Design Consideration and Implementation of the LCX Polarimetric Scatterometer (POLARSCAT)

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Contents

1 Introduction 1

2 System Design 2
   2.1 Design Goals 2
   2.2 Design Considerations of a Network Analyzer Based Scatterometer 3

3 Detailed System Description 6
   3.1 General 6
   3.2 Network Analyzer and Control System 6
   3.3 Amplifier and Pulsing Network 8
   3.4 Microwave Circuitry 11
   3.5 Antennas 16
      3.5.1 Design 16
      3.5.2 Patterns 17

4 Calibration and Measurement Accuracy 22
   4.1 Introduction 22
   4.2 System Transfer Function 25
   4.3 Calibration 26
   4.4 Measurement Accuracy 29

5 Measurement Modes 35
   5.1 Point Target 35
   5.2 Surface 36
   5.3 Volume 37
   5.4 Polarimetry 39

A APPENDIX A. Photographs of the system 42
List of Figures

1 Network analyzer operation as a scatterometer. ........................................ 3
2 Single antenna network analyzer based scatterometer. ................................ 3
3 Block diagram of the LCX scatterometer. ................................................. 6
4 Diagram of the amplifier and pulsing network. ....................................... 9
5 Time domain response of the system with a sphere in the chamber; (a) without switching, (b) with switching. ........................................... 10
6 Switch control pulses for transmit and receive, pulsing period is 225 ns, the on-pulse length is 90 ns. ............................................. 11
7 Block diagram of the L-band RF unit. .................................................... 13
8 Block diagram of the C-band RF unit. ................................................... 13
9 Block diagram of the X-band RF unit. ................................................... 14
10 Schematic of a square pyramidal horn antenna. ..................................... 16
11 L-band vertical polarization antenna pattern. ........................................ 19
12 L-band horizontal polarization antenna pattern. .................................... 19
13 C-band vertical polarization antenna pattern. ....................................... 20
14 C-band horizontal polarization antenna pattern. .................................... 20
15 X-band vertical polarization antenna pattern. ....................................... 21
16 X-band horizontal polarization antenna pattern. .................................... 21
17 Geometry of scattering of a plane wave from a particle. .......................... 23
18 Simplified block diagram of a dual polarized radar system. ..................... 26
19 Automatic radar cross section measurement setup. .................................. 31
20 Geometry of scattering of a plane wave from a long, thin cylinder. .......... 31
21 Geometry of a wire-mesh ................................................................. 32
22 Radar cross section (hh) versus frequency of a cylinder with L=30.48 cm and D=1.625 mm, (—-) measured and (- - -) theory. ....................... 32
23  Radar cross section (vv) versus frequency of a cylinder with L=30.48 cm and
    D=1.625 mm, (---)measured and (---)theory. .................................. 33
24  Radar cross section (hv) versus frequency of a cylinder with L=30.48 cm and
    D=1.625 mm, (---)measured and (---)theory. .................................. 33
25  Relative phase $S_{hh}$ (to $S_{ee}$) versus frequency of a cylinder with L=30.48 cm and
    D=1.625 mm, (---)measured and (---)theory. .................................. 34
26  Relative phase $S_{he}$ (to $S_{ee}$) versus frequency of a cylinder with L=30.48 cm and
    D=1.625 mm, (---)measured and (---)theory. .................................. 34
27  Geometry used in the surface target measurements. ............................ 40
28  Geometry used in the volume target measurements. ............................ 40
29  Photograph of the LCX Antennas. ................................................. 43
30  Photograph of the C-band RF Unit. .............................................. 44
31  Photograph of the X-band RF Unit. .............................................. 44
List of Tables

1  HP 8753 frequency sweep range for the LCX scatterometer.          7
2  Amplifier and pulsing network components.                        10
3  L-band RF unit components.                                       14
4  C-band RF unit components.                                       15
5  X-band RF unit components.                                       15
6  LCX square horn antenna dimensions.                              17
7  Characteristic of LCX antennas.                                  18
8  Gain and beamwidth variations of LCX antennas with frequency.    18
1 Introduction

The LCX polarimetric scatterometer (POLARSCAT) is a radar system designed to measure the backscattering characteristics of extended and discrete targets, over the frequency bands of L, C, and X. It measures the magnitude and phase of the scattered electric field for all linear polarization combinations.

This system is mainly designed to operate from a truck-mounted boom. A platform at the top of the boom carries the antennas and RF equipment, and the control and processing units are housed in a control room on the bed of the truck. Communication between the RF units mounted on the boom and the rest of the system is accomplished via control and RF cables. The control cable is used to control the antenna positioner, TV camera, and the transmit/receive polarization.

In this report the design and implementation of the LCX scatterometer is discussed. The text is divided into four sections: System Design, Detailed System Description, Calibration and Measurement Accuracy, and Measurement modes. Under the system design section, the design goals and how we can satisfy them with a network analyzer based scatterometer are discussed. The section entitled Detailed System Description gives a complete description of all the units used in the system, the network analyzer, pulsing network, microwave circuitry, and antennas. The Calibration and Measurement Accuracy section explains a new calibration procedure and its accuracy for polarimetric scatterometers. Finally, the measurement routines used by the scatterometer are discussed in the Measurement Modes section.
2 System Design

Before starting to discuss the design of a network analyzer based scatterometer, a brief section about the desired design goals is needed.

2.1 Design Goals

The overall objective of designing the LCX polarimetric scatterometer system was to measure the scattering amplitude of point and distributed targets with great accuracy. This includes measuring the amplitude and phase of the signal backscattered from the target for any of the four linear polarization configurations. The design goals include:

- Coverage of L, C, and X-Band frequencies
- System mobility for indoor and outdoor experiments
- Small antenna size and weight to be mounted on a boom truck
- Absolute measurement of scattering coefficient of distributed targets
- Phase measurement capability
- Adequate dynamic range for targets of interest
- High sensitivity to measure targets with small RCS
- Ranging capability to separate targets by range
- Sufficient spatial resolution
- High speed switching between polarizations
- Automated switching and data acquisition
- Real time processing of the measurements

By using a vector network analyzer as the basic signal processor of the scatterometer, we can satisfy most of the requirements stated above.
2.2 Design Considerations of a Network Analyzer Based Scatterometer

In general, network analyzers are designed to make S-parameter measurements in the frequency domain. They can be configured to operate as a scatterometer system (Fig. 1) In the scatterometer configuration the RF signal is coupled to free space by an antenna. The signal reflected from the target is then picked up by the receive antenna, and is compared with a sample of the transmitted signal. This system can also be changed to a single antenna system using a circulator as shown in Fig. 2.

![Diagram of network analyzer operation as a scatterometer.](image1)

**Figure 1: Network analyzer operation as a scatterometer.**

![Diagram of single antenna network analyzer based scatterometer.](image2)

**Figure 2: Single antenna network analyzer based scatterometer.**

Network analyzer based scatterometers have measurement capabilities that are not provided by traditional scatterometers. With the recent development of more powerful network analyzers,
such as the HP 8753 and HP 8720, the advantages are more impressive. They have the capability of computing the inverse Fourier Transform of the measured data to give the time domain response, which displays reflections from the target as a function of time or distance. The time domain response gives great insight into where in the range dimension the reflections occur. The time domain gating feature can also be used to analyze the measured response and reduce the effects of unwanted signals. In addition, the recent HP network analyzers can be fully automated using an external computer over the HP-IB (Interface Bus). A large amount of data reduction associated with a measurement can be performed using a computer, while the system remains flexible enough to be used for a variety of applications.

One of our design requirements is to be able to measure targets with a wide range of radar cross sections (RCS). In practice the limitation is on measuring the targets with small RCS. This minimum detectable target for a given scatterometer at a certain range is limited by three major factors. The first factor is the thermal noise level, which is the absolute minimum detectable signal and can be determined by the product of the noise figure and bandwidth. The dynamic range of the sampler in the network analyzer is the second factor. This problem arises when a single antenna system is used, or when there is insufficient isolation between the transmit and receive antenna. In such cases part of the transmitted signal returns to the receiver and sets the minimum detectable signal level, which can be obtained from dividing the returned signal by the dynamic range of the sampler. Finally, the third limiting factor is the effect of multiple reflection at the target range. Usually in radar systems there are impedance mismatches at interfaces between different RF components, antenna input ports, and antenna to free space transition.

