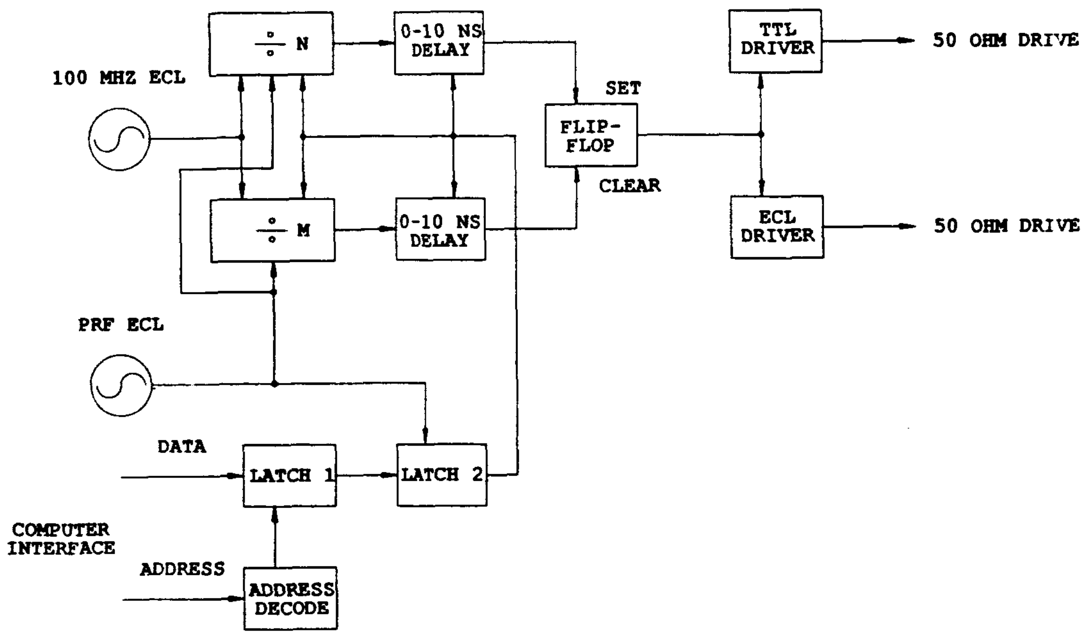


Figure 20: Pulse generator block diagram.

and into the counter circuit.

4. Pulse Generator Description

The pulse generator card has two programmable counter circuits used to generate the pulses as shown in Figure 20. One counter forms the leading edge, and the other forms the trailing edge of the pulse. As with the PRF card, the computer input is asynchronous. After the correct address is sent to the card by the computer, the data is clocked into the first latch by the falling edge of PC7, the MSB of the address byte. In the pulse card, four data bytes are required, course and fine leading edge bytes, and course and fine trailing edge bytes. After all four bytes are loaded into the first buffers, (leading edge course byte always loaded last) and at the end of the next pulse, the data bytes are clocked into the second buffers and into the counter circuits. After each counter circuit is finished, its output is passed through a fine delay line, capable of delaying the edges in 1 ns steps. This allows adjustment of the pulse width and delay in 1 ns increments. After the fine delay lines, the signals are applied to a flip flop to form the actual pulse. The outputs are available in both ECL and TTL levels.

III. SYSTEM SOFTWARE

A. INTRODUCTION

The IBM/AT computer was chosen as the system controller because the hardware and VAX could be rather easily interfaced with existing software and/or hardware. "ASYST" software was used as the basic language because it is designed for such applications. Note that some "assembly language" programming had to be written to speed up the data collection and to provide an "ETHERNET" link to the VAX.

The basic concept of the software on the IBM/AT is to set the system parameters, collect the data, plot the data in fixed formats and output the results to files on the VAX. Using this approach, the IBM/AT is basically running the transceiver, and the VAX is used for signal processing, data file handling and storage.

The IBM/AT is interfaced to the hardware through either the HPIB or the parallel I/O card. The WJ synthesized source and pedestal rotation controller are interfaced through the HPIB. The synchronous detection unit, pulse generator unit, yig-tuned filter, various RF detectors, and computer-controlled attenuators are interfaced to the IBM/AT through the parallel I/O card. Note that the yig-tuned filter hardware card and a data acquisition card are both located within the synchronous detection rack.

Sufficient sensors have been added to the system hardware to allow the range operator to evaluate the operation of each subsystem. As a result, the operator can instruct and examine all pertinent features of the system through the computer. In addition, the computer software is designed to fully automate each type of measurement.

Since there are many features associated with the system, the software is divided into pages. Each page can be accessed through the function keys at the top of the keyboard. The pages which are used more often are grouped as the first three function keys which are indicated in the text by (F1), (F2) and (F3). The less used pages are grouped from (F7) through (F9). Each page is designed in a menu format such that the data can be modified by moving the cursor to the appropriate parameter. In most cases, one can simply type in the desired value if it is numerical, move the cursor and load the result into the software. If data has certain states such as "ON" or "OFF", these states can be toggled by hitting the "ENTER" key. In other cases, the "ENTER" key can be used to toggle numerical data from smaller to larger values; whereas, the "BACKSPACE" key can be used to decrease its value. This concept is used on the pulse timing page to increment the pulse delay or width in 1 ns steps. Even in this mode, one can type in a value and move the cursor to store the new data. Note that the data is not loaded into the system until the cursor is moved which indicates the present value is correct.

The "END" key is used to end system connection and the "CTRL" and "BREAK" key is used to interrupt system connection. The "ESC" key is used to pause the measurement on page 2 or when pushed twice to interrupt the measurement. The "CTRL" and "P" key is used to dump the screen to a printer.

B. TARGET LOG PAGE (F1)

The target log page is used to define the present state of the receiver, the target and file information, the type and extent of scan, and the plot format used to visualize the received data. This page is divided into four major sections, and the operator can move the cursor to all of these areas except some of the receiver values which must be adjusted on the pulse timing page. A screen dump of this page is shown in Figure 21 for various cases.

The right hand side of this page is denoted "OPTIONS" which indicates that various measurement scans can be automatically taken by the system. The operator should begin by selecting the desired option: "AZIMUTH", "FREQUENCY" or "FREQUENCY and AZIMUTH." The "AZIMUTH" scan sets the radar frequency and scans the target as a function of angle. The "FREQUENCY" scan sets the azimuth angle using the pedestal controller and then records the received data as a function of frequency. The "FREQUENCY and AZIMUTH" scan sets the azimuth angle, records the received data, writes the frequency file onto the VAX, rotates the object to a new angle, and repeats the process until all the data is obtained.

The operator should begin using this page by first selecting the appropriate scan option. Once the scan option has been defined, the operator should set all the pertinent parameters for that scan. This is done by moving the cursor to the desired parameter, inputting the data and moving the cursor to load the data.

Whenever a frequency is input, it should always be defined to avoid the pin diode switch harmonics which are related to the pulse repetition frequency. This can be done, say, by scanning from 2002.3 MHz to 18002.3 GHz in steps of 10 MHz with a pulse repetition frequency (PRF) of 5 MHz. With the 5 MHz PRF, it has harmonics at 5N MHz where N is an integer. Thus there is a pulse harmonic at 2000 MHz and 2005 MHz which are avoided by starting at 2002.3 MHz. The 10 MHz steps insure that the other harmonics are avoided.

When the "AZIMUTH" scan option is selected, the operator should specify the angles including the increment. The angle increment in turn defines the speed along with the number of averages used by the receiver hardware. The speed variable need not be adjusted unless speed is the

```
             TARGET LOG                    ¦         FREQUENCY SCAN              OPTIONS
TARGET          : TARGET                   ¦ START FREQ(MHZ)  :      2002.30     AZIMUTH
                                           ¦ STOP FREQ(MHZ)   :     18002.30       SCAN
ORIENTATION   :                            ¦ INCR. FREQ(MHZ)  :        10.00     FREQ&AZIM
FREQ. (GHZ)   : 2-18                       ¦ PED. POS. (DEG)  :          .00       SCAN
POLARIZATION  : VP                         ¦ SCAN CHANNEL     :            A     COMMENT
OPERATOR      :                            ¦ ANTENNA  CODE    :            H     PRESET
FILE NAME       : A0000                    ¦
SUB.DIR.        : DEF                      ¦
-------------------------------------------¦---------------------------------------------
          RECEIVER SETTINGS                ¦           PLOT FORMAT               I/O RESULT
NO. OF AVERAGES   :              64        ¦ # OF DIV.IN FREQ.:            8     MANU-WRI
RF. ATTEN. (DB)   :               0        ¦ MIN. MAGNIT (DB) :       -80.00     WRITE
REFERENCE SIGNAL  :              ON        ¦ MAX. MAGNIT (DB) :          .00     READ
PHA.FLIP:   ON                             ¦ INCR. MAGNIT(DB) :        10.00     -----------
PULSE PRI. (ns) :               200        ¦ MIN. PHASE       :      -180.00       PAGES
TU1 DELA:    90   TU1 WIDT:      30        ¦ MAX. PHASE       :       180.00     MEASURE
TU2 DELA:     0   TU2 WIDT:     125        ¦ INCR. PHASE      :        90.00     PROCESS
TU3 DELA:    54   TU3 WIDT:     120        ¦
TU5 DELA:    55   TU5 WIDT:      20        ¦
```

```
             TARGET LOG                    ¦          AZIMUTH SCAN               OPTIONS
TARGET          : TARGET                   ¦ START ANGLE        :        .00     FREQUENCY
                                           ¦ STOP ANGLE         :     360.00       SCAN
ORIENTATION   :                            ¦ INCR. ANGLE        :        .25     FREQ&AZIM
FREQ. (GHZ)   : 8                          ¦ ACCELERATION (S)   :       3.00       SCAN
POLARIZATION  : VP                         ¦ SPEED              :    1157.00     COMMENT
OPERATOR      :                            ¦ SCAN CHANNEL       :          A     PRESET
FILE NAME       : A0000                    ¦ ANTENNA  CODE      :          H
SUB.DIR.        : DEF                      ¦
-------------------------------------------¦---------------------------------------------
          RECEIVER SETTINGS                ¦           PLOT FORMAT               I/O RESULT
NO. OF AVERAGES   :              64        ¦ # OF DIV. IN ANG.:            8     MANU-WRI
RF. ATTEN. (DB)   :               0        ¦ MIN. MAGNIT (DB) :       -80.00     WRITE
REFERENCE SIGNAL  :              ON        ¦ MAX. MAGNIT (DB) :          .00     READ
PHA.FLIP:   ON                             ¦ INCR. MAGNIT(DB) :        10.00     -----------
PULSE PRI. (ns) :               200        ¦ MIN. PHASE       :      -180.00       PAGES
TU1 DELA:    90   TU1 WIDT:      30        ¦ MAX. PHASE       :       180.00     MEASURE
TU2 DELA:     0   TU2 WIDT:     125        ¦ INCR. PHASE      :        90.00     PROCESS
TU3 DELA:    54   TU3 WIDT:     120        ¦
TU5 DELA:    55   TU5 WIDT:      20        ¦
```

Figure 21: Target log page.

```
           TARGET LOG              :  FREQUENCY & AZIMUTH SCAN        OPTIONS
TARGET        : TARGET             :  START ANGLE      :       .00    FREQUENCY
                                   :  STOP ANGLE       :    360.00      SCAN
ORIENTATION   :                    :  INCR. ANGLE      :      5.00    AZIMUTH
FREQ. (GHZ)   : 2-18               :  START FREQ(MHZ)  :   2002.30      SCAN
POLARIZATION  : VP                 :  STOP FREQ(MHZ)   :  18002.30    COMMENT
OPERATOR      :                    :  INCR. FREQ(MHZ)  :     10.00    PRESET
FILE NAME     : A0000              :  SCAN CHANNEL     :         A
SUB.DIR.      : DEF                :  ANTENNA  CODE    :         H
-----------------------------------:-------------------------------------------
        RECEIVER SETTINGS          :         PLOT FORMAT              I/O RESULT
NO. OF AVERAGES  :            64   :  # OD DIV.IN FREQ.:         8    MANU-WRI
RF. ATTEN. (DB)  :             0   :  MIN. MAGNIT (DB) :    -80.00    WRITE
REFERENCE SIGNAL :            ON   :  MAX. MAGNIT (DB) :       .00    READ
PHA.FLIP:  ON                      :  INCR. MAGNIT(DB) :     10.00   -----------
PULSE PRI. (ns) :            200   :  MIN. PHASE       :   -180.00     PAGES
TU1 DELA:    90  TU1 WIDT:    30   :  MAX. PHASE       :    180.00    MEASURE
TU2 DELA:     0  TU2 WIDT:   125   :  INCR. PHASE      :     90.00    PROCESS
TU3 DELA:    54  TU3 WIDT:   120   :
TU5 DELA:    55  TU5 WIDT:    20   :
                                   :
```

```
           TARGET LOG              :  FREQUENCY & AZIMUTH SCAN        OPTIONS
TARGET        : TARGET             :  START ANGLE      :       .00    FREQUENCY
                                   :  STOP ANGLE       :    360.00      SCAN
ORIENTATION   :                    :  INCR. ANGLE      :      5.00    AZIMUTH
FREQ. (GHZ)   : 2-18               :  START FREQ(MHZ)  :   2002.30      SCAN
POLARIZATION  : VP                 :  STOP FREQ(MHZ)   :  18002.30    COMMENT
OPERATOR      :                    :  INCR. FREQ(MHZ)  :     10.00    PRESET
FILE NAME     : A0000              :  SCAN CHANNEL     :         A
SUB.DIR.      : DEF                :  ANTENNA  CODE    :         H
-------------------------                                        -------------
        RECEIVER SETTING    COMMENT EDITOR                         I/O RESULT
NO. OF AVERAGES  :            EXIT          INSERT                 MANU-WRI
RF. ATTEN. (DB)  :      LINE1: THIS IS A TEST OF NEW               WRITE
REFERENCE SIGNAL :      LINE2: RADAR SYSTEM                        READ
PHA.FLIP:  ON           LINE3:                                    ------------
PULSE PRI. (ns) :       LINE4:                                      PAGES
TU1 DELA:    90  TU1 WID                                           MEASURE
TU2 DELA:     0  TU2 WID                                           PROCESS
TU3 DELA:    54  TU3 WIDT:   120   :
TU5 DELA:    55  TU5 WIDT:    20   :
                                   :
```

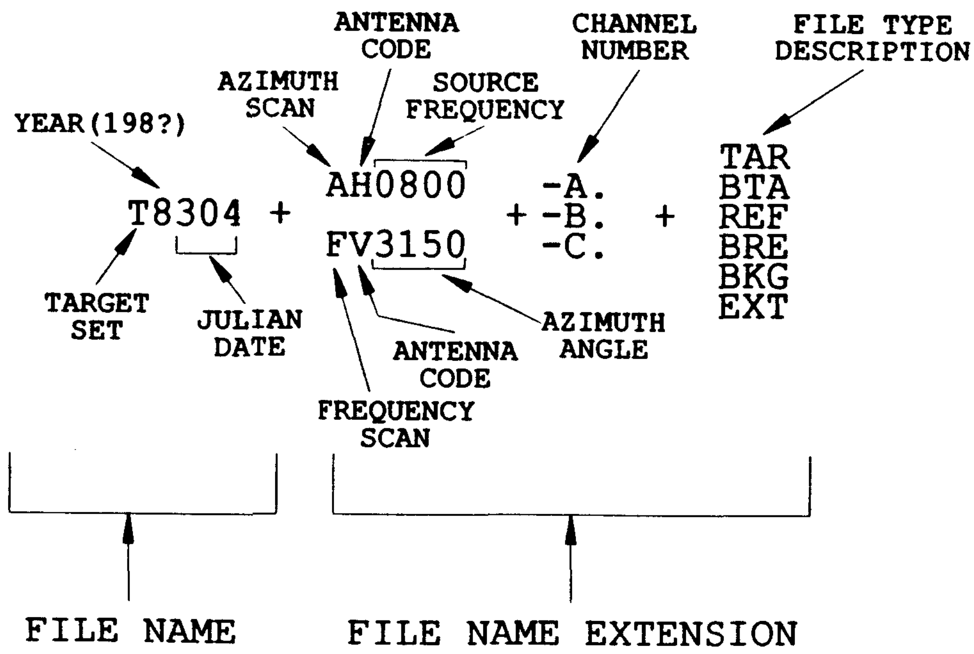
Figure 21: Continued.

most important parameter. If so, the speed will affect the angle increment automatically because the receiver can only run so fast. The acceleration should be evaluated based on the target rotation rate requirements. It is suggested that one start with an acceleration setting of three (3).

Since the system is designed to have two receive channels (A and B), and can be extended to three channels (A, B, and C) the operator has several options for each measurement scan. He can record, plot and write the results from Channel A, B, A & B, C, or A & B & C. If the A & B option is selected, then both sets of data will be recorded. They are then sequentially plotted on the measurement page. Both sets of data will be written out if the "WRITE" command is selected. The operator selects the appropriate channel using the "SCAN CHANNEL" parameter which is toggled between "A", "B", "A & B" "C" and "A & B & C" using the "ENTER" key. The next function is the antenna code setting which is used to set the normal switch interconnection and will be discussed in Section III-F.

Next, one should proceed to define the desired plot parameters. This input is rather straight-forward, but if there are any questions, one can switch to the measurement page (F2) and examine the plot format. If it needs to be adjusted, return to (F1) and modify the appropriate parameter.

The target log section is used to specify the most significant header information that will appear as a legend on the processed plots. (The first line can be logged by the "ENTER" key between "TARGET", "REFERENCE TARGET", "TARGET BKG", "REFERENCE BKG", and "TARGET & REF BKG".) The target information is described by the first two lines, then its orientation. The incident polarization and frequency are defined next, and the operators are specified by appropriate initials. Note that for an azimuth scan, the measurement frequency is defined in the target log section, and the frequency rules discussed earlier to avoid pulse harmonics still apply. The target file name is specified using the following general format:



Using this character format, the target identification is defined by the first one or two characters, the numerical Julian date is positioned on the second, the scan type character is in the third. The antenna code name is in the fourth. The frequency in 10's of MHz (for an AZ scan) or the azimuth angle in 0.1 degrees (for an FR scan) is in the fifth, the channel specification is in the sixth, and finally the file type extension which follows the dot using the normal VAX file structure. It is easy to process a sequence of files with this file name structure. Note that the file name will not be changed until one of the sections in the file name changes. The last target log line is used to specify the subdirectory into which the files are to be written. Note that once the IBM/AT system is activated, the user must log on to a "USER NAME" on the VAX and into its associated directory. Thus, the subdirectory option makes it possible to send data to various subdirectories within the defined "USER NAME". Note that the subdirectories must already exist on the VAX.