Since the network analyzer is a coherent system its bandwidth is very narrow, hence thermal noise usually is not a limiting factor. Dynamic range and multiple reflection problems limit the performance of the scatterometer, and they can be improved by increasing the isolation between the transmit and receive paths of the system. A two antenna system can solve these problems, but antenna size limitations and small beamwidth (spatial resolution) requirement force us to use a single antenna system. Deploying a pulsing network and including isolators in the microwave
circuitry can somewhat eliminate the antenna mismatch and multiple reflections. A detailed description of the system is given in the next section of this report.

Another design requirement is that the antennas should be mounted on a platform at the top of a boom truck, with rotatable positioner, where there are limitations in space and weight handling. Thus, the network analyzer and its peripherals must be operated from the base platform on the bed of the truck. In this case the RF transmit and receive signals should pass through long coaxial cables that run from the network analyzer to the antennas. In order to avoid the high losses in cables at C and X-Band frequencies, a lower IF is up-converted to the desired RF band using a single side-band up-converter. Then the received signal is down-converted by the same local oscillator used for up-conversion to maintain phase coherence.
3 Detailed System Description

3.1 General

Figure 3 presents an overall system block diagram. It divides the system into 4 subsections: network analyzer and control network, amplifier and switching network, microwave circuitry and antennas. Description of each subsystem is presented in the following sections.

![Block diagram of the LCX scatterometer.](image)

3.2 Network Analyzer and Control System

The HP 8753A is a high performance RF vector network analyzer used to measure reflection and transmission parameters. It integrates a high resolution synthesized RF source and a dual channel receiver to measure and display magnitude and phase responses of active and passive RF networks. It has the capability of transforming measured data from the frequency domain to the time domain.
<table>
<thead>
<tr>
<th></th>
<th>L-Band</th>
<th>C-Band</th>
<th>X-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Frequency</td>
<td>1.5 GHz</td>
<td>1.75 GHz</td>
<td>1.5 GHz</td>
</tr>
<tr>
<td>Frequency Bandwidth</td>
<td>300 MHz</td>
<td>500 MHz</td>
<td>1.0 GHz</td>
</tr>
</tbody>
</table>

Table 1: HP 8753 frequency sweep range for the LCX scatterometer.

It consists of three receiver inputs R, A and B with identical samplers. The R input is usually used as a reference for phase-locking the source. A directional coupler is used in our system to provide a reference signal for the R input. A minimum of -35 dbm power is required for phase-locking to occur.

The built-in synthesized source generates a swept RF signal in the range of 300 KHz to 3.0 GHz. The frequencies used in the HP 8753A for the LCX system are listed in Table 1. The X-band scatterometer is operated with a bandwidth(BW) of 500 MHz in field experiments because a BW of 1.0 GHz would require twice the number of points to avoid aliasing in the time domain presentation.

The RF output power of the network analyzer ranges from -5 to 20 dBm. This power should be adjusted according to the length of RF cables used in the system. Another factor that determines the amount of transmit power is the use of the pulsing network which will be described later in the report.

The HP 8753A is equipped with a remote programming interface using the HP-IB. This provides a controlling computer to send commands or instructions to and receive data from the network analyzer. Several output modes are available for outputting data. We use a polar format for data transfer that provides us with the magnitude and phase of the signal.

Automatic control of all equipment is accomplished by the HP 9386 computer. The HP 8753A system and peripheral equipment, including a disc drive and printer, are all interfaced with the computer, providing automated measurement, real-time data reduction, hard copy output and data storage. The computer also controls a HP 59306A relay actuator which selects the frequency and polarization of the measurement. The 10 ms switching time on the relays allows us to make
fast polarimetric measurements.

3.3 Amplifier and Pulsing Network

To detect small targets or targets that are far away from the antenna, we needed to add an amplifier in the receive path of the system. In addition to the signal reflected from the target, the short-range returns from the antenna and circulator leakage are also amplified, and may result in saturation of the receiver. To reduce the level of these direct returns, a pulsing network is used.

With this network, during the time that the signal is transmitted, the receiver is turned off, and when the return from the target is expected the receiver is turned on and the transmitter is switched off. Because this switching is done at a rate which is much higher than the bandwidth of the receiver in the network analyzer, the analyzer does not sense that the incoming signal is pulsed and measures it as CW.

The block diagram of the components used in our pulsing network is shown in Figure 4 and their characteristics are listed in Table 2. The two high-speed microwave switches are placed in the transmit and receive arms. They are driven by two pulse generators in a way that one is triggered by the other. An isolator and a high pass filter are used to remove switching transients that can create adverse effects on the response of the network analyzer. It should be noted that the pulsing network is not interfaced with the network analyzer and is operated independent of the analyzer operating sequence.

The effect of pulsing was tested with the X-band system when operated inside an anechoic chamber. An 8-inch diameter sphere was placed in the chamber on a styrofoam pedestal about 15 meters away from the antenna. Figure 5 shows the time domain response of the scene as displayed by the network analyzer. Without switching (upper trace) there is a large return at the start of the trace caused by the antenna reflections. The return from the sphere is some 100 nanoseconds later. The noise floor is about 23 dB below the sphere, mostly attributable to thermal(random) noise. Switching is timed in such a way that the antenna reflection is decreased by 50 dB (lower trace), the transmitted power can now be increased without overdriving the receiver. The signal
to noise ratio is now improved to 35 dB.

Figure 6 shows the timing sequence used for the switches. The scale is 20 ns/div. The transmitter is turned on for 90 ns and off for 135 ns, corresponding to 4.4 MHz repetition rate. These parameters were obtained experimentally for optimum response and depend mostly on the spacing between the antenna and the target. For distributed targets these parameters must be chosen more carefully in such a way that no part of the backscattered signal is chopped off.

![Diagram](attachment:image.png)

**Figure 4:** Diagram of the amplifier and pulsing network.
<table>
<thead>
<tr>
<th>Component</th>
<th>MFG Model No.</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPST PIN Diode switch</td>
<td>HP 33132A</td>
<td>Isol. 33dB, Ins. Loss 1dB @ 1-2GHz</td>
</tr>
<tr>
<td>Switch driver</td>
<td>HP 33190B</td>
<td>Off 0-0.8V, On 2.5V min.</td>
</tr>
<tr>
<td>50 MHz Pulse Generator</td>
<td>HP 8012B</td>
<td>Period 20ns-1s, Trans. time 5ns-0.5s</td>
</tr>
<tr>
<td>Amplifier</td>
<td>MITEQ AMMIC 1047</td>
<td>50-2500MHz, 38.7dB, 15V, 150mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>power @1dB Comp. 18dBm</td>
</tr>
<tr>
<td>High pass filter</td>
<td>Mini-Circuits SHP-1000</td>
<td>1GHz cutoff, -40dB at 0.6GHz</td>
</tr>
<tr>
<td>Isolator</td>
<td>UTE CT-2102-OT</td>
<td>Isol&gt;20dB at 1-2GHz, VSWR&lt;1.2</td>
</tr>
</tbody>
</table>

Table 2: Amplifier and pulsing network components.

Figure 5: Time domain response of the system with a sphere in the chamber; (a) without switching, (b) with switching.
Figure 6: Switch control pulses for transmit and receive, pulsing period is 225 ns, the on-pulse length is 90 ns.

3.4 Microwave Circuitry

The microwave circuitry in the LCX scatterometer is designed such that it enables the system to transmit and receive two orthogonal linear polarizations (vertical and horizontal) at the desired frequencies. The diagrams in Figures 7, 8 and 9 illustrate the designs used in the RF units of the three systems.

Because losses in the cables are tolerable at L-band, the base swept frequency of the network analyzer is itself used for transmission. Two switches are placed in the transmit and receive paths to provide us with easy switching between transmit and receive polarizations, which are controlled by the relay actuator in the control unit. The performance specifications of the components used in the L-band RF unit are listed in Table 3.

To avoid high losses at C and X-band frequencies, a lower frequency signal (IF) provided by the network analyzer is up-converted using a local oscillator(LO). This is accomplished using a mixer that produces the sum and difference frequencies \( f_{RF} = f_{LO} \pm f_{IF} \). In the C-band unit \( f_{LO} - f_{IF} \) is used and the sum frequency is rejected with a low pass filter. In the X-band unit
we use a high pass filter that passes \((f_{LO} + f_{IF})\) and rejects the difference frequency. The C and X-band systems are almost identical in design except that one uses the lower side-band frequency and the other the upper side-band.

An amplifier is placed after the mixer to compensate for the conversion loss of the mixer. A power divider is used to split the LO power for use in the down-conversion section. Two separate sets of down-converter sections are used (one for each polarization) to provide the option of receiving both polarizations with two receivers. For the time being a transfer switch located at the end of these two sections selects the receive polarization.

Isolators are distributed throughout the system to help reduce reflections, and hence the system noise level, which arise from the relatively high VSWR of the mixer ports. Because variations in temperature can cause performance changes in the oscillator and the amplifier, a heater with a temperature-controlled unit is placed in both C and X-band RF units to stabilize the temperature.
Figure 7: Block diagram of the L-band RF unit.

Figure 8: Block diagram of the C-band RF unit.
<table>
<thead>
<tr>
<th>Component</th>
<th>MFG Model No.</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulator</td>
<td>UTE CT-2104-O</td>
<td>Isol&gt;20dB at 1-2GHz, VSWR&lt;1.2</td>
</tr>
<tr>
<td>SPDT switch</td>
<td>Teledyne CS-33S10</td>
<td>Switch time 10ms, 28V, 80mA</td>
</tr>
<tr>
<td>Transfer switch</td>
<td>Transco 715C70100</td>
<td>Switch time 20ms, 28V, 120mA</td>
</tr>
</tbody>
</table>

Table 3: L-band RF unit components.

Figure 9: Block diagram of the X-band RF unit.
<table>
<thead>
<tr>
<th>Component</th>
<th>MFG Model No.</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oscillator</td>
<td>EMF Systems 251003</td>
<td>6.5GHz, +17.7dBm, 15V, 250mA</td>
</tr>
<tr>
<td>Mixer</td>
<td>Watkins Johnson M14</td>
<td>4-8GHz, Conv loss &lt;7dB</td>
</tr>
<tr>
<td>SPDT switch</td>
<td>Teledyne CS-33S10</td>
<td>Switch time 10ms, 28V, 80mA</td>
</tr>
<tr>
<td>Transfer switch</td>
<td>Transco 715C70100</td>
<td>Switch time 20ms, 28V, 120mA</td>
</tr>
<tr>
<td>Low pass filter</td>
<td>Microlab/FXR LA-60F</td>
<td>6GHz cutoff, -32dB at 7.5GHz</td>
</tr>
<tr>
<td>Power divider</td>
<td>ARRA 5200-2</td>
<td>4-8GHz, Iso &gt;18dB, VSWR &lt;1.6</td>
</tr>
<tr>
<td>Circulator</td>
<td>UTE CT-4428-O</td>
<td>4-8GHz, Isolation &gt;20dB,</td>
</tr>
<tr>
<td>Isolator</td>
<td>UTE CT-4426-OT</td>
<td>Ins Loss &lt;.4dB, VSWR &lt;1.2</td>
</tr>
<tr>
<td>Amplifier</td>
<td>Avantek AFT-6263</td>
<td>2-6GHz, 28.7dB, 15V, 282 mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>power @1dB Comp. 22.2dBm</td>
</tr>
</tbody>
</table>

Table 4: C-band RF unit components.

<table>
<thead>
<tr>
<th>Component</th>
<th>MFG Model No.</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gunn Oscillator</td>
<td>Custom made</td>
<td>8.0GHz, +16dBm, 10V, 586mA</td>
</tr>
<tr>
<td>Mixer</td>
<td>Watkins Johnson M77C</td>
<td>8-12.5GHz, Conv loss &lt;7.5dB</td>
</tr>
<tr>
<td>SPDT switch</td>
<td>Teledyne CS-33S10</td>
<td>Switch time 10ms, 28V, 80mA</td>
</tr>
<tr>
<td>Transfer switch</td>
<td>Transco 715C70100</td>
<td>Switch time 20ms, 28V, 120mA</td>
</tr>
<tr>
<td>High pass filter</td>
<td>Tapered WR-90 WG</td>
<td>8.7GHz cutoff, -30dB at 8GHz</td>
</tr>
<tr>
<td>Power divider</td>
<td>ARRA A6200-2</td>
<td>8-12.4GHz, Iso&gt;18dB, VSWR&lt;1.6</td>
</tr>
<tr>
<td>Circulator</td>
<td>UTE CT-5158-O</td>
<td>8-12.4GHz, Isolation &gt;20dB,</td>
</tr>
<tr>
<td>Isolator</td>
<td>UTE CT-5157-OT</td>
<td>Ins Loss &lt;.4dB, VSWR &lt;1.2</td>
</tr>
<tr>
<td>Amplifier</td>
<td>Avantek AFT-12664</td>
<td>6-12GHz, 31dB, 15V, 350 mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>power @1dB Comp. 21.5dBm</td>
</tr>
</tbody>
</table>

Table 5: X-band RF unit components.
3.5 Antennas

3.5.1 Design

After extensive research, square horn antennas were chosen as the best design that could meet our design goals. Low VSWR constraint and physical size limitation ruled out the use of reflector and array antennas. Also the fact that their cross-pol purity remains constant across the main beam make them particularly suitable for polarimetric measurement of distributed targets.

An orthogonal mode transducer (OMT) feed provides the capability of transmitting and receiving both polarizations. It has two ports (vertical and horizontal) each of which can be used to transmit and receive the signal. The physical dimensions of each antenna were determined by first selecting a certain gain and beamwidth and then optimizing them to get a reasonable size square horn[1]. A schematic of a square pyramidal horn is shown in Figure 10 and the dimensions are given in Table 6.

![Figure 10: Schematic of a square pyramidal horn antenna.](image)
<table>
<thead>
<tr>
<th></th>
<th>L-Band</th>
<th>C-Band</th>
<th>X-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture width a(cm)</td>
<td>92.4</td>
<td>43.0</td>
<td>40.5</td>
</tr>
<tr>
<td>Waveguide width b(cm)</td>
<td>12.1</td>
<td>4.7</td>
<td>2.03</td>
</tr>
<tr>
<td>Waveguide length c(cm)</td>
<td>20.0</td>
<td>5.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Antenna length l(cm)</td>
<td>188.7</td>
<td>136.0</td>
<td>142.2</td>
</tr>
</tbody>
</table>

Table 6: LCX square horn antenna dimensions.

3.5.2 Patterns

Antenna pattern measurements were performed with the HP 8510 network analyzer in the anechoic chamber. The source antenna was positioned at the neck of the chamber. The test antenna was placed on a wooden pedestal attached to a stepper-motor centered at the same height as the source antenna. The network analyzer and the stepper-motor were controlled by a HP 9836 computer.

The output of the HP 8510 was sent to a source antenna via a low loss cable. An amplifier was required at the source antenna to increase the signal to noise ratio when the X-band antenna was tested. A horn antenna was used as the source antenna due to its large bandwidth. The signal received by the antenna under test was sent back to the network analyzer and the HP 8510 was set up to display the ratio of the received to transmitted signals. Time domain gating was used to eliminate reflections from ground and other directions, such that only the direct signal picked up by the antenna was being measured.

The pattern measurements were performed for vertical and horizontal polarizations in each of the principal planes. The frequencies used were the same as mentioned in Table 7. The data were recorded every 1 degree over the whole pattern and also every 0.1 degree over the main beam, which were used for the illumination integral calculation. The patterns measured for each antenna at their center frequency are shown in Figures 11 through 16. The characteristics of the LCX antennas are given in Table 7. The gain and beamwidth of the antennas are functions of
frequency. Their limits over the bandwidth of operation are listed in Table 8. The azimuth and elevation values are reversed for the horizontal polarization.