As stated earlier, the data files are written out to the VAX through an "ETHERNET" connection by simply activating the "WRITE" command. Each file recorded in the operator-defined directory has a standard header format which is 512 characters long and precedes the data. This header format is defined in Table 4. Using this information, the operator can determine all the receiver settings and target information recorded at the time of the measurement. For example, this data can be retrieved from a given file by simply using one of the VAX editors and recognizing the header format. On the other hand, it is suggested that a short VAX Fortran program be written which decodes this information automatically once the data file name is input.

The last section of this page is associated with defining the various receiver options such as the number of hardware integrations, reference "ON" or "OFF" and RF attenuation. The remaining parameters are specified on the pulse timing page (F8). These parameters can't be changed on this page, but they should be reviewed so that the operator is satisfied with their values. Let us now examine the "OPTIONS" section again at the right hand side of the screen. The "COMMENT" is used to add a few lines of text to the file header as shown in Figure 21. This mode is selected by

Table 4: File Header Format

ITEM NO.	ITEM DESCRIPTION	NO. OF CHARACTERS		
1	FILE FORMAT (0=DEFAULT, 1=NEW FORMAT, 2, ... = FUTURE USE)	2	FILE INFO	
2	FILE NAME	12		
3	FILE PROCESS TYPE (0=RAW)	2		
4	FILE SCAN TYPE (0=FREQ, 1=AZIM, 2=FREQ & AZIM, 3=PROBE, 4=FREQ & PROBE)	2		
5	DATE	8		
6	TIME	5		
7	SPARE	13		
				44
8	TARGET DESCRIPTION	33	TARGET INFO	
9	TARGET ORIENTATION	16		
10	FREQUENCY	16		
11	POLARIZATION	16		
12	OPERATOR ID	16		
13	FILE NAME EXTENSION	12		
14	SPARE	18		
				127
15	CHANNEL (A or B)	2	TARGET INFO	
16	NO. OF AVERAGES	5		
17	RF ATTENUATION (dB)	3		
18	REFERENCE SIGNAL (1=OFF, -1=ON)	3		
19	PHASE FLIP (1=0FF, -1=ON)	3		
20	PULSE PRF (NS)	8		
21	TU1 DELAY (NS)	5		
22	TU1 WIDTH (NS)	5		
23	TU2 DELAY (NS)	5		
24	TU2 WIDTH (NS)	5		
25	TARGET: TU3 or TU5 DELAY (NS)	5		
26	TARGET: TU3 or TU5 WIDTH (NS)	5		
27	TARGET: TU4 or TU6 DELAY (NS)	5		
28	TARGET: TU4 or TU6 WIDTH (NS)	5		
29	REFERENCE: TU4 or TU6 DELAY (NS)	5		
30	REFERENCE: TU4 or TU6 WIDTH (NS)	5		
31	ANTENNA SETTING	6		
32	SPARE	37		
				117
33	START FREQUENCY (MHz)	8	SCAN INFO	
34	STOP FREQUENCY (MHz)	8		
35	INCR FREQUENCY (MHz)	8		
36	START ANGLE (DEG)/POSITION (INCH)	8		
37	STOP ANGLE/POSITION	8		
38	INCR ANGLE/POSITION	8		
39	PEDESTAL (DEG)/PROBER (INCH) POSITION	8		
40	PEDESTAL ACCELERATION	8		
41	SPARE	40		
				104
42	GENERAL COMMENT	120	RANGE INFO	
				120
			TOTAL CHARACTERS:	512

moving the cursor to "COMMENT" and hitting the "ENTER" key. While in this mode, one can type four comment lines which basically describe the measurement and any important parameters which remain constant throughout a measurement sequence. Once the comment is complete, the operator should move the cursor to the "EXIT" and the comment lines will be stored and written out as part of the header.

The "PRESET" option allows one to store the various parameters on the target log page in a file. If this option is selected, the system requests either a store or recall file name or optionally to show the directory of present files. This name is then typed into the computer as a store or recall to either write or read, respectively, the desired file. If "PRESET-DIR" is selected, the system shows the preset files stored on the floppy in drive B. Note that the receiver settings are not affected by the stored "PRESET" data from this page. Some other "PRESET" options will be used for F4, F7 and F8 to store system settings.

Also on the right hand column of this page, one can read and write files between the IBM/AT and VAX. This is done by moving the cursor and hitting the "ENTER" key. If one wishes to READ a file, then he must type in the appropriate name at the bottom of the screen. Once the "ENTER" key is hit, the system will obtain the file and update the system for that complete system setting. Note that if a file is not written, the "WRITE" function will be yellow in color and blink to indicate that the file has not been written.

C. MEASUREMENT PAGE (F2)

The measurement page is shown in Figure 22 and used to collect, record and plot the received data using the receiver setting from the pulse timing page (F8) and the scan parameters from the target log page (F1). The

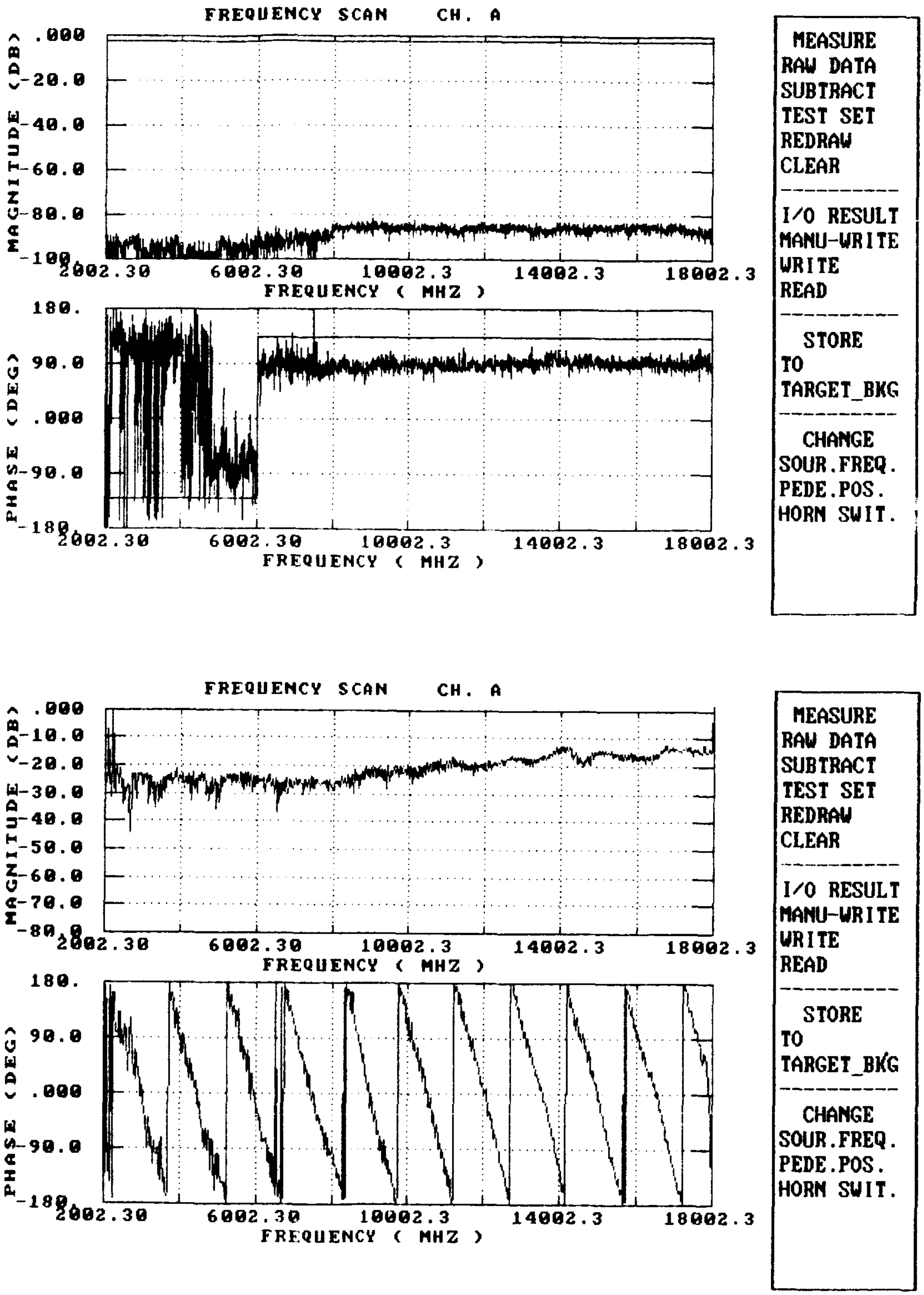


Figure 22: Measurement page.

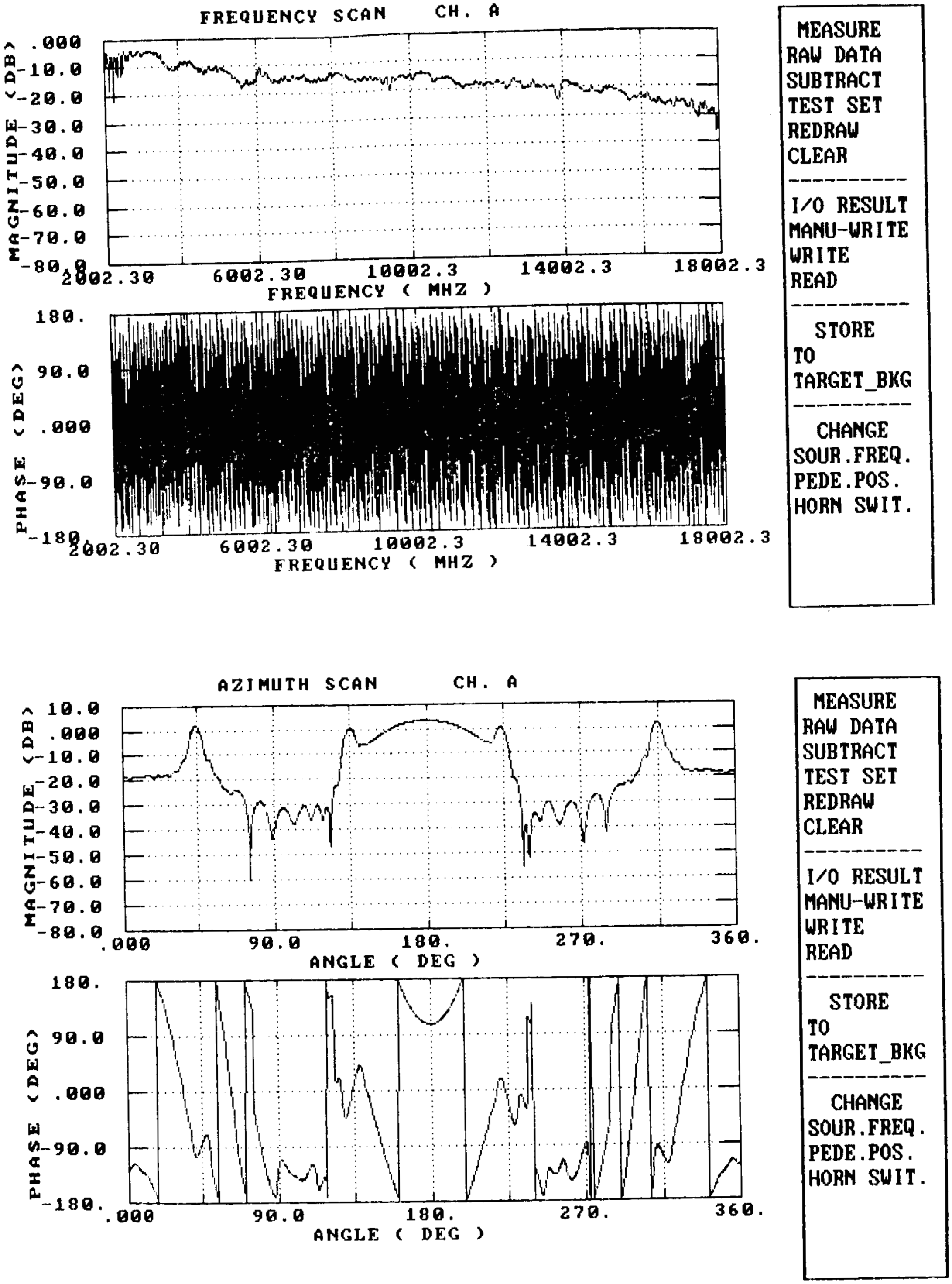


Figure 22: Continued.

data can be plotted in two formats for a single channel (A or B) scan. These are listed as the "RAW", and "SUBTRACTED" options. Using the "RAW" option, the receive magnitude and phase data is directly plotted on the screen. With the "SUBTRACT" option, one must first store a background "RAW" data file into the "TARGET_BKG". This is done by collecting the "RAW" data, moving the cursor to "TARGET_BKG" and hitting the "ENTER" key. When the "SUBTRACT" option is activated, the software will automatically obtain the RAW data and subtract the stored "TARGET_BKG" data term by term and plot the result.

Note that as the subtracted data is collected, it is plotted as "RAW" data in red and "SUBTRACTED" in another color. Once the complete data set is obtained, it can be written out using the "WRITE" option. Under this command, the data can be written to the VAX automatically or manually by selecting the appropriate command in the I/O option section. Note this is selected directly above the "READ" and "WRITE" options as shown in Figure 22. When "AUTO" is selected, the system will output the file to the VAX automatically after the "RAW" data is collected. Otherwise, if "MANU" is selected, the write command will be shown as a different color to indicate to the user that raw data is collected but not written out yet. The IBM/AT computer is just used for data collection and diagnosis; while, the VAX has the appropriate hardware, speed, storage space and processing power to do the data reduction much more effectively.

Note the file name will not be changed until the system specification is changed. If the "FREQUENCY and AZIMUTH" scan is used, the software automatically updates the file name, rotates the pedestal to the new azimuth angle and updates the new angle position in the target log so that the target header is correct.

For "FREQUENCY" scans, the system automatically steps the synthesizer from the start frequency to the end and records the received data. To minimize the plotting overhead time, the received data is recorded for a hundred samples before it is plotted in a burst.

For "AZIMUTH" scans, the system automatically rotates the target past the starting angle, stops and rotates back toward the starting angle in a clockwise direction. A computer algorithm is used to determine the angle overshoot so that the rotation speed is back to the speed selected on page (F1) by the time the target rotates past the starting angle. As the target rotates at the desired speed, data is collected and plotted as fast as the system can collect, process and plot the results. Since the pedestal controller rotates the target at a uniform speed, the data is collected at rather uniform steps. In order to output uniform samples, the IBM/AT records the received data and rotation angle. Then before the data is written out, the VAX Fortran program converts the non uniform samples to uniform ones using a linear interpolation method. This way the data is taken at maximum efficiency but still recorded at the angle increments requested by the operator.

The last three options associated with the measurement page allow the operator to set the source frequency, pedestal angle and/or horn switch interconnection. If one of these options is selected, the operator must input the appropriate response followed by hitting the "ENTER" key. Note that one can use this approach to define a new frequency for an azimuth scan or a new angle for a frequency scan or a code name which sets the desired horn switches. When these parameters are changed, the target log data is updated. Thus, one can stay on the "MEASUREMENT" page (F2) if he simply wants to change these parameters, collect data and write another file to the VAX.

Since the yig-tuned filter used in conjunction with the RF signal is temperature dependent, the source frequency should be held at 16 GHz for a minute or two so that it will approach its normal running temperature. This only needs to be done if the system sits idle or at lower frequencies for long periods of time. Thus, it is suggested that the "SOUR. FREQ." option be selected, and the frequency be held at 16 GHz while one examines the data or other system parameters.

Since this page is normally used most of the time, some special features have been added to improve its usefulness. If the receiver is not run in its normal mode, a message will appear at the bottom of the screen which indicates the receiver state. For azimuth scans, the output at the bottom of the screen indicates the time required to complete the scan. After the azimuth scan is complete, it specifies the location of the pattern peak which can be used to center plots. Finally, one should notice that some of the OPTIONS are written out using a bold character. If the user types one of these bold characters, the cursor will automatically move to that option. This is very useful for loading target background data by hitting the "B" character and then using the "SUBTRACT" option, for example, by hitting the "S" character.

D. PROCESSING PAGE (F3)

The processing page as shown in Figure 23 is used to transform the measured data from the frequency domain to the time domain using a 4096 point fast Fourier transform technique. The options on this page allow the operator to transform the "RAW" or "SUBTRACTED" data provided the appropriate data has been stored on the measurement page (F2). Using the other options, the operator can clear the plot screen or compare results by selecting data from a file on the VAX much like the "READ" command.

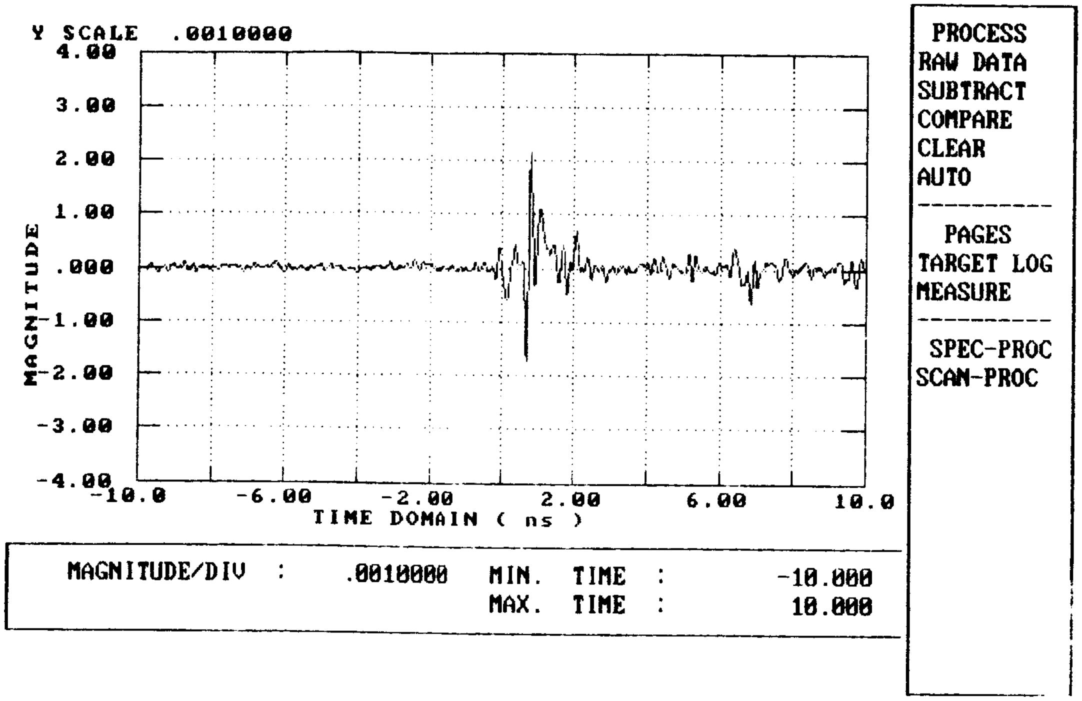
The time domain data can be plotted using operator selected magnitude and time scales if the "MANUAL" option is selected. This is done by moving the cursor to the appropriate scale parameter, inputting the desired value and moving the cursor or typing the "ENTER" or "BACKSPACE" key. The plot will automatically update the scales, once a scale parameter is changed. If the "AUTO" option is selected, the computer will determine the appropriate scales once the data is processed.

This page is normally not used very much because the processing is more efficiently accomplished using the VAX. However, it can be useful to evaluate potential errors and timing problems. Thus, this page is basically used as a diagnostic tool to evaluate the system performance.

E. PROGRAMMABLE MEASUREMENT PAGE (F4)

The programmable measurement page as shown in Figure 24 is used to set the measurement sequence which cannot be set in terms of a normal measurement using the TARGET LOG PAGE (F1). For example if the user wants to measure three different horn responses, he can choose proper options on this page to set up a measurement sequence to scan all three horns at once. This method is especially useful when a lot of the scans are needed, and the operator cannot stay around to set it manually (overnight scan).

The "OPTION" section at the right side of the screen contains the items that can be selected by the user to put in the "SCHEME" portion as a program element. The selection is made by moving the cursor to the proper item and typing the "ENTER" key. Any item in the measurement sequence can be deleted by moving the cursor to the "SCHEME" portion to a proper position and typing the "BACKSPACE" key.



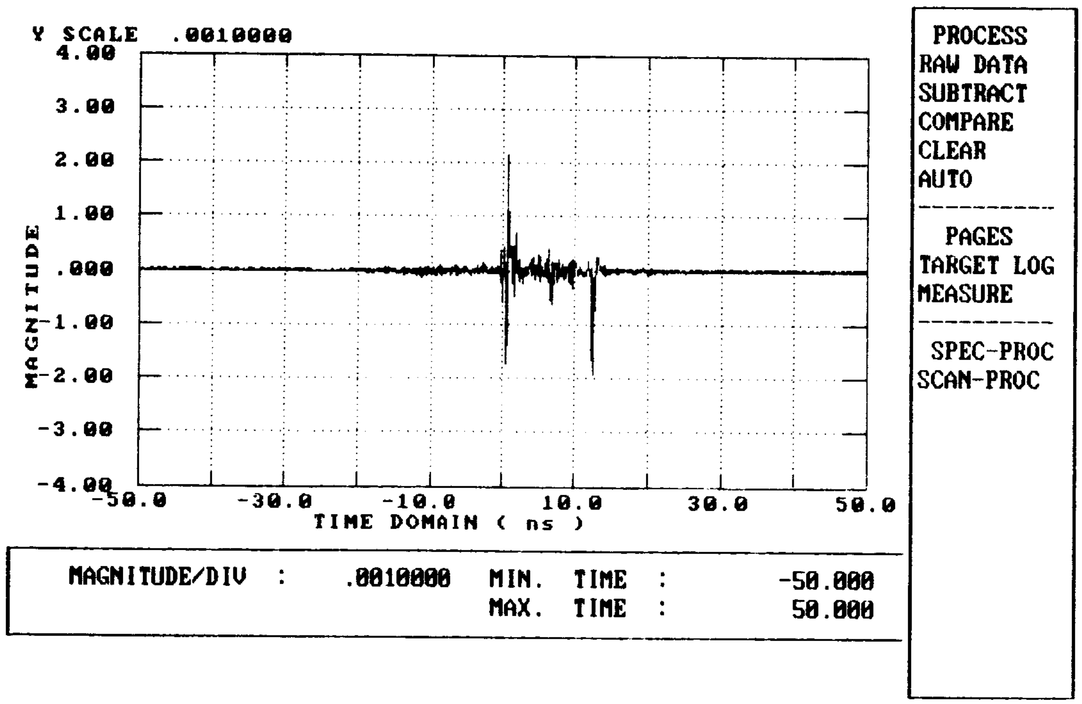


Figure 23: Processing page.

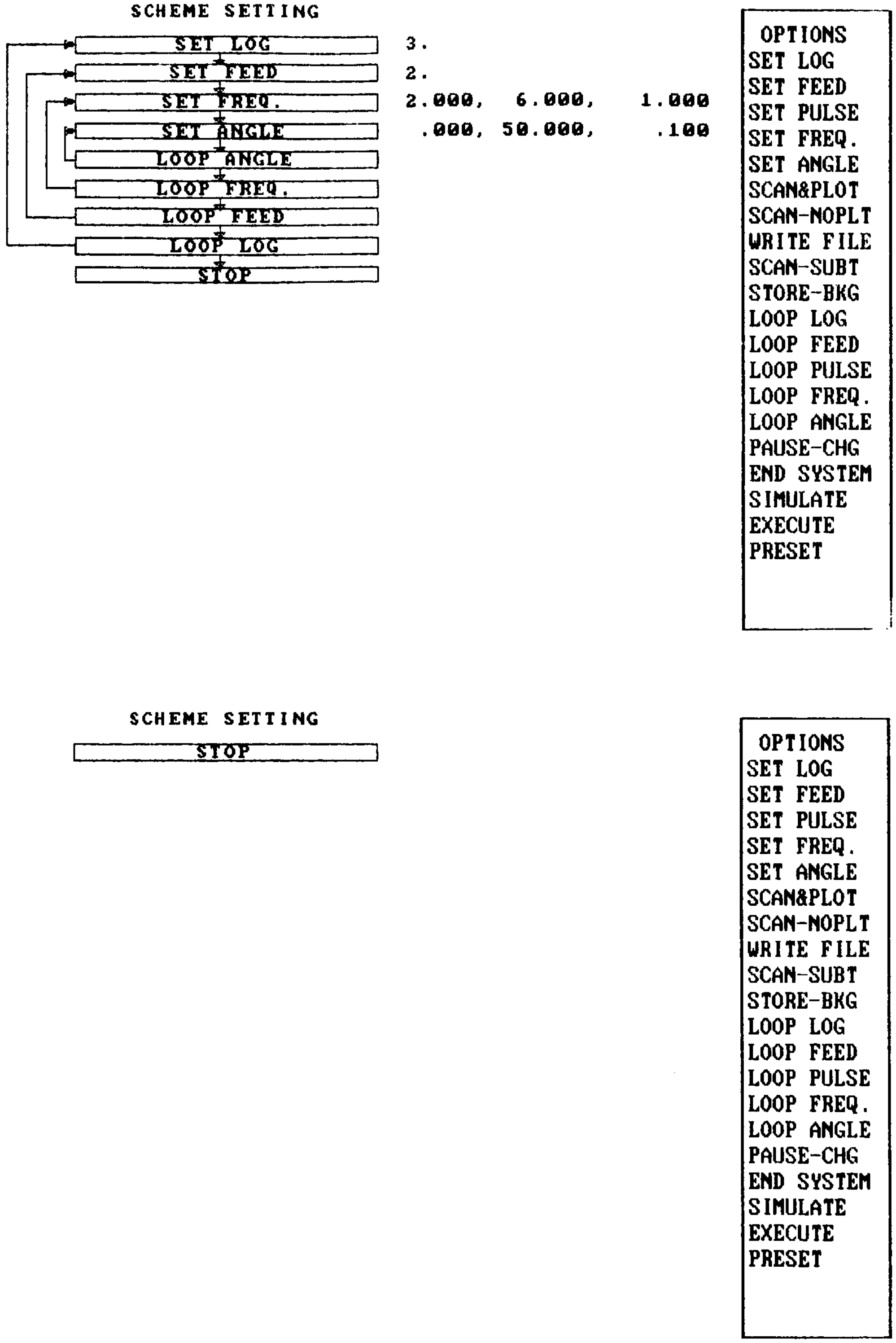


Figure 24: Programmable measurement page.

The items listed under the "OPTION" section are explained below:

SET LOG - Load the specified preset to set the TARGET LOG PAGE.
SET FEED - Load the specified preset to set the FEED SWITCH CONTROL PAGE.
SET PULSE - Load the specified preset to set the PULSE TIMING PAGE.
SET FREQ - Set the source frequency.
SET ANGLE - Set the pedestal azimuth angle.
SCAN AND PLOT - Scan raw data and plot the data on the screen.
SCAN-NOPLT - Scan raw data but do not plot on the screen.
WRITE FILE - Output file to the VAX.
SCAN-SUBT - Scan raw data and subtract the background data.
STORE-BKG - Store the raw data to the background data.
LOOP LOG - Use more than one preset of the TARGET LOG PAGE.
LOOP FEED - Use more than one preset of the FEED SWITCH CONTROL PAGE.
LOOP PULSE - Use more than one preset of the PULSE TIMING PAGE.
LOOP FREQ. - Set up start, stop and increment frequencies.
LOOP ANGLE - Set up start, stop and increment angles.
PAUSE CHG - Pause system to change target, for example.
END-SYSTEM - Exit system and log out from VAX.
SIMULATE - Simulate program sequence and load scan parameters.
EXECUTE - Run the measurement sequence.
PRESET - Store or recall the program setting page.

Note that in the "SIMULATE" mode, the system will step through each phase of the program so the user can change any variable and store the appropriate preset. After the user changes the variables, he only needs to type a function key then the system will store the right preset. In general, the selected values for option variables are displayed in appropriate positions next to the measurement scheme blocks. The function of each item in the "SIMULATE" mode is explained below:

SET LOG - Change the TARGET LOG PAGE settings.

SET FEED - Change the FEED SWITCH CONTROL PAGE settings.

SET PULSE - Change the PULSE TIMING PAGE settings.

SET FREQ - The user is prompted for the RF frequency.

SET ANGLE - The user is prompted for the pedestal azimuth angle.

SCAN AND PLOT SCAN-NOPLT WRITE FILE SCAN-SUBT STORE-BKG	These items do not prompt the user for input. The simulation steps through each item and goes on to the next.

LOOP LOG - The user is prompted for the number of loops. The simulation loops to SET LOG to set the TARGET LOG PAGE the specified number of times.

LOOP FEED - The user is prompted for the number of loops. The simulation loops to the FEED SWITCH CONTROL PAGE the specified number of times.

LOOP PULSE - The user is prompted for the number of loops. The simulation loops to the PULSE TIMING PAGE the specified number of times.

LOOP FREQ. - The user is prompted for start, stop and increment frequencies. The simulation then loops to SET FREQ. the appropriate number of times.

LOOP ANGLE - The user is prompted for start, stop and increment angles. The simulation then loops to SET ANGLE the appropriate number of times.

PAUSE-CHG END SYSTEM	These items do not prompt the user for input. The simulation steps through each and goes on to the next.

Another way to set the scan variables is to move the curser to the desired "SCHEME" item, hit the "ENTER" key and set the variables. Then hit any function key to store the values. This method can be used to set a single item without going through the entire simulation.

F. FEED SWITCH CONTROL PAGE (F7)

The feed switch control page as shown in Figure 25 is used to set the switches at the feed site. Since various feed antenna assemblies are being projected to feed the compact range, a set of six switch control lines have been interfaced to the IBM/AT computer through the parallel I/O card. Each line can be controlled by the operator to output an "OFF" (0 volts) or "ON" (5 volts) state, which satisfies the normal TTL logic levels. These control lines run to the feed area and up the transmit channel to the feed mounting bracket. Using this approach, the range operator can connect his own antenna assembly to the system and remotely control its feed through the software using the parameters defined on this page.

This page has a "PRESET" option which allows the operator to load the horn switch connection into or from a file. These files are stored on the floppy disk in drive B and can be stored or recalled by writing the file name at the appropriate location.

Since various antenna configurations require different control settings for the switches, the operator can specify different types of control interconnection states. For each interconnection state the user can specify an antenna code to represent this condition and this code is used in the file name.

The system will remember the code and its interconnection so that when the user inputs different code names it will recall the right interconnection states. The user can specify the 26 different code names ("A" to "Z").

FEED SWITCH CONTROL

OPTIONS

ANTENNA CODE : H

PRESET

SWITCH NUMBER	USER DEFINED DESCRIPTION	INTERCONNECT CODE	SWITCH STATE	EXTEND STATE
ANT1	ANTENNA #1	1*	ON	OFF
ANT2		1*	OFF	OFF
ANT3		C	OFF	OFF
ANT4		D	OFF	OFF
ANT5		E	OFF	OFF
ANT6		F	OFF	OFF

FEED SWITCH CONTROL

OPTIONS

ANTENNA CODE : A

PRESET

SWITCH NUMBER	USER DEFINED DESCRIPTION	INTERCONNECT CODE	SWITCH STATE	EXTEND STATE
ANT1		A	OFF	OFF
ANT2		B	OFF	OFF
ANT3		C	OFF	OFF
ANT4		D	OFF	OFF
ANT5		E	OFF	OFF
ANT6		F	OFF	OFF

STORE : RECALL : VH PRESET-DIR

Figure 25: Feed switch control page.

The control layout may require for only one of four lines to be active at one time, or in another case, all four control lines may be active at the same time. To satisfy these different needs, an interconnect state has been added to each switch control line through the software. It is designated by the "INTERCONNECT" column shown in Figure 25. The various interconnect states can be toggled by the operator using the "ENTER" and "BACKSPACE" keys. Note that there are potentially twelve states, A, B, C, D, E, F, 1*, 2*, and 3*. If one wants a set of switches to have the same state, then the interconnect character should be the same without the "*" such as "A". If only one of a set is "ON" at a time, then they should have the same interconnect character with the "*" such as "1*". If a switch has independent control relative to all other switches, it should have its own interconnect code such as "C". To illustrate this logic, let us examine the following examples:

1) Switch	Interconnect Code	State
SW1	A	ALL 3 WILL HAVE THE SAME SWITCH STATE EITHER "ON" OR "OFF"
SW2	A	
SW3	A	
SW4	1*	ONLY ONE OF THESE SWITCHES WILL BE ON AT A TIME
SW5	1*	
SW6	C	INDEPENDENT CONTROL

2) Switch	Interconnect Code	State
SW1	1*	ONLY ONE "ON" AT A TIME
SW2	1*	
SW3	C	BOTH HAVE THE SAME STATE
SW4	C	
SW5	2*	ONLY ONE 1 "ON" AT A TIME
SW6	2*	

Using these interconnect codes, the operator can define a predetermined network which follows his feed antenna hardware concept.

The "EXTEND STATE" is used when the user specifies three channel (A&B&C) data collection. When all three are used, the switches will change state between the basic and extend states in order to connect the appropriate antenna for the channel A, B and C data. Note that channel C operation is described in the Multiple Channel Operation Chapter.

G. PULSE TIMING PAGE (F8)

The pulse timing page as shown in Figure 26 is used to set all the pulse time delays, widths and repetition frequency. This is done by moving the cursor to the appropriate parameter, inputting the desired value and moving the cursor. Since it is very convenient to toggle the delay times and pulse widths by a nanosecond, the software allows the user to hit the "ENTER" to increase the present value by 1 ns and "BACKSPACE" to decrease the value by 1 ns. This approach allows the operator to watch the scope as the timing sequence is being evaluated by moving selected pulse gates very small increments.