<table>
<thead>
<tr>
<th></th>
<th>L-Band</th>
<th>C-Band</th>
<th>X-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Frequency $f_c$(GHz)</td>
<td>1.5</td>
<td>4.75</td>
<td>9.5</td>
</tr>
<tr>
<td>Frequency bandwidth(MHz)</td>
<td>300</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>OMT frequency range(GHz)</td>
<td>1.35-1.72</td>
<td>4.5-5.0</td>
<td>8.5-10.0</td>
</tr>
<tr>
<td>Gain at $f_c$(dB)</td>
<td>22.1</td>
<td>25.3</td>
<td>29.5</td>
</tr>
<tr>
<td>Cross-pol isolation at $f_c$(dB)</td>
<td>22.1</td>
<td>26.3</td>
<td>28.7</td>
</tr>
<tr>
<td>V-pol beamwidth El,Az at $f_c$(deg)</td>
<td>12.0,15.2</td>
<td>8.0,10.4</td>
<td>5.4,6.5</td>
</tr>
<tr>
<td>Far field distance at $f_c$(meter)</td>
<td>8.5</td>
<td>5.8</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Table 7: Characteristic of LCX antennas.

<table>
<thead>
<tr>
<th></th>
<th>L-Band</th>
<th>C-Band</th>
<th>X-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain variation over bandwidth</td>
<td>20.8-23.4</td>
<td>25.5-27.5</td>
<td>26.7-31.5</td>
</tr>
<tr>
<td>V-pol elevation beamwidth(deg)</td>
<td>11.1-12.9</td>
<td>7.7-8.4</td>
<td>5.2-5.5</td>
</tr>
<tr>
<td>V-pol azimuth beamwidth(deg)</td>
<td>13.8-16.5</td>
<td>10.1-10.8</td>
<td>6.5-6.9</td>
</tr>
</tbody>
</table>

Table 8: Gain and beamwidth variations of LCX antennas with frequency.
Figure 11: L-band vertical polarization antenna pattern.

Figure 12: L-band horizontal polarization antenna pattern.
Figure 13: C-band vertical polarization antenna pattern.

Figure 14: C-band horizontal polarization antenna pattern.
Figure 15: X-band vertical polarization antenna pattern.

Figure 16: X-band horizontal polarization antenna pattern.
4 Calibration and Measurement Accuracy

4.1 Introduction

A polarimetric radar is a phase-coherent instrument used to measure the polarization scattering matrix $S$ of point or distributed targets. The matrix $S$ relates the field $E'$ scattered by the target to the field $E'$ of a plane wave incident upon the target [4, p.1087],

$$E' = \frac{e^{-ikr}}{r} SE',$$

(1)

where $r$ is the distance from the center of the target to the point of observation and $k$ is the wave number. For a plane wave incident upon the particle in the direction $\hat{k}_i$, its electric field vector may be written in terms of vertical and horizontal polarization components, $E'^i_v$ and $E'^i_h$, using the coordinate system ($\hat{v}_i, \hat{h}_i, \hat{k}_i$) shown in Fig. 17,

$$E'^i = (E'^i_v \hat{v}_i + E'^i_h \hat{h}_i)e^{-ik_i r},$$

(2)

where

$$\hat{v}_i = \cos\theta_i \cos\phi_i \hat{x} + \cos\theta_i \sin\phi_i \hat{y} - \sin\theta_i \hat{z}$$

(3)

$$\hat{h}_i = -\sin\phi_i \hat{x} + \cos\phi_i \hat{y}$$

(4)

$$\hat{k}_i = \sin\theta_i \cos\phi_i \hat{x} + \sin\theta_i \sin\phi_i \hat{y} + \sin\theta_i \hat{z}.$$  

(5)

In (2), a time dependence of the form $e^{+i\omega t}$ is assumed and suppressed.

The far-field wave scattered in the direction $\hat{k}_s$ is a spherical wave given by

$$E' = E'^i_v \hat{v}_s + E'^i_h \hat{h}_s,$$

(6)

where ($\hat{v}_s, \hat{h}_s, \hat{k}_s$) are defined by the same expressions given in (3) to (5) except for replacing the subscript $i$ with the subscript $s$. For the backscattering case, $\theta_i + \theta_s = \pi$, $\phi_i + \phi_s = \pi$, $\hat{k}_s = -\hat{k}_i$, $\hat{v}_s = \hat{v}_i$, and $\hat{h}_s = -\hat{h}_i$.

In matrix form, (1) may be rewritten as

$$\begin{bmatrix} E'^i_v \\ E'^i_h \end{bmatrix} = \frac{e^{-ikr}}{r} \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \begin{bmatrix} E'^i_v \\ E'^i_h \end{bmatrix}$$

(7)
where

\[ S = \begin{bmatrix} S_{vv} & S_{vh} \\ S_{hv} & S_{hh} \end{bmatrix} \]  

is defined in terms of the scattering amplitudes \( S_{mn} \) with \( m \) and \( n \) denoting the polarization (\( v \) or \( h \)) of the scattered and incident fields, respectively. The scattering amplitude \( S_{mn} \) is, in general, a complex quantity comprised of a magnitude \( s_{mn} = |S_{mn}| \) and a phase angle \( \psi_{mn} \),

\[ S_{mn} = s_{mn} e^{i\psi_{mn}}; \quad m,n=v \text{ or } h, \]  

and it is related to the radar cross section (RCS) of the target, \( \sigma_{mn} \), by

\[ \sigma_{mn} = 4\pi |S_{mn}|^2 \]

\[ = 4\pi s_{mn}^2; \quad m,n=v \text{ or } h. \]  

Figure 17: Geometry of scattering of a plane wave from a particle.

Interest in measuring \( S \) stems from the fact that if the elements of \( S \) are known, we can compute the RCS of the target that would be observed by a radar with any specified combination of transmit and receive antenna configuration, including elliptical and circular polarizations [6]. In fact, we do not need to know all four magnitudes and four phases of \( S \) in order to synthesize
the desired RCS; it is sufficient to know the four magnitudes and any three of the phase angles, measured with respect to the fourth as reference. Thus, if we choose $\psi_{uv}$ as reference, we can write (8) in the form

$$S = e^{i\psi_{uv}} \begin{bmatrix} s_{uv} & s_{uh} e^{i\psi_{uh}} \\ s_{hv} e^{i\psi_{hv}} & s_{hh} e^{i\psi_{hh}} \end{bmatrix} = e^{i\psi_{uv}} S'$$

(11)

where

$$\psi_{mn}' = \psi_{mn} - \psi_{uv}, \quad m,n=v \text{ or } h.$$  

(12)

For backscattering, the reciprocity theorem mandates that $S_{hv} = S_{vh}$, which further reduces the number of unknown quantities from 7 to 5.

The formulation given above is equally applicable to a distributed target. If the effective area illuminated by the radar antenna is $A$, the polarimetric scattering behavior of the distributed target is characterized by the differential scattering matrix $S^0 = S/\sqrt{A}$.

In principle, $S_{uv}$ and $S_{hv}$ can be determined by measuring $E_i^e$ and $E_i^h$ with the target illuminated by a pure vertically polarized wave $E_i = E_i^v \hat{v}_i$ and, similarly, $S_{vh}$ and $S_{hh}$ can be determined by measuring the same quantities when the target is illuminated by $E_i = E_i^h \hat{h}_i$. Such a procedure requires that (1) the transmit and receive antennas of the measurement system each have excellent isolation between its v- and h-ports, and (2) the receive-transmit transfer functions of the measurement system be known for all four polarization combinations (vv, vh, hv, and hh). Design techniques are currently available to achieve antenna polarization isolation on the order of 30 dB. For a radar scatterometer system intended to measure the differential scattering matrices of distributed targets such as ground surfaces and vegetation canopies, such a level of isolation is sufficient to insure good measurement accuracy of the magnitudes and phases of all four scattering amplitudes. The error associated with measuring the like-polarized components $S_{uv}$ and $S_{hh}$ is negligibly small, and for $S_{hv}$ (and $S_{vh}$) the error also is less than 0.85 dB if $|S_{hv}|/|S_{uv}| \geq 0.31$, which corresponds to $\sigma_{hv}/\sigma_{uv} \geq 0.1$ (or -10 dB). For natural targets the like- and cross-polarized components, $S_{hv}$ and $S_{uv}$ for example, are uncorrelated and

24
for $\sigma_{hv}/\sigma_{vv} \geq 0.01$ the associated error would be less than 0.4 dB.

If the radar antennas do not individually have good polarization isolation between their v- and h-ports, it is necessary to characterize each antenna by a polarization distortion matrix that accounts for the coupling between the two ports, and to use at least two, and preferably three, targets of known scattering matrices in order to calibrate the radar completely [7]. Now, we will focus our attention on the problems associated with measuring the receiver-transmitter transfer function for a radar with reasonably good overall cross-polarization isolation using suitable external calibration targets.

### 4.2 System Transfer Function

Although a radar may use a single antenna to provide both transmit and receive functions and may also use a polarization switching network capable of exciting either v- or h-polarized waves in the antenna, we shall use the block diagram shown in Fig. 18 to represent the general case of a two-pole transmitter and a two-pole receiver. Assuming perfect isolation between antenna ports, the voltage received by the v-polarized receive antenna due to illumination of a target at range $r$ by a v-polarized wave is given by

$$ E_{vv} = \left[ \frac{P_t G_t G_r \lambda^2}{(4\pi)^2} \right]^{1/2} e^{-ikr} R_v T_v S_{vv} $$

$$ = \frac{K}{r^2} e^{-ikr} R_v T_v S_{vv} $$

where

$$ K = \left[ \frac{P_t G_t G_r \lambda^2}{(4\pi)^2} \right]^{1/2} $$

$S_{vv}$ is the scattering amplitude of the target, $P_t$ is the transmitted power, and $G_r$ and $G_t$ are the nominal gains of the transmit and receive antennas. The quantities $R_v$ and $T_v$ are field transfer functions for the receive and transmit antennas, respectively, which account for the deviation in both amplitude and phase from the nominal condition described by $G_t G_r$. Similarly, for any receive-transmit polarization configuration, we have

$$ E_{mn} = \frac{K}{r^2} e^{-ikr} R_m T_n S_{mn}, \quad m, n = v \text{ or } h. $$

25
4.3 Calibration

The standard calibration approach involves the use of one reference target of known scattering matrix. Upon measuring $E_{mn}$ with $S_{mn}$ known, the quantity $(KR_m T_n)$ can be determined in amplitude and phase, with the latter being relative to some reference distance time delay.

In principle, the procedure is simple and straightforward. The problem arises when we need to select a reference target of known scattering matrix. The metal sphere is the easiest target to align and its scattering matrix can be computed exactly [2, p.297]. Unfortunately, it can only be used to calibrate the vv- and hh-channels because its $S_{hv}^{vv} = S_{vh}^{hh} = 0$. Targets that exhibit significant cross-polarized scattering include the dihedral corner reflector, tilted cylinders, and others, but scattering from such targets is inherently sensitive to the orientation of the target relative to the $(\hat{v}_i, \hat{h}_i, \hat{k}_i)$ coordinate system. This, and other factors such as edge scattering, may lead to significant errors between the calculated values of the scattering amplitudes and their actual values. The orientation problem may be reduced down to an acceptable level when
operating in an anechoic chamber under controlled laboratory conditions, but it poses a difficult problem when it is necessary to calibrate a truck-mounted scatterometer, under field conditions.

To solve this problem, we use two reference targets, namely a sphere and any target with strong cross-polarized RCS. As will be shown below, it is not necessary to know the RCS of the second reference target in order to calibrate the radar system.

First, let us use a metal sphere of known size, and place it at a distance $r_0$ from the radar. The scattering amplitudes of a metal sphere are $S_{hh} = S_{vv} \equiv S_0$, and $S_{hv} = S_{vh} = 0$. The received fields for vv and hh polarizations are

$$E_{vv}^0 = \frac{K}{r_0^2} e^{-i2kr_0} R_v T_v S_0$$  \hspace{1cm} (16)  

$$E_{hh}^0 = \frac{K}{r_0^2} e^{-i2kr_0} R_h T_h S_0$$  \hspace{1cm} (17)  

and consequently,

$$K_{vv} = \frac{E_{vv}^0}{S_0} = \frac{K}{r_0^2} e^{-i2kr_0} R_v T_v S_0$$  \hspace{1cm} (18)  

$$K_{hh} = \frac{E_{hh}^0}{S_0} = \frac{K}{r_0^2} e^{-i2kr_0} R_h T_h S_0.$$  \hspace{1cm} (19)  

where the subscript and superscript 0 denote quantities associated with the metal sphere.

Next, let us use any point target that exhibits strong cross-polarized scattering, and let us measure the received field for hv and vh polarizations,

$$E_{hv}^c = \frac{K}{r_c^2} e^{-i2kr_c} R_v T_v S_{hv}^c$$  \hspace{1cm} (20)  

$$E_{vh}^c = \frac{K}{r_c^2} e^{-i2kr_c} R_h T_h S_{vh}^c$$  \hspace{1cm} (21)  

where the subscript and the superscript $c$ refers to the cross-polarization calibration target. The reciprocity theorem states that in the backscattering direction, the cross-polarized scattering amplitudes are always equal. Hence,

$$S_{hv}^c = S_{vh}^c$$  \hspace{1cm} (22)  

and consequently,

$$K_d = \frac{E_{hv}^c}{E_{vh}^c} = \frac{R_h T_v}{R_v T_h}.$$  \hspace{1cm} (23)  

27
Now for a test target with unknown scattering matrix $S_u$, placed at a distance $r_u$ from the radar, the received field is

$$E_{uv}^u = \frac{K}{r_u^2} e^{-i2kr_u} R_u T_v S_{uv}^u,$$  \hspace{1cm} (24)

$$E_{hh}^u = \frac{K}{r_u^2} e^{-i2kr_u} R_h T_h S_{hh}^u,$$  \hspace{1cm} (25)

$$E_{hv}^u = \frac{K}{r_u^2} e^{-i2kr_u} R_h T_v S_{hv}^u,$$  \hspace{1cm} (26)

$$E_{vh}^u = \frac{K}{r_u^2} e^{-i2kr_u} R_v T_h S_{vh}^u.$$  \hspace{1cm} (27)

Since we are interested in the phase angle $\psi'$, we can eliminate the factor $e^{-i2kr_u}$ in the above equations. Using (18), (19), and (23) in combination with (24)-(27) we obtain the following expressions for the unknown scattering amplitudes

$$S_{uv}^u = \frac{E_{uv}^u}{K_{uv}} \left( \frac{r_u}{r_0} \right)^2,$$  \hspace{1cm} (28)

$$S_{hh}^u = \frac{E_{hh}^u}{K_{hh}} \left( \frac{r_u}{r_0} \right)^2,$$  \hspace{1cm} (29)

$$S_{hv}^u = \frac{E_{hv}^u}{\sqrt{K_{uv}K_{hh}K_d}} \left( \frac{r_u}{r_0} \right)^2,$$  \hspace{1cm} (30)

$$S_{vh}^u = \sqrt{\frac{K_d}{K_{uv}K_{hh}}} E_{vh}^u \left( \frac{r_u}{r_0} \right)^2.$$  \hspace{1cm} (31)

Equations (28)-(31) provide expressions for the four scattering amplitudes in terms of (1) the like-polarized received voltages for the metal sphere, $E_{uv}^0$ and $E_{hh}^0$, (2) the ratio of the cross-polarized received voltages for the second calibration target, $K_d = E_{hv}^d / E_{vh}^d$, (3) the like-polarized scattering amplitude of the sphere, $S_0$, and (4) the ranges to the sphere and the test target, $r_0$ and $r_u$. Note that knowledge of the scattering amplitude of the second calibration target is not required.
4.4 Measurement Accuracy

To verify the validity of the calibration technique summarized by equations (28)-(31), we measured the scattering matrix of a tilted cylinder with the X-band scatterometer. The scatterometer was used in continuous chirped mode operating at a frequency of 9-10 GHz. The scattering measurements were performed in a 13-m long anechoic chamber using the setup diagrammed in Fig. 19.