The pulse repetition frequency (PRF) is toggled also because it only has certain values that the hardware can achieve. Note that the PRF is

```
                            CHANNEL A PULSE TIMING
-------------------------------------------------------------------------  OPTIONS
 PULSE PERIOD(ns)¦            TARGET PULSE DELAYS ( ns )
             200 ¦      SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED             CHANN_B
-----------------¦      -------¦----------¦----------¦---------
 FREQUENCY (GH)  ¦       TU1   ¦       90 ¦       30 ¦   SET               TAR.PUL
        16.0000  ¦       TU2   ¦        0 ¦      125 ¦   SET               ALONE
-----------------¦       TU3   ¦       54 ¦      120 ¦   SET
 REFERENCE       ¦       TU4   ¦        6 ¦       10 ¦   SET               REF.PUL
             OFF ¦                                                         ALONE
-----------------¦
 PHASE FLIP      ¦                                                         PRESET
              ON ¦-------------------------------------------------------
-----------------¦          REFERENCE PULSE DELAYS ( ns )
 RAW DATA        ¦      SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED
I        -.0007  ¦      -------¦----------¦----------¦---------
Q         .0044  ¦       TU4   ¦      165 ¦        6 ¦   NO_ACT
AMP    -47.0142  ¦
PHS     99.0915  ¦
-----------------¦-------------------------------------------------------

  STORE :                   RECALL : OSU-SPDT        PRESET-DIR
```

```
                            CHANNEL A PULSE TIMING
-------------------------------------------------------------------------  OPTIONS
 PULSE PERIOD(ns)¦            TARGET PULSE DELAYS ( ns )
             200 ¦      SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED             CHANN_B
-----------------¦      -------¦----------¦----------¦---------
 FREQUENCY (GH)  ¦       TU1   ¦       90 ¦       30 ¦   SET               TAR.PUL
        16.0000  ¦       TU2   ¦        0 ¦      125 ¦   ON                ALONE
-----------------¦       TU3   ¦       54 ¦      120 ¦   ON
 REFERENCE       ¦       TU4   ¦        6 ¦       10 ¦   ON                REF.PUL
             OFF ¦                                                         ALONE
-----------------¦
 PHASE FLIP      ¦                                                         PRESET
              ON ¦-------------------------------------------------------
-----------------¦          REFERENCE PULSE DELAYS ( ns )
 RAW DATA        ¦      SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED
I          .1465 ¦      -------¦----------¦----------¦---------
Q          .3760 ¦       TU4   ¦      165 ¦        6 ¦   ON
AMP      -7.8821 ¦
PHS      68.7187 ¦
-----------------¦-------------------------------------------------------
```

Figure 26: Pulse timing page.

```
                              CHANNEL B PULSE TIMING
------------------------------------------------------------------------  OPTIONS
 PULSE PERIOD(ns)¦              TARGET PULSE DELAYS ( ns )
             200 ¦       SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED           CHANN_A
-----------------¦      --------¦----------¦----------¦--------
 FREQUENCY (GH)  ¦       TU1    ¦       90 ¦       30 ¦   SET             TAR.PUL
       16.0000   ¦       TU2    ¦        0 ¦      125 ¦   OFF             ALONE
-----------------¦       TU5    ¦       55 ¦       20 ¦   ON
 REFERENCE       ¦       TU6    ¦      124 ¦        7 ¦   NO_ACT          REF.PUL
          OFF    ¦                                                        ALONE
-----------------¦
 PHASE FLIP      ¦                                                        PRESET
          ON     ¦------------------------------------------------------
-----------------¦            REFERENCE PULSE DELAYS ( ns )
 RAW DATA        ¦       SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED
I       -.0000   ¦      --------¦----------¦----------¦--------
Q        .0000   ¦       TU6    ¦       78 ¦        7 ¦   SET
AMP   -87.9083   ¦
PHS    99.0007   ¦
-----------------¦------------------------------------------------------
```

```
                              CHANNEL A PULSE TIMING
------------------------------------------------------------------------  OPTIONS
 PULSE PERIOD(ns)¦              TARGET PULSE DELAYS ( ns )
             200 ¦       SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED           CHANN_B
-----------------¦      --------¦----------¦----------¦--------
 FREQUENCY (GH)  ¦       TU1    ¦       90 ¦       30 ¦   SET             TAR.PUL
       16.0000   ¦       TU2    ¦        0 ¦      125 ¦   SET             ALONE
-----------------¦       TU3    ¦       54 ¦      120 ¦   SET
 REFERENCE       ¦       TU4    ¦        6 ¦       10 ¦   SET             REF.PUL
          ON     ¦                                                        ALONE
-----------------¦
 PHASE FLIP      ¦                                                        PRESET
          ON     ¦------------------------------------------------------
-----------------¦            REFERENCE PULSE DELAYS ( ns )
 RAW DATA        ¦       SWITCH ¦  DELAY   ¦  WIDTH   ¦  PULSED
I       -.0396   ¦      --------¦----------¦----------¦--------
Q        .0532   ¦       TU4    ¦      165 ¦        6 ¦   SET
AMP   -23.5658   ¦
PHS   126.6546   ¦
-----------------¦------------------------------------------------------
```

Figure 26: Continued.

derived from the 100 MHz pulse timing clock so it must be a submultiple of 100 MHz; i.e., $\frac{100}{N}$ MHz, where N is an integer. For the OSU/ESL range the PRF is normally set at 5 MHz (which has a 200 ns period).

The operator can select the radar operational frequency on this page in that some of the timing can be done better if the frequency is varied. For example, the reflector bounce is larger at lower frequencies such that it is informative to adjust the reference timing using 2 GHz. On the other hand, if a corner reflector is used to set the target timing, it might be helpful to use a higher frequency, say 10 GHz, because the target cross-section increases with frequency. Then an intermediate frequency, say 6 GHz, could be used to see both terms.

The operator can select whether the reference should be activated or not by toggling the ON/OFF conditions. Normally the reference is turned off during the timing sequence so that the receive pulse remains stationary on either the target or reference delay and width settings. The actual method used to time the system is described in the Pulse Timing Chapter.

The next option available to the operator is designated as "PHASE FLIP" which can be toggled "ON" and "OFF". This command is used to activate a sign change in the receiver hardware. With this sign change, the DC offset slow drift problems associated with the D to A converters, operational amplifiers and A to D converter are removed. Since these components see a positive and negative version of the same value in rapid succession, the DC drift will be seen as a positive and then a negative error. The negative sign is then removed after the A to D converter in the digital hardware, and the two results are added which cancels the error terms. Normally the "PHASE FLIP" is left "ON" because the performance of the system degrades dramatically without it.

The "OPTIONS" section, on the right hand side of this page, allows the operator to adjust the timing for channels A and B individually. The channels can simply be selected by moving the cursor to the channel option and hitting the "ENTER" key. Note that the channel being timed is shown in the title at the top of the screen.

This page also has a "PRESET" option which allows the operator to load the timing parameters into a file. These files can be stored or recalled by writing the file name at the appropriate location. Note that this approach is the most convenient way to insure that the timing is correct for a given measurement type. However one should also set up the corner reflector and double check the whole system timing before a measurement sequence is initiated. In fact, it is strongly suggested that the timing procedure be examined during the warm up period each morning. While this is being done, the frequency should be set to 18 GHz whenever possible so that the yig-tuned filter will warm up.

H. MAINTENANCE PAGE (F9)

The maintenance page is shown in Figure 27 and is used to evaluate the operation of the radar by examining various system sensors and/or loop modes. The "OPTIONS" section allows the operator to individually test either channel A or B. During this testing, the software automatically turns the reference "OFF" and aligns the receive pulse with the target position. This is done so that the loop mode levels can be evaluated and compared against recorded values. If the reference were operational, all the loop mode results would be basically unity since they are not pulsed.

In this operational mode, the operator can individually change the state of each pin diode switch using the "ENTER" with cursor moved to the appropriate target pulse state. Just below the switch state section, the

```
                          CHANNEL A MAINTENANCE
------------------------------------------------------------------------  OPTIONS
     RF LEVEL        !        LOOP MODE          !  TARGET PULSE
LO      :      OFF   ! RF          :       OFF   ! SWITCH !  STATE        CHANN_B
TX1     :      OFF   ! RF(1.5G)    :     ` OFF   ! -------!--------
TX2     :      OFF   ! IF(1.5G)    :       OFF   !   TU1  !   SET
RX1     :      OFF   ! IF(100K)    :       OFF   !   TU2  !   SET
---------------------! SEL. CAL    :       OFF   !   TU3  !   SET
   RF FREQ (GHZ)     ! ATTEN.(DB)  :      MUTE   !   TU4  !   SET
           16.0000   ! PHASE (DEG) :         0   !
---------------------!                           !-------------------
     YIG SCALE       !---------------------------! ATTENUATOR LEVEL
             189.0   !     SWITCH CONTROL        ! TX(LO)ATTEN(DB)
---------------------! SW(TX:BAND) :    6-18 G   !                0
      RAW DATA       ! SW(TX:KA)   :    2-18 G   ! TX(RF)ATTEN(DB)
I   :       -.0007   ! SW(PED.)    :        ON   !                0
Q   :        .0044   ! PED.RAMPING :       OFF   !-------------------
AMP :     -47.0643   !                           ! IF PHASE CONTROL
PHS :      98.8513   !                           !               .0
                     !                           !
---------------------!---------------------------!-------------------
REFERENCE IS OFF AND THE TIMING IS IN TARGET PULSE !
```

```
                          CHANNEL A MAINTENANCE
------------------------------------------------------------------------  OPTIONS
     RF LEVEL        !        LOOP MODE          !  TARGET PULSE
LO      :        0   ! RF          :       OFF   ! SWITCH !  STATE        CHANN_B
TX1     :        0   ! RF(1.5G)    :       OFF   ! -------!--------
TX2     :      OFF   ! IF(1.5G)    :       OFF   !   TU1  !   SET
RX1     :      OFF   ! IF(100K)    :       OFF   !   TU2  !   SET
---------------------! SEL. CAL    :       OFF   !   TU3  !   SET
   RF FREQ (GHZ)     ! ATTEN.(DB)  :      MUTE   !   TU4  !   SET
           16.0000   ! PHASE (DEG) :         0   !
---------------------!                           !-------------------
     YIG SCALE       !---------------------------! ATTENUATOR LEVEL
             189.0   !     SWITCH CONTROL        ! TX(LO)ATTEN(DB)
---------------------! SW(TX:BAND) :    6-18 G   !                0
      RAW DATA       ! SW(TX:KA)   :    2-18 G   ! TX(RF)ATTEN(DB)
I   :       -.0007   ! SW(PED.)    :        ON   !                0
Q   :        .0044   ! PED.RAMPING :       OFF   !-------------------
AMP :     -47.0671   !                           ! IF PHASE CONTROL
PHS :      98.7731   !                           !               .0
                     !                           !
---------------------!---------------------------!-------------------
```

Figure 27: Maintenance page.

```
                            CHANNEL A MAINTENANCE
--------------------------------------------------------------------  OPTIONS
      RF LEVEL      |       LOOP MODE          |   TARGET PULSE
LO     :     OFF    | RF           :     OFF   | SWITCH |  STATE      CHANN_B
TX1    :     OFF    | RF(1.5G)     :     OFF   | -------|--------
TX2    :     OFF    | IF(1.5G)     :     OFF   |   TU1  |   SET
RX1    :     OFF    | IF(100K)     :     OFF   |   TU2  |   OFF
--------------------| SEL. CAL     :     OFF   |   TU3  |   SET
   RF FREQ (GHZ)    | ATTEN.(DB)   :    MUTE   |   TU4  |   SET
          16.0000   | PHASE (DEG)  :       0   |
--------------------|                          |--------------------
     YIG SCALE      |--------------------------| ATTENUATOR LEVEL
            189.0   |     SWITCH CONTROL       | TX(LO)ATTEN(DB)
--------------------| SW(TX:BAND)  :   6-18 G  |                0
      RAW DATA      | SW(TX:KA)    :   2-18 G  | TX(RF)ATTEN(DB)
I   :      -.0000   | SW(PED.)     :     ON    |                0
Q   :       .0001   | PED.RAMPING  :     OFF   |--------------------
AMP :    -82.3101   |                          | IF PHASE CONTROL
PHS :     95.2687   |                          |               .0
                    |                          |
--------------------|--------------------------|--------------------
```

```
                            CHANNEL A MAINTENANCE
--------------------------------------------------------------------  OPTIONS
      RF LEVEL      |       LOOP MODE          |   TARGET PULSE
LO     :     OFF    | RF           :     OFF   | SWITCH |  STATE      CHANN_B
TX1    :     OFF    | RF(1.5G)     :     OFF   | -------|--------
TX2    :     OFF    | IF(1.5G)     :     OFF   |   TU1  |   SET
RX1    :     OFF    | IF(100K)     :     OFF   |   TU2  |   SET
--------------------| SEL. CAL     :     ON    |   TU3  |   SET
   RF FREQ (GHZ)    | ATTEN.(DB)   :       6   |   TU4  |   SET
          16.0000   | PHASE (DEG)  :      18   |
--------------------|                          |--------------------
     YIG SCALE      |--------------------------| ATTENUATOR LEVEL
            189.0   |     SWITCH CONTROL       | TX(LO)ATTEN(DB)
--------------------| SW(TX:BAND)  :   6-18 G  |                0
      RAW DATA      | SW(TX:KA)    :   KA BAND | TX(RF)ATTEN(DB)
I   :       .2403   | SW(PED.)     :     ON    |                0
Q   :      -.3251   | PED.RAMPING  :     OFF   |--------------------
AMP :     -7.8661   |                          | IF PHASE CONTROL
PHS :    -53.5284   |                          |               .0
                    |                          |
--------------------|--------------------------|--------------------
```

Figure 27: Continued.

operator can either attenuate the LO or RF levels. This is again done by using the "ENTER" and "BACKSPACE" keys to toggle the values. The receiver output can be examined in the lower left hand corner of the page.

The loop modes, found in the middle of the maintenance page, are the most useful test features of the system. The operator can evaluate each one individually by toggling its state using the "ENTER" key. Note that only one can be "ON" at a time; so if one is selected, then the others are turned "OFF". In order to change the "ATTEN.(DB)" or "PHASE(DEG)", the operator must first turn the "SEL.CAL" to the "ON" state. This activates the calibrator card, and one can then attenuate or change the phase of this test signal. Note that this test can be used to evaluate the 100 KHz signal detection system by changing the amplitude and phase and seeing if the receiver changes appropriately. As before, the receiver output is shown at the lower left hand corner of the screen. The other loop modes should be individually activated, and the receiver values compared with previous results. Thus, this data should be written down in a log book for future reference.

At the bottom of the middle column, the operator can control the transmit band switch, the Ka-band switch, the pedestal switch and the pedestal ramping switch. Using the band switch, one can evaluate how each band is functioning say at 6 GHz where they both should be operational. The Ka-band switch is used to activate the Ka- band ports for operation from 27 to 36 GHz. The pedestal switch is used to deactivate the pedestal controller in order to test the radar without the pedestal. The pedestal ramping switch is used to help mount the target on the pedestal. All of these switches are turned on or off by typing the "ENTER" key with the cursor moved to the proper position.

The "RF LEVEL" section at the far left column is used to evaluate the various detector outputs. There are four detector levels which can be activated by moving the cursor to the appropriate option and toggling the "ENTER" key. Once the detector output is activated the "OFF" is replaced with output values obtained from the data acquisition card which simply converts the analog detector output to a multiplexed digital output. Then every time the keyboard is hit, these values are updated along with the receiver output. Note that these detector outputs are useful to evaluate the various hardware sections.

Just below the "RF LEVEL" section, the operator can select the desired RF frequency by moving the cursor and inputting the desired value. Below that, the operator can select the appropriate "YIG NUMBER" which is specified for each yig-tuned filter. This value should normally <u>not</u> be changed unless the yig-tuned filter is suspected of some type of failure. If it is changed, its original value should be recorded so that one could return to that setting.

In order to evaluate the system operation under these various modes, the operator can select a particular case using this page and then move to the measurement page (F2). If the "RAW DATA" is selected, the system will operate in the maintenance page mode during the measurement. Note that this mode is indicated at the bottom of the measurement page. Using this approach, one can evaluate the various features as the system is scanned from 2 to 18 GHz, for instance. Now in an IF loop mode, the RF frequency means nothing; however, in the RF loop mode, it can be very useful such as indicating certain frequency failures. If this test is selected, the pulse timing should be chosen appropriately, by setting TU1, TU2 and TU3 to the "ON" state. In any event, one can clearly see the value of the maintenance page and its associated testing functions.

The operator needs to be reminded that once he leaves the maintenance page, the reference is turned "OFF". If he wants the reference activated, he must use (F1) or (F8) in order to turn it back "ON". If this is forgotten, a message will appear at the bottom of the measurement page (F2) to remind the operator of the state of the system.

IV. PULSE TIMING PROCEDURE

A. INTRODUCTION

The transceiver has potentially three channels (A,B and C) which need to be individually timed using the pulse timing page (F8). This timing process is initiated by setting the reference "OFF" so that the receiver doesn't move the pulse for each measurement. Recall that every time a key is hit, the receiver values are measured and written out in the lower left hand corner of the screen. Thus, if the reference is "ON", the receive pulse will move every time the keyboard is hit, which is not appropriate during the timing sequence.

The four channel scope mounted in the cabinet is ideal for evaluating the pulse timing because many waveforms can be viewed simultaneously. The pulse generator signals which are denoted as TU1 to TU6 and detector outputs which are denoted as TX1, TX2, RX1 and RX2 are all brought to the front face of the scope; so, the operator need only cable the signal of interest to the appropriate scope channel. The interconnection of these various signals is shown in Figure 28. Note that both the pulse generator outputs and detector signals can be viewed on the scope. In order to evaluate the timing, the scope needs a fixed trigger which should be the PRF pulse input. It is suggested that this signal be input on channel 4 which is also specified as the scope trigger.

B. TRANSMIT PULSE ALIGNMENT

Start this sequence by selecting channel A set to measure the co- polarized backscattered field of a small (6") corner reflector. The first transmit pulse (TU1) is defined initially to have a pulse width of 20 ns. This pulse width is set by connecting the RF transmit detector output (TX1 or TX2) to

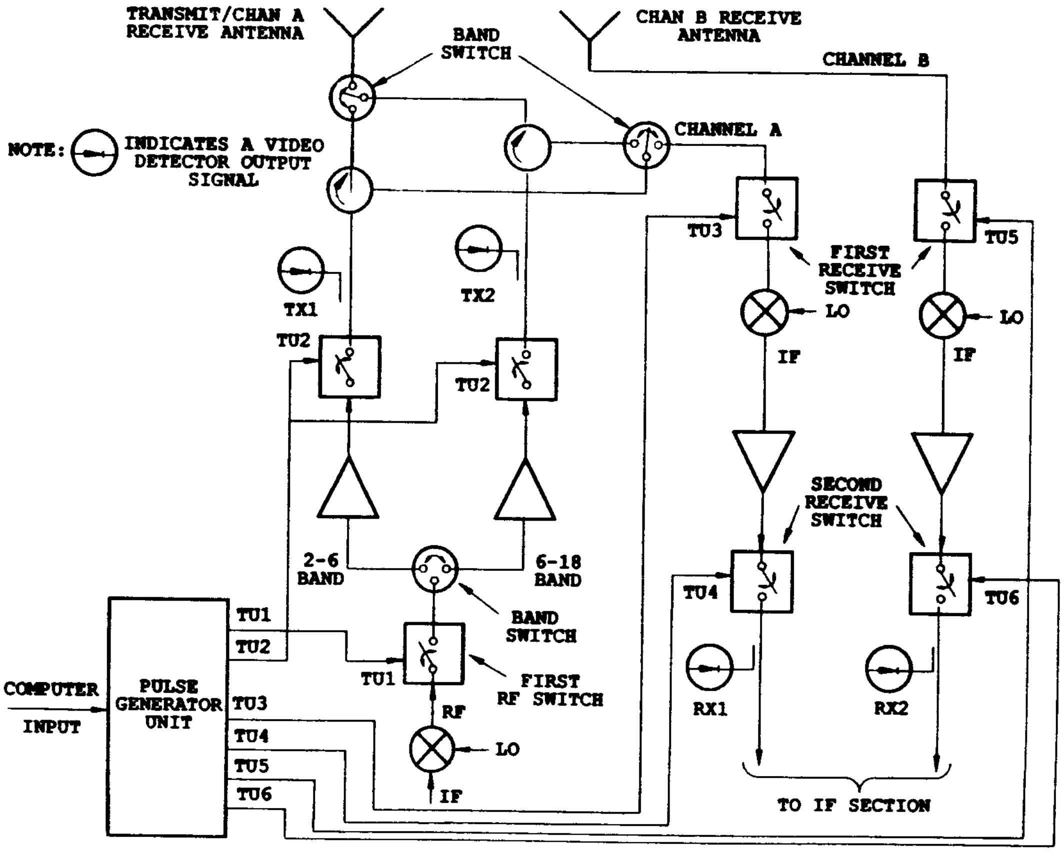


Figure 28: Pulse control system and video detector locations.