Although an exact theoretical solution for a finite-length, conducting cylinder does not exist, the solution based on the assumption that the current along the axis of the cylinder is constant provides accurate results in the specular direction, if the length of the cylinder \( L \) is much larger than the wavelength \([8]\). In order to minimize edge effects caused by scattering by the ends of the cylinder, the diameter of the cylinder \( D \) must also be chosen to be much smaller than the wavelength. Hence, we selected a cylinder with \( L=30.48 \text{ cm} \) and \( D=1.625 \text{ mm} \).

Correct positioning of the test target with respect to the antenna coordinates is very important. First, the target must be placed at the center of the antenna beam in order to avoid phase variations of the incident field along the axis of the target. This was accomplished using a pair of two laser beams. Another alignment parameter that has to be carefully controlled is the angle \( \phi \) between the incidence direction \( \hat{k}_i \) and the projection of the cylinder axis onto the horizontal plane (Fig. 20). The elements of the scattering matrix are very sensitive to variations in azimuth angle and the rate of change is proportional to the length of the cylinder. This angle was set to 90° with a fine-control stepper motor (steps of a fraction of a tenth of a degree) by maximizing the received power. The 13p \((\hat{\nu}_i)\). Accurate setting of this angle is very difficult. This angle was set to 50° using an inclinometer.

Under the mentioned conditions a signal to noise ratio of 25 dB was achieved for the test cylinder and after background subtraction the signal to noise ratio was improved to 40 dB. To eliminate short-range reflections from the antenna circulators, the returned signal was time-gated, as a result of which the frequency response around the beginning and the end of the frequency band was distorted and discarded.
A 15-cm sphere was used for sphere calibration and a 45° wire-mesh (Fig. 21) was employed as the cross-polarization target. The distances of all the targets from the scatterometer, which were accurately measured using the time-domain feature of the HP 8753, were arranged such that \( r_0 = r_z = r_u \). The measured amplitudes of the scattering matrix elements of the cylinder are compared with theoretical values in Figures 22-24. The measured values are within ±0.3dB of the theoretical results. For relative phase, the measured values (Figs. 25 and 26) are within ±5° of theoretical predictions. These deviations are attributed to alignment errors and to the imperfect polarization isolation of the antenna.

The excellent agreement between measurements and theory demonstrates that the calibration technique is an effective approach for calibrating single antenna polarimetric scatterometer systems. This technique is particularly useful for field operations because it does not require accurate alignment of calibration targets or knowledge of the radar cross section of the cross-polarization target.
Figure 19: Automatic radar cross section measurement setup.

Figure 20: Geometry of scattering of a plane wave from a long, thin cylinder.
Figure 21: Geometry of a wire-mesh

Figure 22: Radar cross section (hh) versus frequency of a cylinder with $L=30.48$ cm and $D=1.625$ mm, (——)measured and (---)theory.
Figure 23: Radar cross section (vv) versus frequency of a cylinder with L=30.48 cm and D=1.625 mm, (——)measured and (- -)theory.

Figure 24: Radar cross section (hv) versus frequency of a cylinder with L=30.48 cm and D=1.625 mm, (——)measured and (- -)theory.
Figure 25: Relative phase $S_{hh}$ (to $S_{vv}$) versus frequency of a cylinder with $L=30.48$ cm and $D=1.625$ mm, (---)measured and (- - -)theory.

Figure 26: Relative phase $S_{hv}$ (to $S_{vv}$) versus frequency of a cylinder with $L=30.48$ cm and $D=1.625$ mm, (---)measured and (- - -)theory.
5 Measurement Modes

The LCX polarimetric scatterometer can perform measurements in four different modes: (a) point target, (b) surface, (c) volume, and (d) polarimetry, each of which will be discussed in the sections that follows. A software (LCX Version 4.0) was written to facilitate the use of the scatterometer. By selecting from various menus and responding to on-screen prompts, the operator can calibrate and use the scatterometer in the desired mode without having to manually set the parameters on the network analyzer and the relay actuator.

To simplify the equations in the following sections, we redefine the cross polarization calibration factors as follows

\[
K_{he} = \sqrt{K_{ee}K_{hh}K_d}
\]

(32)

\[
K_{eh} = \sqrt{\frac{K_{ee}K_{hh}}{K_d}}
\]

(33)

such that equations (28)-(31) become

\[
S_{mn}^u = \frac{E_{mn}}{K_{mn}} \left( \frac{r_u}{r_0} \right)^2.
\]

(34)

In the next four sections the assumption is that calibration has been performed and the calibration factors \(K_{mn}\) and the distance to the calibration target \(r_0\) are known at all \(N\) discrete frequencies across the bandwidth of operation.

5.1 Point Target

The point target routine measures the scattering amplitude of a target with finite size such that the solid angle subtended by the target is smaller than the antenna solid angle. The target should be placed in the far field of the antenna. Point target measurements are done in the frequency domain. Time domain gating is set such that only the target characteristic is being
observed in the frequency response. While setting the gate parameters, the operator is asked to specify the target range \( r_u \) on the time domain trace which will be used in calibrating the data.

After setting the gate parameters the program steps through each selected polarization and records \( N \) complex values each corresponding to the scattered field \( E_{mn}^u \) at that frequency. After removal of the target, a measurement of the background signal \( E_{mn}^b \) is obtained with the same gate parameters. Then the program calculates the scattering amplitude of the target at each frequency point using

\[
S_{mn}^u = \frac{(E_{mn}^u - E_{mn}^b)}{K_{mn}} \left( \frac{r_u}{r_0} \right)^2. \tag{35}
\]

We can calculate the radar cross section of the target using equation (10) which gives

\[
\sigma_{mn} = 4\pi \left| \frac{E_{mn}^u - E_{mn}^b}{K_{mn}} \right|^2 \left( \frac{r_u}{r_0} \right)^4. \tag{36}
\]

### 5.2 Surface

The surface routine measures the average surface backscattering coefficient \( \sigma^2 \). The measurements are performed in the frequency domain for \( N \) frequency points from each of \( M \) independent samples. The gate parameters are set at the beginning of the program and will remain the same for all the \( M \) samples.

To derive the equations used in calibration of the distributed target measurements we begin with the radar equation for a point target located at \( r_u \)

\[
P_r = \frac{P_t G_{t0} G_{r0} \lambda^2 \sigma}{(4\pi)^3 r_u^4}. \tag{37}
\]

where \( P_r \) is the received power, \( P_t \) is the transmitted power, \( G_{t0} \) and \( G_{r0} \) are the boresight transmit and receive antenna gains, respectively, \( \lambda \) is the wavelength, and \( \sigma \) is the radar cross section of the target. By comparing equations (36) and (37) and substituting \( P_r/P_t \) for \( |E_{mn}^u - E_{mn}^b|^2 \)
and $|K|^2$ for $|K_{mn}|^2$ we get

$$|K|^2 r_4^2 = \frac{G_{10} G_{00} \lambda^2}{(4\pi)^2}. \quad (38)$$

The form of the radar equation used in determining the return power from a surface is given by the expression\[3\]

$$P_r = \frac{P_i \lambda^2}{(4\pi)^3} \int_{\text{ill.area}} G_{10} G_{00} \frac{\sigma^o}{r^4} dA. \quad (39)$$

Figure 27 illustrates the geometry used. If we assume $\sigma^o$ to be constant over the illuminated area and writing the gains as $G_t(\theta, \phi) = G_{10} g_t(\theta, \phi)$, the above equation can be rewritten as

$$P_r = \frac{P_i G_{10} G_{00} \lambda^2 \sigma^o}{(4\pi)^3} \int_{\text{ill.area}} g_t(\theta, \phi) g_r(\theta, \phi) \frac{1}{r^4} dA. \quad (40)$$

Using equation (38), we can write

$$\frac{P_r}{P_i} = \frac{|K|^2 r_4^2 \sigma^o}{4\pi} \int_{\text{ill.area}} g_t(\theta, \phi) g_r(\theta, \phi) \frac{1}{r^4} dA. \quad (41)$$

The integral in this equation is known as the illumination integral, I. Values of the illumination integral for a given height and incidence angle have been evaluated using the main-lobe patterns of the antenna.