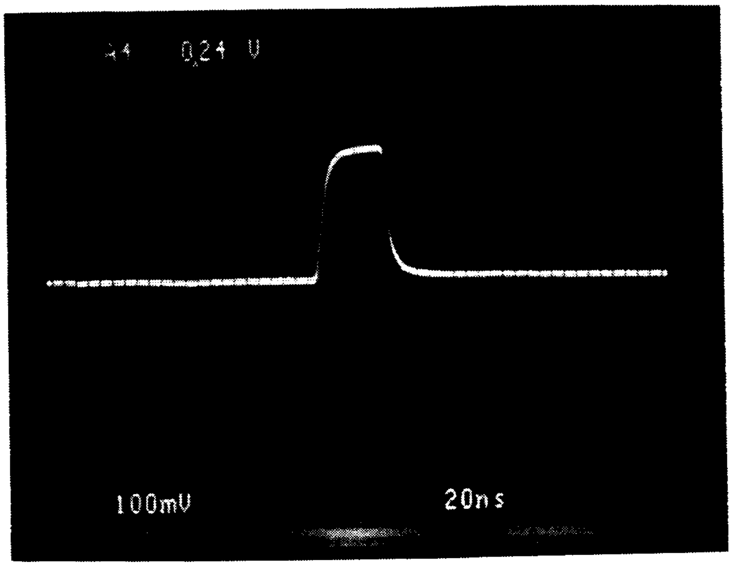


Figure 29: Transmit detector output with TU1 pulse "SET", TU2 "ON".

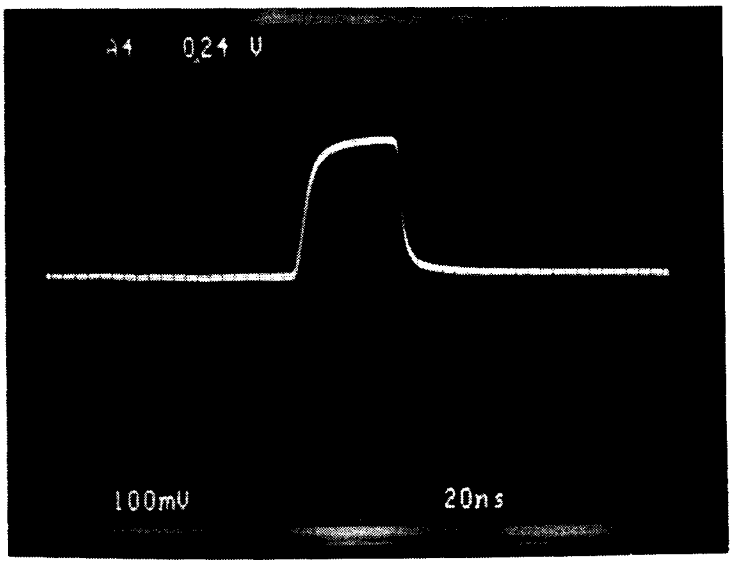


Figure 30: Transmit detector output with TU1 "ON", TU2 pulse "SET".

one of the scope channels. Note that there are two transmit detectors, one for the 2 to 6 GHz band (TX1) and one for the 6 to 18 GHz band (TX2). Connect each transmit detector to a scope channel so that both can be seen simultaneously when the band switch is toggled. Set TU2 to the "ON" state and the frequency to 6 GHz. Looking at the detector output (TX1 or TX2), adjust the pulse width of TU1 to about 20 ns, as shown in Figure 29. The time delay for TU1 should be set at about 10 ns because TU2 must be timed around the TU1 pulse as will be shown later. Note that the cable length may require more than 10 ns but this will become clearer later.

Referring to the basic operation chapter, recall that TU1 is used to set the transmit pulse width. Switch (TU2) is used to remove the power amplifier noise from the receive line and increase the isolation between the transmit and receive lines. Since TU2 is on the output side of the amplifier, it should not control the pulse width because of the power levels involved. In fact, if the amplifier output is modulated by TU2, it tends to oscillate for as long as 50 ns which is completely unacceptable. To avoid this situation, TU2 should have a pulse width of about 30 ns and should surround the TU1 pulse. In other words, the TU2 leading edge should occur about 5 ns before the leading edge of TU1, and the same for the trailing edge as illustrated in Figures 30 and 31. To accomplish this timing adjustment, first put TU2 into the "SET" condition and TU1 into the "ON" state. Then adjust the TU2 pulse width to 30 ns using the transmit detector output (TX1 or TX2), as shown in Figure 30. To set the appropriate delay between the pulses, one should center the TU1 pulse on the scope display by putting TU1 in the "SET" mode and TU2 in the "ON" mode, as shown in Figure 29 while looking at (TX1 or TX2). With TU1 centered, put TU1 in the "ON" mode and TU2 in the "SET" mode. This leaves the TU2

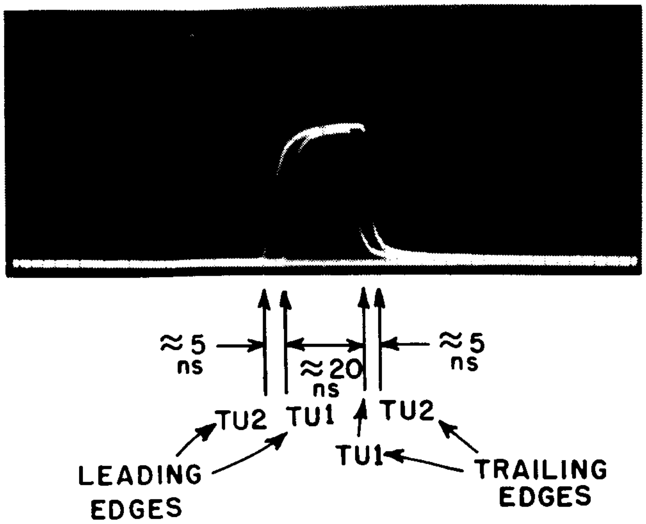


Figure 31: TU1 and TU2 pulses superimposed, showing TU2 centered around TU1.

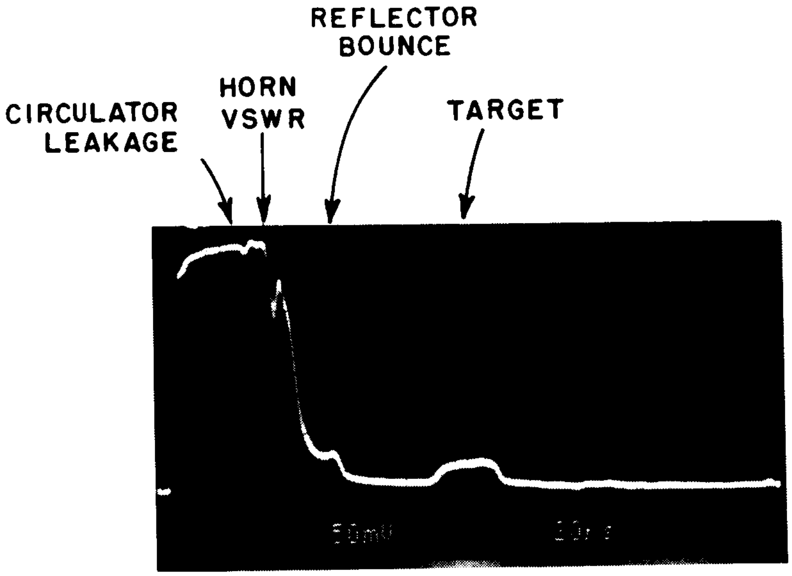


Figure 32: Receive detector output with TU1 and TU2 "SET" and TU3 and TU4 "ON".

pulse on the scope, as shown in Figure 30. The TU2 delay should then be adjusted to center it on the scope which should center both pulses, as shown in Figure 31 looking at (TX1 or TX2). An easy way to check to see if they are centered is to toggle through the TU1 modes. In the "ON" mode, one observes the TU2 pulse; whereas, in the "SET" mode, the TU1 pulse is seen because it sets the pulse width. Note that the previous adjustment should be checked for both bands [2 to 6 GHz (TX1) and 6 to 18 GHz (TX2)] using the band switch and appropriate detector outputs or scope channels.

Once the transmit switch timing is set, it remains the same for both channels. So there is no need to switch to channel B at this point.

Note that the maximum target length which can be measured is related to the transmit pulse (TU1) width. The recommended 20 ns TU1 width gives a target zone length of about seven feet. For larger targets, TU1 width should be specified by TU1 width $= 2\times$ (length of target in feet) + TU4 width. So if one wishes to measure a 10 foot target with TU4 = 6 ns, TU1 width should be 26 ns.

C. TARGET RECEIVE PULSE ALIGNMENT

The pulse timing page should be set initially for channel A, and the corner reflector should be placed in the center of the target zone. The two receive switches (TU3 and TU4) should initially be set in the "ON" mode, and the operator should connect the channel A receive detector (RX1) to a scope input. At this point, one should adjust the scope such that just one pulse period is observed. If the PRF is 5 MHz, set the scope time base to 20 ns per division. Then center the target (corner reflector) response on the scope. An (RX1) time waveform similar to that shown in Figure 32 should be observed on the scope. The early time response is dominated by

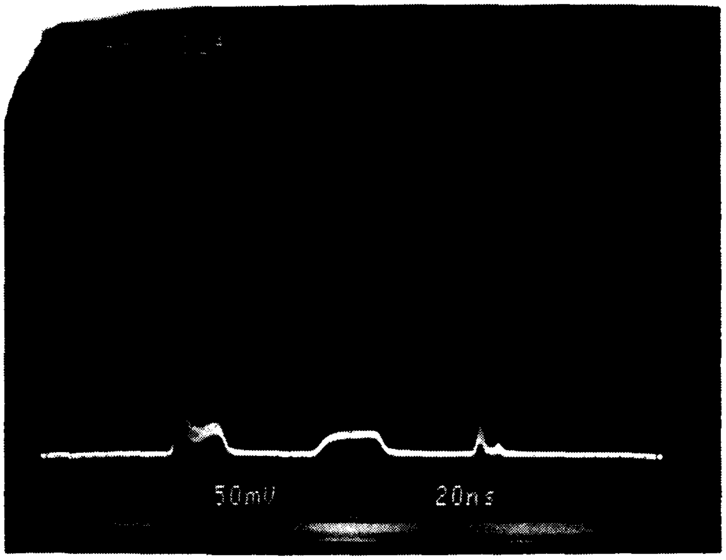


Figure 33: Receiver detector output with TU1 and TU2 "SET", TU3 "SET", TU4 "ON". TU3 aligned to remove circulator leakage and horn VSWR.

the circulator leakage and horn VSWR returns. These terms need to be removed by the first receive switch (TU3). This is done by putting TU3 into the "SET" mode; while, TU4 is in the "ON" condition. At this point, set TU3 width to 100 ns. Adjust the TU3 delay so the large early terms are just barely removed from the received response. Start with a zero delay and move it forward until the large undesired terms are eliminated, such as shown in Figure 33. The TU3 pulse width should be set so that it turns off at least 30 ns after the target pulse. At this point, the TU3 pulse timing has been specified.

Before proceeding to align TU4, one should check the pulse waveform associated with TU3. This can be done by turning TU1 and TU2 into the "ON" mode. One should then observe the TU3 pulse and compare it to that shown in Figure 34 using detector output (RX1). If it is satisfactory, one should proceed; otherwise, the previous steps should be repeated.

Now, TU4 should be aligned with the target return. First center the

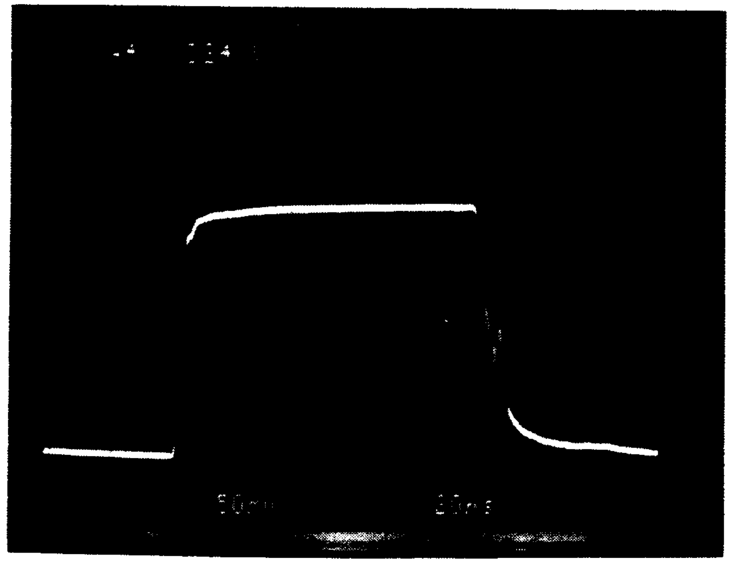


Figure 34: Receive detector output with TU1 and TU2 "ON", TU3 "SET", TU4 "ON". TU3 pulse timing.

corner reflector pulse on the scope by adjusting the horizontal position dial as shown in Fig. 33. Next, set TU1, TU2 and TU3 into the "ON" state; while TU4 is "SET." The TU4 pulse width should be set to 5 ns. The TU4 delay should then be changed until it is centered on the scope, as shown in Figure 35, which means that the TU4 pulse overlaps the timing of the target response. The TU4 pulse is now roughly centered on the target.

This next step is precision pulse centering. Adjust all 4 switches to the "SET" state. By watching the scope waveform or receiver output level on the timing page, the operator should change the delay and find the extreme values where the target response is just overlapped by the received waveform. On the scope, one observes that as the delay is increased that the target pulse waveform eventually has its leading edge moved by the receive gate; whereas, eventually the trailing edge is changed as the delay is decreased. This occurs because the receive pulse will eventually move through the target response and, in the extreme case, isolate it from the

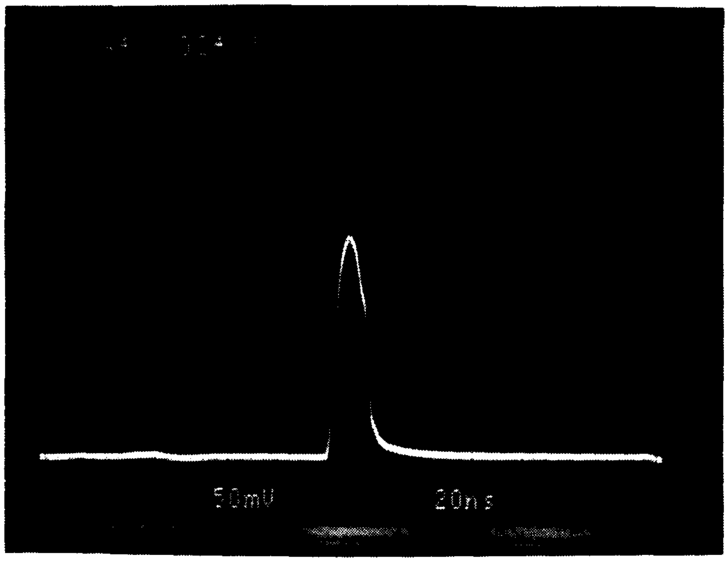


Figure 35: Receive detector output with TU1, TU2 and TU3 "ON", TU4 "SET". TU4 pulse timing.

receiver. Once the extreme limits of the delay are obtained, one can determine accurately the target size that can be measured and delay needed to center the pulse. The target size is found in feet by taking the difference in the extreme delays and dividing by 2. If this is the target size in feet that is desired, then the TU1 pulse width is correct. Otherwise, the TI1 pulse width should be increased for larger targets or decreased for smaller ones.

The relationship between TU3 and TU4 can be observed by toggling TU4 between the "ON" and "SET" states. If all of these pulses appear to have the correct delay and pulse width, the channel A target pulse has been timed correctly.

The channel B target pulse is set in the same way except a strong cross-polarized scatterer must be placed in the center of the target zone if channel B is connected to a cross polarized antenna. Then both TU5 and TU6 are timed in the same way as done for TU3 and TU4 for channel A.

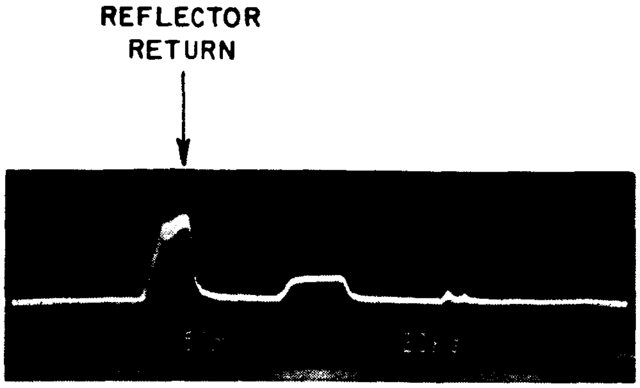


Figure 36: Receive detector output with TU1, TU2 and TU3 "SET," TU4 "ON."

D. REFERENCE RECEIVE PULSE ALIGNMENT

The reference pulse is timed using channel A in that the channel B response will also be referenced using the channel A bounce off the reflector. This process is only initiated after the previous timing has been completed.

Since the bounce off the reflector is larger at lower frequencies, one should set the RF frequency to say 4 GHz. The cursor should be moved to the reference timing parameters at the bottom of the timing page (F8) and adjust TU4 to the "SET" state. Then the (TU4) pulse width should be set to 5 ns. Next, it is put into the "ON" state so that the compact range reflector bounce is clearly visible on the RX1 detector output as shown in Figure 36. This response should then be centered on the scope using the horizontal position adjustment of the scope as shown in Figure 37, and the TU4 reference switch put in the "SET" or pulsed mode. Its delay should then be changed until the pulse is centered on the scope, or more importantly, it is overlapped with the reflector bounce as shown in

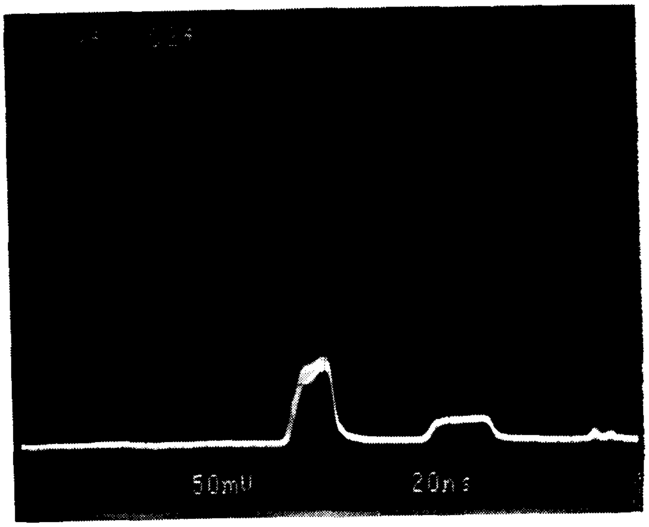


Figure 37: Receive detector output with TU1, TU2 and TU3 "SET," TU4 "ON." Reflector bounce centered.

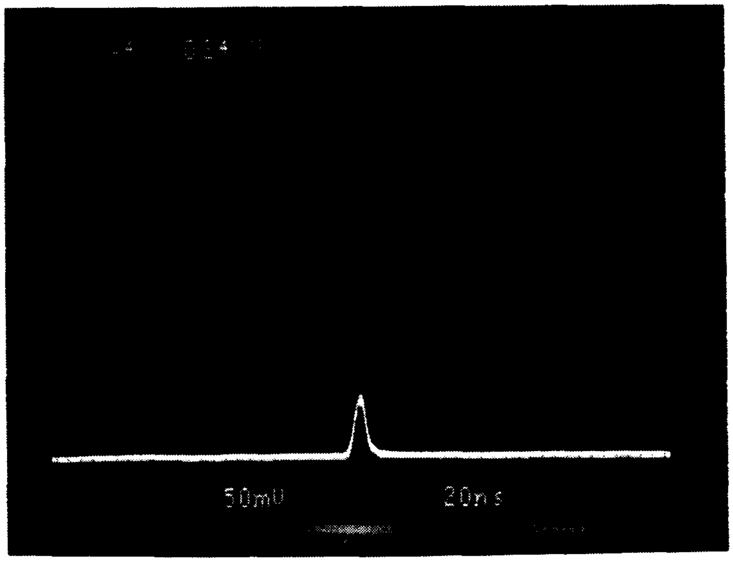


Figure 38: Receive detector output with TU1, TU2 and TU3 "SET," TU4 reference "SET," and centered on reflector bounce.

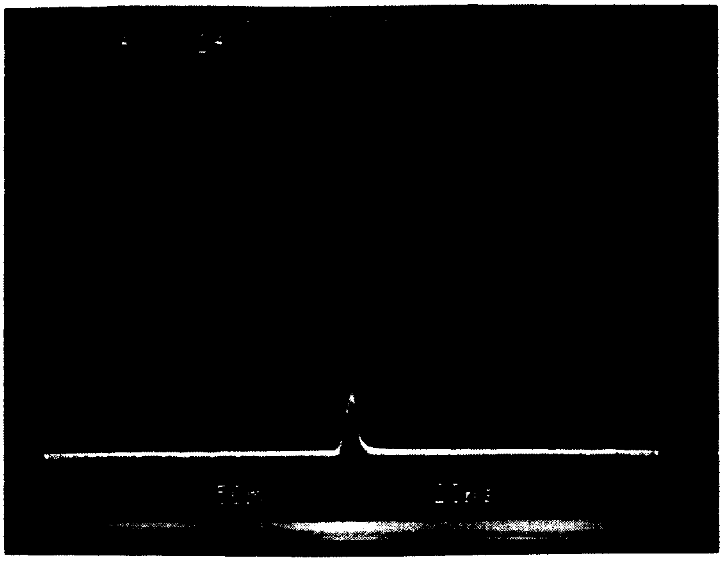


Figure 39: Receive detector output with TU1, TU2 and TU3 "SET," TU4 "SET," reference "ON." TU4 pulse moving between reflector and target returns.

Figure 38. To check this, the TU4 reference pulse can be toggled between the "ON" and "SET" states to insure its proper timing.

E. OVERALL TIMING EVALUATION

All the pulses have been examined individually and time aligned for the operator defined target zone. Next, the total alignment should be evaluated by taking a few simple measurements. First set the frequency to 4 GHz, then the reference command should be activated by turning it "ON." An arrow key should then be hit several times and the scope should be examined to see that the reference and target pulses occur at the appropriate times and have the same shapes as they did earlier (see Figure 39). The receiver output should then be watched to see that it remains relatively stable as the arrow key is hit. This should indicate that the system is referencing properly.

Next, the operator should evaluate the target zone extent. This can be done by moving a corner reflector through the down range of the target zone. While it is being moved, the operator should hit an arrow key to update receiver values. As the corner reflector is moved through the appropriate target zone, the receiver value should remain relatively stable. Note that there will be some variation due to the corner reflector rotating slightly. This should insure the target zone extent and that the receiver timing has been specified properly.

Once this procedure has been completed, the operator should output the timing information to an appropriate file using the "PRESET" option. At this point, the operator should move to the measurement page (F2) and record the referenced output of a standard target from 2 to 18 GHz. This data should be written out for future reference so that system changes can be observed when future data is compared with this result.

V. MULTIPLE CHANNEL OPERATION

As discussed earlier, the transceiver system can be configured with two receive Channels (A and B). These two separate and complete hardware channels can be used to measure several responses at once by connecting them to the appropriate receive antennas. Channel A is normally connected to the transmit antenna through the circulator in the transmit stem which means that it used to measure the co-polarized return because the transmitted and received signals are, respectively, radiated and received by the same antenna. So from hence forth, let us assume that channel A is always connected to the transmit antenna. Then, one can use channel B to measure the cross-polarized response, for example, by connecting it to a second antenna at the feed sight which is oriented orthogonal to the transmit antenna. In this case, the transceiver can be used to measure both the co- and cross- polarized returns at the same time.

In order to fully grasp how the transceiver works during these measurements, let us examine its operation in more detail. First, channel A is always used as the reference receive line because it is connected to the co-polarized receive antenna which is needed to acquire the significant co-polarized reflector bounce. Recall, that one uses channel A reference timing as shown in the previous section to acquire the reflector bounce response. Since the reference signal for the system is a co-polarized return, it can't be used with channel B, in that channel B may be connected to a cross-polarized antenna. Obviously, one should never use a weak signal as a reference, because it can be strongly contaminated by clutter and noise. As a result, channel B data is then referenced by the channel A measurement of the reflector bounce. In other words, with the reference option activated ("ON"), the transceiver will measure the following four responses:

$A_1 =$	reflector bounce (reference)	$= A_{ref}$
$A_2 =$	co-polarized backscattered return	= A
$B_1 =$	first channel B response	= B

and

$$B_2 = \quad \text{second channel B response} \quad = \text{C}$$

Note that A_1 and B_1 are measured using reference timing; while, A_2 and B_2 are measured with the target timing. The antennas connected to the system can be selected from the "FEED SWITCH CONTROL" page (F7) for the reference measurement using the "EXTEND STATE" setting and for the target measurement using the "SWITCH STATE".

Now let us examine how all these features fit together when the reference option is turned "ON". The transceiver sets the timing for channels A and B using the reference settings from page (F8), and the antennas according to the "EXTEND STATE" definition given on page (F7). The transceiver then measures $A_1 = A_{ref}$ on channel A and $B_1 =$ B on channel B. Next the system automatically shifts the timing to the target settings on page (F8) and the antennas are selected using the "SWITCH STATE" from page (F7). The transceiver again measures the responses on the two channels such that $A_2 = A$ and $B_2 = C$. Finally, the data is normalized using the following expressions:

$$A = \frac{A_2}{A_{ref}}$$

$$B = \frac{B_1}{A_{ref}}$$

and $$C = \frac{B_2}{A_{ref}} \quad .$$

Thus, the transceiver appears to have three channels (A,B and C), all of which can be normalized in order to minimize any system drift over long periods of time.

After the data is collected, the transceiver must distinguish these results so that they can be processed in the correct way. This is done by using the file name structure described earlier. For example, if one defines "E9106" as the root file name on page (F1) and takes a target frequency scan at an angle of 180° using antenna "V" for vertical polarization, the files written out to the VAX would have the following names:

A = E9106FV1800 - A.TAR
B = E9106FV1800 - B.TAR
and C = E9106FV1800 - C.TAR.

Using this file name approach, one can quickly determine the following:

"E"	$\Rightarrow$	a target measurement sequence
"9"	$\Rightarrow$	1989
"106"	$\Rightarrow$	106^{th} day of the year
"F"	$\Rightarrow$	frequency scan
"V"	$\Rightarrow$	V settings for antennas were used which normally implies vertical polarization transmitted.
"1800"	$\Rightarrow$	target oriented at 180°, and
$-\begin{matrix} A \\ B \\ C \end{matrix}$	$\Rightarrow$	channel used for measurement.

With all this information, one can quickly determine how to process this data. In fact, all three channels can be processed in the same way except that "-A" is used for channel A data, "-B" for B and "-C" for C. The result of the file name used to define the calibration will be the same. For example, the previous data could be calibrated using the following expression:

$$\mathrm{CAL} = \left(\frac{\mathrm{TAR} - \mathrm{BTA}}{\mathrm{REF} - \mathrm{BRE}}\right) \mathrm{EXT}$$

where

$$\text{TAR} \Rightarrow \text{E9106FV1800 -} \begin{matrix} A \\ B \\ C \end{matrix} \text{.TAR (target)}$$

$$\text{BTA} \Rightarrow \text{E9106FV1800 -} \begin{matrix} A \\ B \\ C \end{matrix} \text{.BTA (target background)}$$

$$\text{REF} \Rightarrow \text{E9106FV1800 -} \begin{matrix} A \\ B \\ C \end{matrix} \text{.REF (reference target)}$$

$$\text{BRE} \Rightarrow \text{E9106FV1800 -} \begin{matrix} A \\ B \\ C \end{matrix} \text{.BRE (reference background)}$$

and

$$\text{EXT} = \text{EXACT.EXT (exact reference).}$$

Note that the file name structure automatically specifies how to calibrate the data and what files are to be used. In addition, one must calibrate each channel using only data measured with that same channel.

Since the transceiver system has three separate channels, one can configure the receive lines in many different ways. Previously, it was suggested that channel A be used as the co-polarized response and channel B as the cross-polarized one. This can be very useful in many applications, and the transceiver should normally be configured in this way. However, there are many other ways of setting up the system which take full advantage of the three channels (A,B and C). One configuration, which is very useful for diagnostic purposes, is to place three antennas with the same polarization at the feed site. The transmit antenna (channel A) should be located at the focus, the next receive antenna (channel B) should be horizontally displaced, and the last receive antenna (channel C) should be vertically displaced. Using this antenna form, one can simultaneously measure the three antenna responses. These responses can then be used to create a real-time image of the target if the data is processed using the procedure presented in Appendix A. Note that with this antenna arrangement that channel A is a true backscatter response; whereas, channels B and C represent small angle bistatic measurements. If these antennas are tightly packed, the small bistatic data represents a backscatter response. In any event, this example illustrates another way that the transceiver can be configured to efficiently collect data.

VI. SYSTEM INITIALIZATION AND SELF TEST ROUTINES

A. INTRODUCTION

The transceiver system involves several different subsystems which are digital, analog or combinations of both. As such, there needs to be initialization and self test procedures which can be evoked by the operator to insure that the various subsystems are performing properly. The system was designed with loop modes and sensors placed in appropriate spots to evaluate each portion of the system. These sensors and test loops can be activated by the operator using the maintenance page (F9). In addition, the system software will perform a systematic check of itself as the system is initialized each new day or if requested by the "TEST SET" option from the measurement page (F2). Note that the system checks are identical for the initialization and self test.

The basic self test approach taken in the development of this computer algorithm has been to start with the basic 100 KHz calibrator signal and check out the synchronous detection unit. Once this unit is operational, it checks the hardware using the 100 KHz and then the 1.5 GHz loop modes. These tests insure that the IF hardware units are operational. Next, the RF components are tested using the 1.5 GHz and RF loop modes. This testing procedure progresses backward through the system to insure that each section is working before it tests the next. The attractive feature of this approach is that the testing is done using its own hardware to evaluate itself.

The initialization page used to check out the system is shown in Figure 40.

B. CALIBRATOR TEST OF SYNCHRONOUS DETECTION UNIT

The synchronous detection unit is used to determine the real (I) and imaginary (Q) parts of a synthesized 100 KHz signal. In order to test the performance of this unit, it needs to be evaluated as various magnitudes and phases of the 100 KHz signal are input. This function is performed by a calibrator card which is mounted in the same rack and provides phase changes in very accurate 9 degree steps and amplitudes in 3 dB steps. During this test, the calibrator card is activated, and its output connected directly to the synchronous detector. The amplitude and phase of the calibrator output is then varied in a predetermined pattern, and the received I and Q values examined to find any inconsistencies between the calibrator input and receiver output. If the values during this test don't fall within certain bounds, the calibrator test failure is indicated by the "FAILED", and the software will automatically proceed to test the IF hardware unit.

C. IF HARDWARE UNIT TEST

As described in the system overview chapter, the IF transmit and receive units consist of several sources, amplifiers and mixers, any one of which can fail, and the IF hardware unit will become inoperable. There are two loop modes that are used to test the performance of this unit. As shown in Figure 41, there is a 100 KHz loop mode which is injected into the output lines of the unit and directly connected to the synchronous detector. This is used to test all the interconnections between the IF and synchronous detection units. If this signal level is within bounds, the system proceeds to activate the 1.5 GHz loop mode as shown in Figure 41. This test requires that the 1.5116 GHz signal is properly generated by the IF transmit unit and

```
                         SYSTEM TESTING

CALIBRATOR TESTING -- ATTEN. CHAN. A :  PASSED    -1.8088 DB
                   -- ATTEN. CHAN. B :  FAILED    19.8982 DB
CALIBRATOR TESTING -- PHASE  CHAN. A :  PASSED   -72.0881 DG
                   -- PHASE  CHAN. B :  FAILED    44.9061 DG
100KHz LOOP MODE   -- CHANNEL A      :  FAILED   -85.3007 DB
                   -- CHANNEL B      :  PASSED    19.8982 DB
1.5GHz LOOP MODE   -- CHANNEL A      :  PASSED   -85.3475 DB
                   -- CHANNEL B      :  PASSED    19.8982 DB
RF(1.5GHz) LOOP MODE -- CHAN. A      :  FAILED   -86.0424 DB
                     -- CHAN. B      :  PASSED    19.8982 DB
RF (2-6GHz) LOOP MODE-- CHAN. A      :  FAILED   -85.1422 DB
                     -- CHAN. B      :  PASSED    19.8982 DB
RF(6-18GHz) LOOP MODE-- CHAN. A      :  FAILED   -84.7659 DB
                     -- CHAN. B      :  PASSED    19.8982 DB
```

DO YOU WANT TO CHECK THE LOOP MODE VALUE ?

```
CALIBRA|     LOOP MODE VALUE SETTING          |D     -1.8088 DB
       |                                      |D     19.8982 DB
CALIBRA|                              EXIT    |D    -72.0881 DG
       |                              RETEST  |D     44.9061 DG
100KHz | 100KHz LOOP - CHAN. A :  -84.870     |D    -85.3007 DB
       |             - CHAN. B :   19.900     |D     19.8982 DB
1.5GHz | 1.5GHz LOOP - CHAN. A :  -85.440     |D    -85.3475 DB
       |             - CHAN. B :   19.900     |D     19.8982 DB
RF(1.5G| RF(1.5GHz)  - CHAN. A :  -84.950     |D    -86.0424 DB
       |             - CHAN. B :   19.900     |D     19.8982 DB
RF (2-6| RF(2-6GHz)  - CHAN. A :  -85.770     |D    -85.1422 DB
       |             - CHAN. B :   19.900     |D     19.8982 DB
RF(6-18| RF(6-18GHz) - CHAN. A :  -86.100     |D    -84.7659 DB
       |             - CHAN. B :   19.900     |D     19.8982 DB
```

Figure 40: System testing page.

that the downconversion in the IF receiver unit to 100 KHz is functioning properly. It represents a complete evaluation of the IF hardware. Again, if the loop mode value as seen by the receiver is within certain bounds, then the IF hardware is considered satisfactory. If not, the testing sequence is aborted, and the operator is informed that the IF hardware unit is not operating properly.

If the IF unit has failed the previous tests, it should be tested on the bench to find the cause of the problem. Note that it contains its own power supply such that it can be evaluated as a stand-alone unit on the bench. One must, however, keep in mind that the loop mode switches have been disconnected from the computer drive signals. Thus, one must inject the appropriate loop mode switch control signals, if he wishes to change their state. Also, the 100 KHz signal provided by the synchronous detection unit must also be input.