After rearranging equation (41) to obtain the backscattering coefficient we get

$$\sigma^o = \frac{4\pi P_r / P_i}{|K|^2 I r_4^2}. \quad (42)$$

The averaging process is performed over N frequency points and M independent samples. If we write $\sigma_{ij}^o$ for the backscattering coefficient at the $j^{th}$ point of the $i^{th}$ trace, then we obtain the overall average of the backscattering coefficient using

$$\sigma^o = \frac{1}{M} \sum_{i=1}^{M} \frac{1}{N} \sum_{j=1}^{N} \sigma_{ij}^o. \quad (43)$$

5.3 Volume

The volume measurement mode measures the differential volume backscattering coefficient. The measurements are performed in the time domain mode of the network analyzer and an
integration range over the target return is set by the operator. The program divides this range into \( N \) slices and measures \( M \) independent samples. After averaging the samples, it evaluates the volume backscattering coefficient of the \( k^{th} \) slice attenuated by the volume above that slice.

The development of the formulas is similar to those explained in the previous section. Consider a volume illuminated by the scatterometer as in Figure 28, and divide this volume into \( k \) slices perpendicular to the direction of propagation, each with range extent \( \Delta r_k \). Similar to the surface case we can write an expression for the power received from each of these slices[3]. The power received from the \( k^{th} \) slice is given by

\[
P_{rk} = \frac{P_{l}G_{b0}G_{v0}A^2}{(4\pi)^3} I_v(h_k, \theta) \frac{\sigma_{v,\perp}}{L(z_k)} \Delta r_k
\]

(44)

where \( L(z_k) \) is the two way loss through the medium above the \( k^{th} \) slice in the \( z \)-direction and \( I_v \) is the volume illumination integral and is given by

\[
I_v(h_k, \theta) = \int_{\text{ill.area}} g_\rho(\theta, \phi) g_r(\theta, \phi) \frac{1}{r_k^2} dA
\]

(45)

where \( A_\perp = A \cos \theta \) is the illuminated area perpendicular to the antenna beam. The volume integral equation can be written as

\[
I_v(h_k, \theta) = I(h_k, \theta) \cos \theta
\]

(46)

so that only the surface illumination integral needs to be evaluated.

Since the volume measurement mode is done in the time domain we need to take the average of the calibration constants obtained in the frequency domain and use that as the correction factor. Using equation (38) and (46), we can rearrange equation (44) and get

\[
P_{rk}/P_t = \frac{|K|^2 \rho_0^2}{4\pi} I(h_k, \theta) \frac{\sigma_{v,\perp}}{L(z_k)} \Delta r_k \cos \theta
\]

(47)

Thus, the volume backscattering coefficient for the \( k^{th} \) slice attenuated by the volume above it can be obtained from
\[ \frac{\sigma_{e_k}}{L(z_k)} = \frac{4\pi P_{r_k}/P_i}{|K|^2 r_k^3 I(h_k, \theta) \Delta r_k \cos \theta}. \] (48)

In many instances it is desirable to have the integrated backscattering coefficient \( \sigma^o \). It can be written as a summation over \( N \) slices as

\[ \sigma^o = \sum_{k=1}^{N} \frac{\sigma_{e_k}}{L(z_k)} \Delta r_k \cos \theta. \] (49)

### 5.4 Polarimetry

The polarimetric measurement mode measures the calibrated magnitude and phase of the four polarizations of the returned signal from a distributed target. It measures several independent samples and stores them separately. These data can be used to calculate the average phase matrix.

In this mode only the center frequency data is recorded. Time domain gating is set by the operator over the target return. For each sample, all four polarizations are measured sequentially with very short intervals, so that the phase information is conserved.

This routine uses a calibration scheme similar to that of the point target except for scaling the result by the illumination integral instead of the point target range. The equation used is given below

\[ S^u_{mn} = \frac{E^u_{mn}}{K_{mn} r_0^2 \sqrt{I}}. \] (50)

where \( I \) is the illumination integral.
Figure 27: Geometry used in the surface target measurements.

Figure 28: Geometry used in the volume target measurements.
References


A  Photographs of the system
Figure 29: Photograph of the LCX Antennas.
Figure 30: Photograph of the C-band RF Unit.

Figure 31: Photograph of the X-band RF Unit.
B Measurement Software Listing
L/C/X POLARIMETER MEASUREMENT PROGRAM

LAST EDIT: JUNE 1989

RE-WRITE OF PROGRAM TO CALIBRATE ANTENNAS USING A SPHERE AND A CROSS-POL TARGET. DATE FEB 4, 1989. THE SUBROUTINE RARADAR MENU HAS BEEN LEFT ESSENTIALLY INTACT, BUT MOST OF THE OTHER ROUTINES HAVE BEEN MODIFIED TO REDUCE COMPLEXITY.

NAME DATE VER. CHANGE

OPTION BASE 1


DATA "L","C","X"
DATA "U","H","V","U","V","H"
DATA 1.5,1.75,1.5
DATA 3.5,3
DATA 12.5,5,0.6,2
DATA 1.0,0.6,0.6
DATA 7*A53B346","7*A53B346","7*A53B346"
DATA 7*A53B346","7*A53B346","7*A53B346"
DATA 7*A53B346","7*A53B346","7*A53B346"
DATA 7*A53B346","7*A53B346","7*A53B346"
DATA 7*A53B346","7*A53B346"| 0.750,0.4| DRIVE A,B,C
READ Freq$(*)
READ Poly$(*)
READ freq_cent(*)
READ freq_span(*)
READ Beam$(*)
READ Bin_rgn$(*)
READ Poly$(*)
READ Drive_a$(Drive_b$(Drive_c$(

| Set up error handling routine. |
| ON ERROR CALL Fiq_error |

READ illumination integral coefficients from disc. Also define look-up table for FORMI to FORMI conversion.

ASSIGN R0 tac TO FNFileloc$("ILLSM","/LCK/ILL"0Drive_a$)
Enter R1 Tac@C(*)
ASSIGN R1 tac TO *
CALL Table def

Initialize important parameters.

DSC
MAT Donecal= (0)
MAT Cal_flag= (0)
MAT Meas_flag= (0)
Modes="MATRIX"
F disp=1
P disp=1
Out_type$="PRINT/DISC"
Span_time=3.000E-7

Zero$(*) is the 2-way time domain return from the antenna
L-Band aperture is 13.50 ns away from the vv-pol max return.
C-Band aperture is 12.25 ns away from the vv-pol max return.
X-Band aperture is 13.75 ns away from the vv-pol max return.