D. RF HARDWARE UNIT TEST

The RF hardware is located out by the range feed antenna which is quite a distance from the receiver cabinet. As a result, the local oscillator and IF (1.5116 GHz) signals must be sent to the RF hardware by long RF cables. To insure that these interconnections are functioning properly, the first RF loop mode injects the 1.5116 GHz IF signal into the output of the receive lines as shown in Figure 42. This loop is again measured using the receiver and compared against a stored value. If it is within certain limits, the test verifies that this portion of the system is performing satisfactorily.

Next the RF generated loop mode is directly injected into the receive lines as shown in Figure 42. This CW signal is tested at 4 GHz and 8 GHz, and the measured results are compared with stored standards. If this data is consistent with the stored data the RF unit is considered operational at

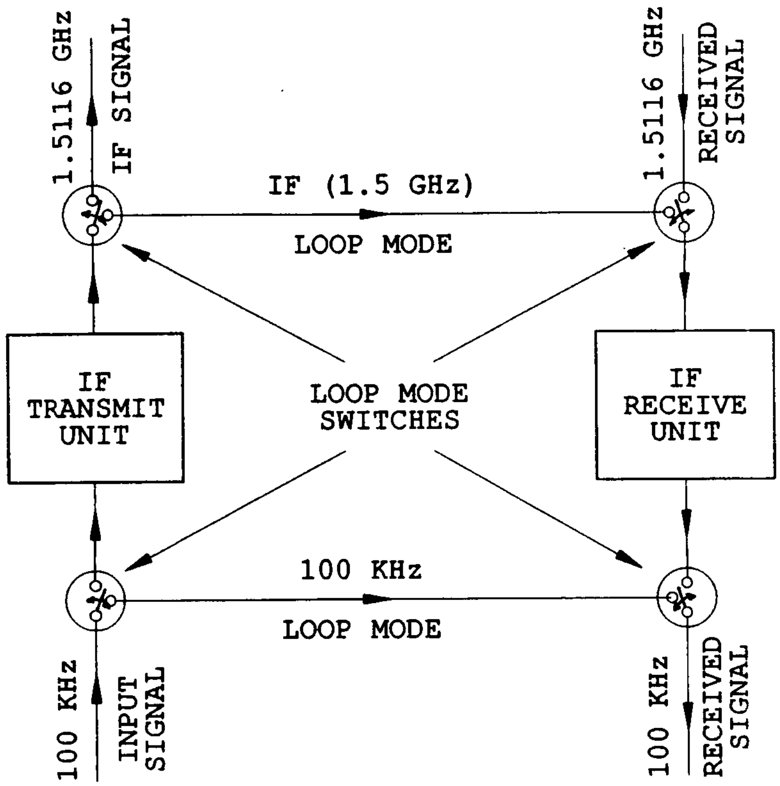


Figure 41: IF hardware loop mode.

least in a CW mode. If this test fails, the RF system could have problems in several subsystems. To distinguish whether it is related to the transmit or receive lines, one should examine the detector outputs on the transmit and receive lines. Don't forget that the transmit subsystem has two bands, each of which should be examined. Once it is determined which line has the problem, that line can be removed from the feed mount and tested on the bench.

If the preset values are not correct for the system, the operator can update their values. After the test is completed, the system will ask if the operator wants to check the loop mode values (Y=yes and N=no) as shown in Fig. 40. If "Y" is chosen, the system will show all the presets, which can be changed under cursor control. Then the system can be rechecked to see if it is operating correctly.

After these tests are completed, the system is basically considered operational. However, the pulse aspects of the system have not been evaluated since the pulse testing is strongly related to the timing aspects used for a specific measurement sequence. As a result, the operator should compare appropriate pulsed results with previously stored data. In order to make this comparison, the operator should store certain key test cases for this purpose while the system is operating properly. The important thing is that the system has been checked other than the pulses and found to be working properly. Thus, errors shouldn't be attributed to the basic system operation, which the operator has a hard time determining on his own. On the other hand, the pulse timing is clearly obvious to the operator using the detector outputs and scope.

These steps form the basis of insuring total system operation. If the "TEST SET" is selected from the measurement page, the previous tests

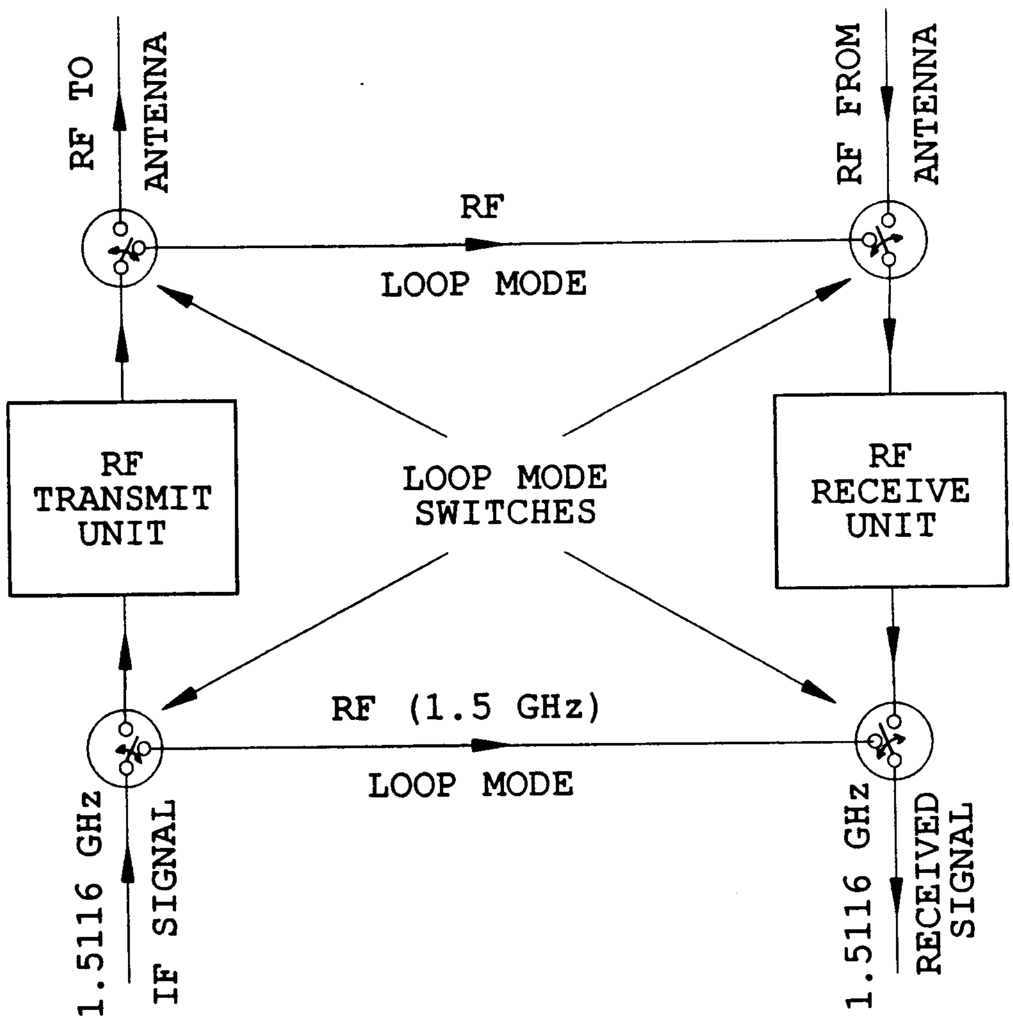


Figure 42: RF hardware loop modes.

would have been performed, and the software would have indicated that the system "PASSED" or "FAILED" each test. If the initialization routine is being activated at system startup, the previous tests would have been performed, and the software would automatically proceed to the pulse timing page (F8) if it "PASSED" all tests where the operator should load the appropriate preset from a floppy disk mounted in floppy drive B. If the preset is found, the pulse information will be loaded, and the operator will be able to set up a measurement sequence.

In order to start a measurement sequence for the first time, the operator is referred to the System Software Chapter where the manipulation of the system is described. However, to see how the system functions, the operator can follow the demonstration measurement sequences listed in the next section.

E. SYSTEM DEMONSTRATION

The demonstration inputs have been loaded onto a "DEMO" floppy which is included with the system. This floppy should be loaded into drive B of the IBM/AT computer. In any case, the operator should start the measurement sequence on the target log page (F1). This is done by simply hitting function key (F1) at the top of the keyboard. The presets which are taken from the floppy will then be used to define the system parameters so the operator doesn't need to be concerned with these values but simply observe how the software functions.

1. Frequency Scan Steps

   (a) move the cursor to the "PRESET" option on the measurement page (F1) and hit the ENTER key.

(b) move the cursor to the "RECALL" position and input TLFSØ plus hit the ENTER key.

(c) the system automatically loads in the preset values.

(d) jump to the pulse timing page by hitting function key (F8).

(e) move the cursor to the "PRESET" option and input PTFSØ.

(f) jump to the measurement page by hitting the function key (F2).

(g) move the cursor to the "RAW DATA" option and hit the ENTER key.

(h) the system then automatically takes a frequency scan from 2 to 18 GHz.

(i) after the measurement is completed move the cursor to the store "TARGET_BKG" and hit the ENTER key which loads the RAW DATA into the background array.

(j) move the cursor to the "SUBTRACT" option and hit the ENTER key. Type "Y" and hit the ENTER key to start the scan.

(k) the system will automatically take the data and plot the <u>raw result in red</u> and the <u>subtracted one in yellow</u>.

(l) after the measurement is complete move the cursor to the "WRITE" command and hit the ENTER key. The system will output the measurement file to the VAX under the name TESTFS.

(m) jump to the processing page by hitting the function key (F3).

(n) move the cursor to "RAW" and hit the ENTER key.

(o) the system will automatically transform the RAW data to the time domain and plot out the results.

(p) move the cursor to the scale positions and try different scale parameters. This can only be done if the system is in the "MANUAL" mode as opposed to "AUTO". Then move to "RAW" and repeat plot.

(q) move the cursor to "SUBTRACT" and hit the ENTER key.

(r) now that you have become familiar with these three pages (F1, F2, and F3) you should try other cases such as jumping to F1 and change the frequency scan limits.

2. Azimuth Scan Steps

   (a) select the "AZIMUTH SCAN" option on the measurement page (F1) then move the cursor to the "PRESET" option and hit the ENTER key.

   (b) move the cursor to the "RECALL" position and input TLASØ plus hit the ENTER key.

   (c) the system will automatically load the preset values.

   (d) jump to the pulse timing page by hitting function key (F8).

   (e) move the cursor to the "PRESET" option and input PTASØ.

   (f) jump to the measurement page by hitting function key (F2).

   (g) move the cursor to the "RAW DATA" option and hit the ENTER key.

   (h) the system then automatically takes an azimuth scan by moving the pedestal past the start angle and then forward through the desired range (Ø to 36Ø degrees).

   (i) after the measurement is completed move the cursor to the store "TARGET_BKG" and hit the ENTER key which loads the RAW

DATA into the background array.

(j) move the cursor to the "RAW DATA" option and hit the ENTER key.

(k) move the cursor to the "SUBTRACT" option and hit the ENTER key. Type "N" and hit the ENTER key. The system will automatically take the data and plot the raw result in red and the subtracted one in yellow.

(l) now that you have become familiar with these pages (F1, F2, and F3) you should try other cases such as jumping to F1 and change the angle scan limits.

3. Frequency and Azimuth Scan Steps

(a) select the "FREQ & AZIM SCAN" option on the measurement page (F1) then move the cursor to the "PRESET" option and hit the ENTER key.

(b) move the cursor to the "RECALL" position and input TLFASØ plus hit the ENTER key.

(c) the system will automatically load the preset values.

(d) jump to the pulse timing page by hitting function key (F8).

(e) move the cursor to the "PRESET" option and input PTFASØ.

(f) jump to the measurement page by hitting function key (F2).

(g) move the cursor to the "RAW DATA" option and hit the ENTER key.

(h) the system then automatically rotates the object to the start angle, scans the frequency from 2 to 18 GHz, writes out the data, rotates the target to the next angle, and repeats the same sequence till it gets to the stop angle.

(i) at this point you should try other measurement options found on the target log (F1) and measurement (F2) pages.

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Appendix A

A NOVEL APPROACH FOR TWO- AND THREE-DIMENSIONAL IMAGING[1]

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Abstract

Conventional radar imaging requires large amounts of data over large bandwidths and angular sectors to produce the location of the dominant scattering centers. A new approach is presented here which utilizes only two swept frequency scans at two different look angles for two-dimensional images or three swept frequency scans at three different look angles for three-dimensional images. Each swept frequency scan is the backscattered response of a target. A different plane wave illumination angle can be conveniently obtained by offsetting the feed horn from the focus of a compact range reflector without rotating the target. The two- and three-dimensional target information for the location of the dominant scattering centers is then obtained from the bandlimited impulse responses of these swept frequency scans.

I . Introduction

The use of images as a diagnostic tool for radar cross section (RCS) control on structures have been very useful. The images provide a representation of the scattering centers which comprise the scattered field. This information allows not only the determination of the scattering centers for a structure but also an iterative procedure to monitor the effectiveness of a material treatment. A variety of techniques are available to form images of radar targets. All these techniques require a great amount of information pertaining to the frequency and angular scattering characteristics of the target. In spite of the recent advances in compact range technology, the time required to collect this information can be substantial. This paper presents a new image technique which is very fast due to the exceedingly small amount of measured information required.

[1]This work was supported in part by the National Aeronautics and Space Administration Langley Research Center, Hampton, Virginia under Grant NSG 1613 with the Ohio State University Research Foundation.

The first concept to achieve an image for this application was initiated by Kennaugh and Cosgriff [1] using a physical optics time domain approach and was fully implemented by Young [2]. There have been many other techniques developed to generate images such as [3], [4] and [5] but they involve a great amount of information pertaining to the frequency and angular scattering characteristics. A simple image approach is a one-dimensional impulse response [8] obtained from swept frequency scattered field data. The technique presented here involves using this one-dimensional impulse response to identify the dominant scattering centers and to spatially orient them in either a two- or three-dimensional image.

II . The Image Technique

The traditional impulse response illustrates the down range location of a target's scattering centers for a given look angle. This signature is generated from swept frequency scattered field information transformed into the time domain using conventional FFT techniques. Experimentally, this data can be readily obtained using a compact range. Two- and three-dimensional images can be synthesized from impulse responses when they are considered to be simple one-dimensional images.

The concept to generate a multi-dimensional image is based upon the change of the one-dimensional image when the transmit/receive horn for the reflector based compact range is offset from its focus. A different target look angle is generated when the horn is offset from its nominal location (reflector's focus). Figure 1 illustrates the plane wave directions for two horns illuminating an isolated scattering center. Since the associated ray paths have different lengths, the down range scattering centers will occur at different points along the down range axis. The actual down range position is given by the signature generated when the horn is at the reflector's focus. The cross range position is proportional to the difference between the path lengths of the rays. This difference is given by the difference of the observed return location of the two impulse responses. The actual cross range location is obtained by calibrating this difference with a known cross range displacement. Figure 2 illustrates two measured band limited impulse responses for a 6" diameter sphere generated with one feed horn at the reflector's focus and the other with the feed horizontally offset by 5 inches from the focus. For these two measurements, the sphere was displaced 12 inches from the location of the system's calibration sphere. Note that the order of arrival for the two returns indicates the direction of the displacement cross range. The dashed line maximum would have occurred before the solid line maximum if the displacement was in the other direction.

The above description can be applied to generate a three-dimensional

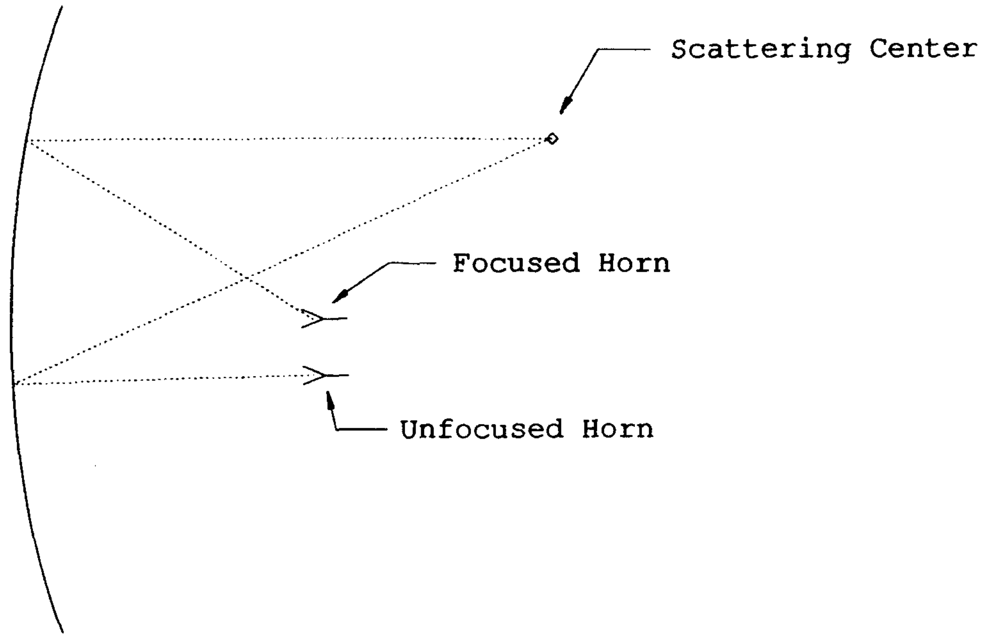

Figure 1: Plane wave direction and associated ray paths for a two horn reflector.

image by simply offsetting two horns, one horizontally and the other vertically. Hence, with three swept frequency measurements, the down range and the two orthogonal cross range locations for scattering centers can be determined. Note that separate calibration measurements have to be performed for the two orthogonal cross range calculations. The calibration is simply the scaling of the return differences to a known cross range displacement.

The major effort in applying this technique is the sorting required to group the proper returns together. Figure 3 is a typical pair for impulse responses whose returns have to be paired. Note that there may be returns in one signature that may not match with the other signature due to the angular dependence of the scattering center. The generation of these signatures can be done with either the traditional Fourier synthesis or with high resolution techniques [6] and [7]. Either approach will yield the same accuracy with small signal to noise ratios. However, high resolution techniques will be superior to Fourier synthesis when the signal to noise ratio is large. Also, the required bandwidth and number of samples are smaller with the high resolution techniques than with the Fourier technique. An improved resolution capability is achieved in the Fourier technique when curve fitting is applied to the sampled data points to more accurately determine the exact position

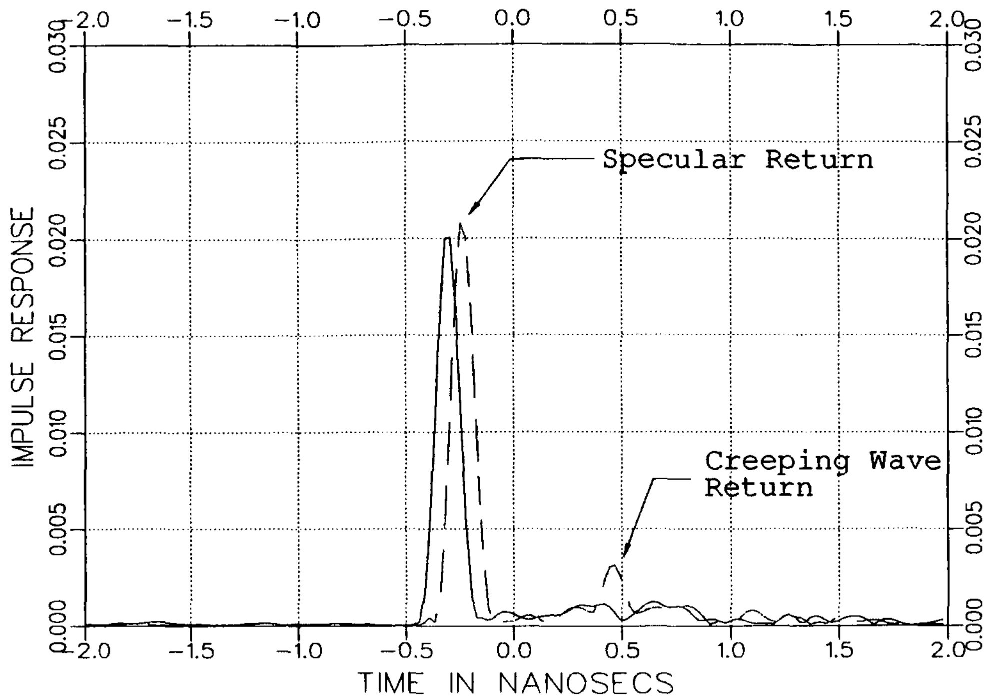

Figure 2: Measured impulse responses for a 6" sphere due to different look angles. Solid line - focused horn, dashed line - offset horn.

of the observed return [9]. In the cases shown, a second order polynomial was used to determine a more precise peak location of the return.

III . Example

This technique is illustrated using a tilted flat conducting rectangular plate. The 12" by 14" plate was tilted with its plane elevated 45° from the horizontal plane and then rotated 25°. The scattering mechanisms present for this plate orientation are first order corner diffraction and higher order edge wave-corner diffraction. The measurements will not only include these but also returns due to a styrofoam mount used to support this plate. The imaging technique will properly identify the spatial location of the direct (line of sight) scattering mechanisms but it will fail for the edge or creeping wave paths in that they are not line of sight scattering mechanisms.

The feed horn assembly consisted of three 2-18 GHz AEL horns with two of them offset from the focus of the reflector. The horn's offset was no more than what was physically needed to mount them as shown in Figure 4. Using

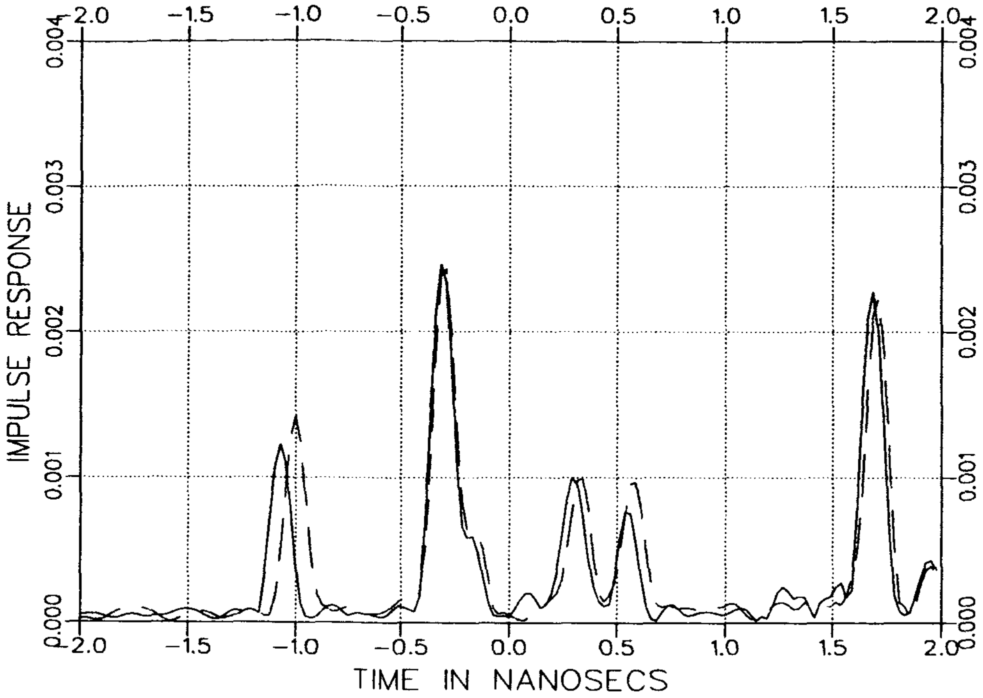

Figure 3: Typical down range signatures from two closly spaced look angles.

this configuration, three swept frequency measurements were taken. Figures 5 and 6 show the bandlimited impulse responses using the horizontal pair of horns and vertical pair of horns, respectively. Note that these returns can be readily matched visually with the strength of the scattering center indicated by the amplitude of the returns. Figures 7 and 8 are two-dimensional images using the information in Figures 5 and 6, respectively Figure 7 represents a top view of the image; whereas, Figure 8 is a side view image. The outline of the plate has been superimposed on these images to correlate the physical geometry to the calculated scattering centers. Note that there are other calculated points that do not map onto the plate outline. They are due to scattering from the styrofoam mount used to support the plate and from non-line of sight scattering mechanisms as discussed earlier.

IV . Conclusions

A simple technique for the generation of two- and three-dimensional images was presented. It utilizes a minimal set of three down range signatures. Each signature is processed from swept frequency data collected using three feed horns located near the focus region of a reflector system in a compact range.

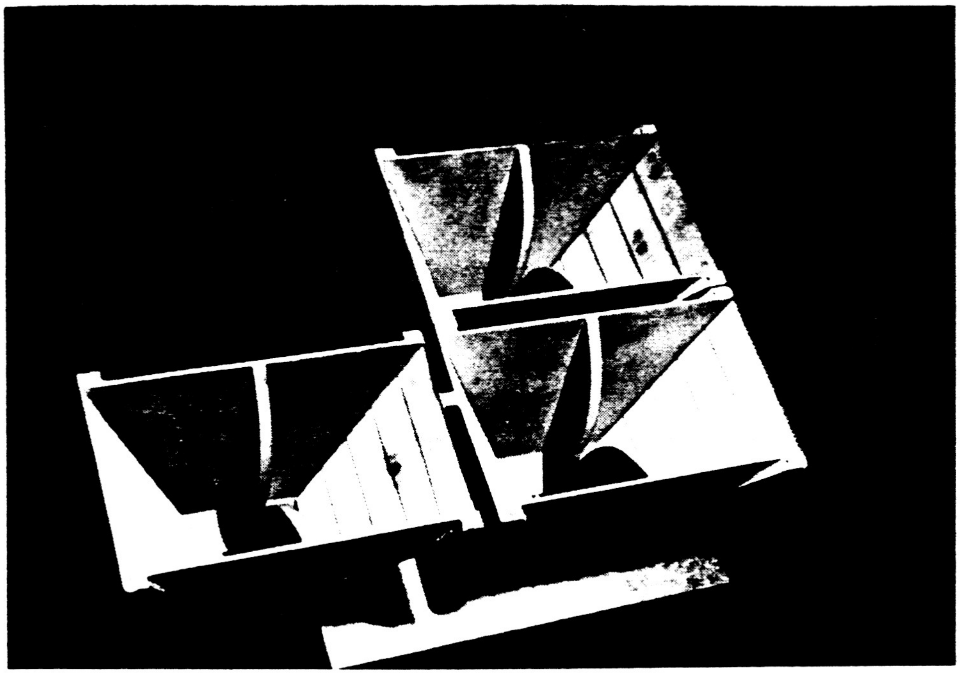

Figure 4: Picture of horn configuration used to collect image data.

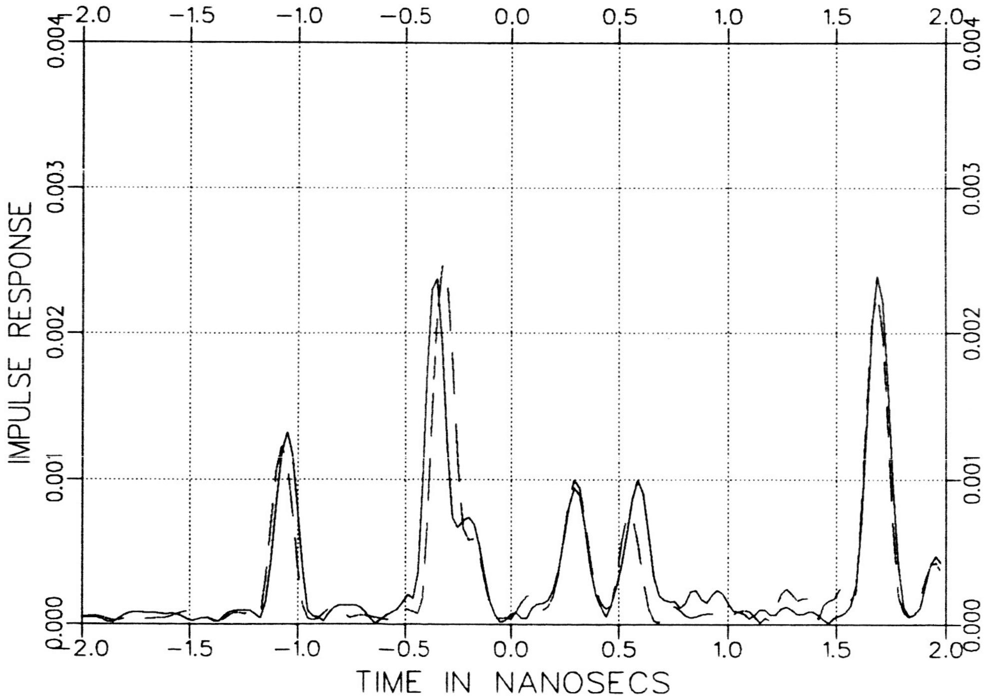

Figure 5: Impulse responses using center horn (solid) and horizontally offset horn (dashed).

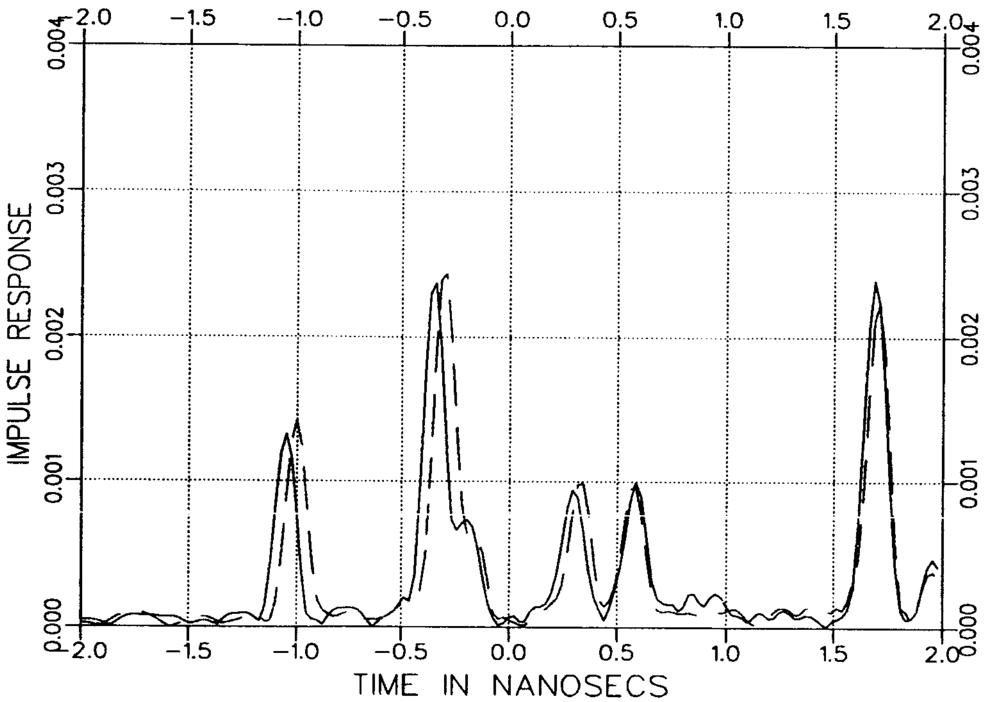

Figure 6: Impulse responses using center horn (solid) and vertically offset horn (dashed) measurements.

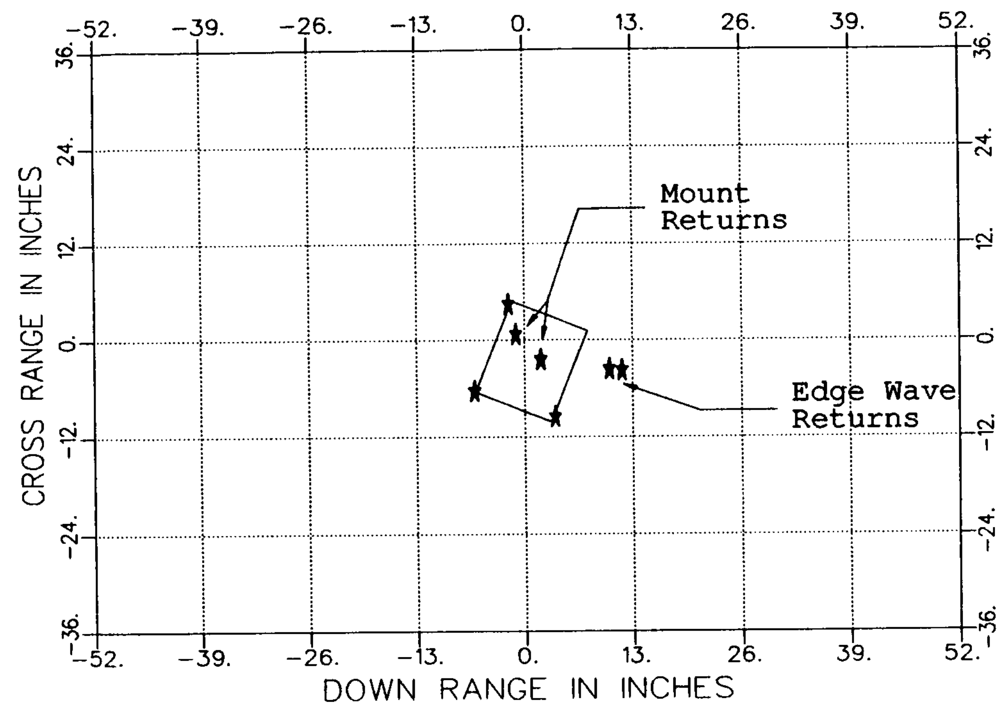

Figure 7: Calculated scattering centers using the horizontally measured data resulting in a top view.

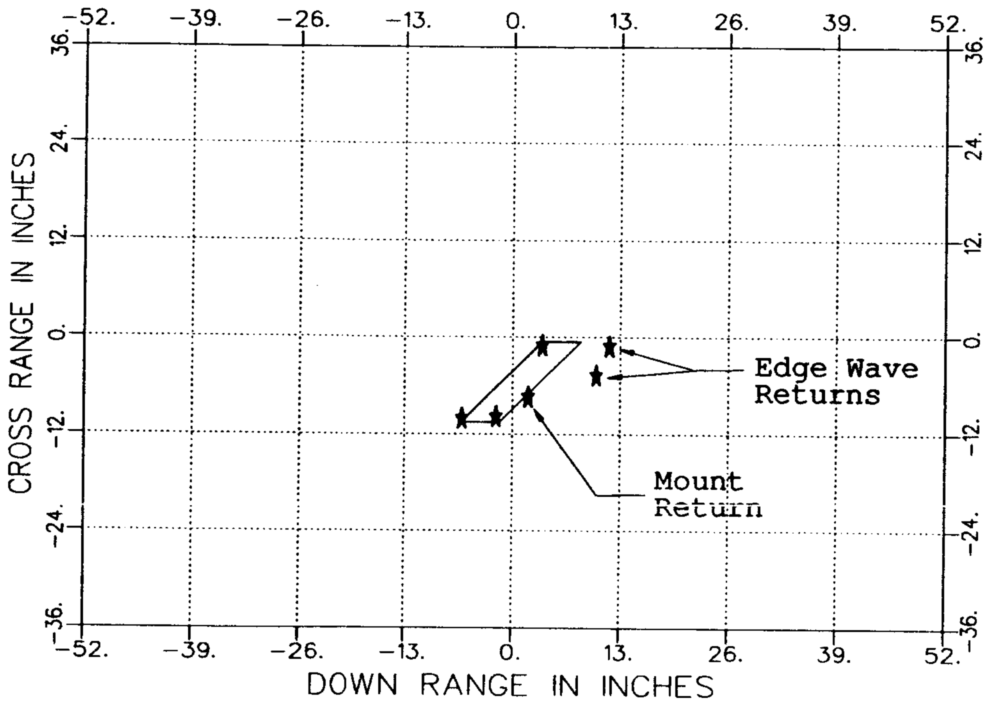

Figure 8: Calculated scattering centers using the vertically measured data resulting in a side view.

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