Zero$(1)$= (1.8700E-7) (1.3500E-8)
Zero$(2)$= (1.8075E-7) (1.2255E-8)
Zero$(3)$= (1.7890E-7) (1.3755E-8)
Vel=2.99792458E-8
920 Ntrace=3
930 Npts=201
940 Angle=0
950 Target=*
960 Sound="ON"
970 Debug="OFF"
980 Bell=""
1000 Version="Version 4.0"
1010 PRINTER IS PRT
1020 PRINT CHR$(27) & "411L" : Set Page Breaks
1030 PRINTER IS CRT
1040 Clear crt
1050 PRINT
1060 PRINT ****
1070 PRINT ****
1080 PRINT ****
1090 PRINT ****
1100 PRINT ****
1110 PRINT ****
1120 PRINT ****
1130 PRINT ****
1140 PRINT ****
1150 PRINT ****
1160 PRINT ****
1170 IF FNAsk("INITIALIZE RAM DISK?"") THEN
1180 INITIALIZE Drive_c$ , 0
1190 INITIALIZE Drive_c$, 1000
1200 END IF
1210 Hpq753_Init(#Nwa, #Nwa_data, #Hpib, #Relay, #Debug$)
1220 Series_Init
1230 OUTPUT #KBD:"SCRATCH KEY*CHR$(255) & CHR$(88)
1240 START_LOOP:1
1250 Read_menu(End$)
1260 IF End$="T" THEN GOTO Program end
1270 IF Modes="POINTER" THEN CALL Point_target
1280 IF Modes="SURFACE" THEN CALL Surface
1290 IF Modes="VOLUME" THEN CALL Volume
1300 IF Modes="MATRIX" THEN CALL Polarimetry
1310 GOTO START_LOOP
1320 RETURN
1330 Program end: ;
1340 DISP "PROGRAM EXIT"
1350 LOAD KEY "EDITREX\MEMORY, 0.1"
1360 STOP
1370 END
1380 ;*********************************************************************
1390 SUB Freq_set(INTEGER Ifreq)
1400 ; This subroutine sets the transmit frequency for the HPq753.
1410 ;
1420 COM /Paths/ #Nwa, #Nwa_data, #Hpib, #Relay
1430 COM /Sys 1/ Freq$(*) , Freq cent$(*) , Freq_span$(*)
1440 OUTPUT #Nwa;"TMINTRANOFF"
1450 OUTPUT #Nwa; CENT "$VAL$ & (Freq cent$(Ifreq) & " GHz"
1460 OUTPUT #Nwa; SPAN "$VAL$ & (Freq_span$(Ifreq) & " GHz"
1470 SUBEND | Freq_set
1480 ;*********************************************************************
1490 SUB Pol_sw(INTEGER Ifreq, Ipol)
1500 ; This subroutine sets the transmit and receive polarization by
1510 ; sending the proper command over the HPIB to the polarization
1520 ; 1 displays. It also displays the freq and pol on HPq753.
1530 ;
1540 COM /Paths/ #Nwa, #Nwa_data, #Hpib, #Relay
1550 COM /Sys 1/ Freq$(*) , Freq cent$(*) , Freq_span$(*)
1560 COM /Sys 2/ Pol$(*) , Polaw$(*)
1570 OUTPUT #Relay;Polaw$(Ifreq, Ipol)
1580 OUTPUT #Nwa; TITL "$Freq$(Ifreq) & BAND = "$Pol$(Ipol)"
1590 WAIT .1
1600 SUBEND | Pol_sw
1610 ;*********************************************************************
1620 SUB Angle_set(Angle)
1630 ; This subroutine tells the user to set the antenna positioner angle.
1640 ;
1650 COM /Sys 5/ Target$, Version$, Mode$, Out_type$, Sound$, Bell$, Debug$
1660 ANGLES="$VAL$(Angle) & CHR$(193) & " Degree alignment"
1670 ;
1680 Disp "SET ANTENNA ANGLE TO "$Angle$; " <CONTINUE>; Bell$ PAUSE
1690 Disp "WORKING"
1700 SUBEND | Angle set
1710 ;*********************************************************************
1720 SUB Series_init
1730 ;*********************************************************************
1740 ; This subroutine prints a header for the printout and sets the system
1750 ; date and time.
1760 ;
1770 ;
1780 ;
1790 ;
DIM Inputs$(80)
PRINT Chr$(12)
Set Clock
INPUT "ENTER MEASUREMENT SERIES TITLE",Inputs$
Print"****#RTS(*.,9)
PRINT RTPS(*.,70)
PRINT Inputs$
INPUT "ENTER OPERATOR NAME",Inputs$
PRINT Inputs$
PRINT Inputs$
PRINT Inputs$
GOTO Loop_start:
Loop_start:
INPUT **,Inputs$
IF Inputs$(1,"=")/" THEN Loop_end
PRINTER IS CRT
PRINT Inputs$
PRINTER IS CRT
GOTO Loop_start:
Loop_end:
PRINT Inputs$
PRINTER IS CRT
PRINT RTPS(*.,70)
PRINT Inputs$
PRINT Inputs$
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PRINT Inputs$
COM /sys 7/ INTEGER Cal_flag(*), Meas_flag(*)
COM /Cal/7 Cal_keep(*), Tcal(*), DoneCall(*)
INTEGER F_disp_old, P_disp_old
INTEGER F,P
!
! This is the main menu subroutine.
!
! ALLOCATE INTEGER Cal_flag_old(2,4)
! ALLOCATE INTEGER Meas_flag_old(2,4)
 EndS~";"
Menu clear: 1
OFF KEY
Clear crt
Menu:
OUTPUT KBK:CHR$(255)@CHR$(84); !home display
PRINT TAB$(1,1)
PRINT
PRINT
PRINT "L/C/X"
PRINT "PARAMETER SELECTION MENU"
PRINT
PRINT "PARAMETER CURRENT VALUE"
PRINT
PRINT "FREQUENCY "
PRINT IF Meas_flag(1,F) THEN PRINT Freq$(F)" "
NEXT F
PRINT ""
PRINT IF Meas_flag(1,P) THEN PRINT Pol$(P)" "
NEXT P
PRINT ""
PRINT "ANTENNA ANGLE "&Angle$&""
PRINT "TARGET TYPE "&Target$&"
PRINT "MEASUREMENT MODE "&Modes$&"
PRINT "CURRENT DISPLAY "&Freq$(F_disp)"&Pol$(P_disp);
Menu 1:
OFF KEY
ON KEY 0 LABEL "FREQ/POLARIZ $ GOTO Freq_pol
ON KEY 1 LABEL "ANGLE $ GOTO Angle
ON KEY 2 LABEL "TARGET $ GOTO Target
ON KEY 3 LABEL "MODE $ GOTO Mode
ON KEY 4 LABEL "BEGIN $ GOTO Begin
ON KEY 5 LABEL "MORE $ GOTO Menu 2
ON KEY 6 LABEL "COMMENTS $ GOTO Comment_print
ON KEY 7 LABEL "DISPLAY $ GOTO Display
ON KEY 8 LABEL "CALIBRATE $ GOTO Calibrate
ON KEY 9 LABEL "QUIT $ GOTO Quit
Spin: GOTO Spin ! WAIT FOR SOFTKEY INTERRUPT
OFF KEY
ON KEY 1 LABEL "PARAMETERS $ GOTO Parameters
ON KEY 3 LABEL "SPHERE RESP $ CALL Sphere_response
ON KEY 9 LABEL "MAIN MENU $ GOTO Menu_clear
GOTO Spin
Spin:
OFF KEY
MAT Meas_flag.old= Meas_flag
MAT Meas_flag$= (0)
ON KEY 0 LABEL "L BAND $ GOTO Set 1
ON KEY 1 LABEL "C BAND $ GOTO Set c
ON KEY 2 LABEL "X BAND $ GOTO Set x
ON KEY 4 LABEL "STORE $ GOTO Store
ON KEY 5 LABEL "VV $ GOTO VV_set
ON KEY 6 LABEL "HH $ GOTO HH_set
ON KEY 7 LABEL "HV $ GOTO HV_set
ON KEY 8 LABEL "VH $ GOTO VH_set
ON KEY 9 LABEL "CANCEL $ GOTO Can
GOTO Spin
Set: 1
OFF KEY 1
Meas_flag(1,1) = 1
GOTO Spin
Set: 1
OFF KEY 2
Meas_flag(1,2) = 1
GOTO Spin
Set: 1
OFF KEY 5
Vv set:
OFF KEY 5
Meas_flag(2,1) = 1
3560 GOTO Spin
3570 Nh set: !
3580 "OFF KEY 6
3590 Mess_flag(2,2)=1
3600 GOTO Spin
3610 Rv set: !
3620 "OFF KEY 7
3630 Mess_flag(2,3)=1
3640 GOTO Spin
3650 Vh set: !
3660 "OFF KEY 8
3670 Mess_flag(2,4)=1
3680 GOTO Spin
3690 Can: !
3700 OFF KEY
3710 MAT Mess_flag= Mess_flag_old
3720 GOTO Menu
3730 Store: !
3740 OFF KEY
3750 GOTO Menu
3760 !-----------------------------------------------
3770 Angle: !
3780 KEY
3790 INPUT "ENTER MEASUREMENT ANGLE",Angle
3800 Angle=VAL(ANS(Angle)$CHR$(179)) * 1degree sign
3810 GOTO Menu
3820 !-----------------------------------------------
3830 Target: !
3840 KEY
3850 INPUT "ENTER TARGET TYPE",Target$
3860 Target=TRIMS(Target$)
3870 Target=Target$R$RSTS$" *, 3O-LEN(Target$))
3880 GOTO Menu
3890 !-----------------------------------------------
3900 Comment print: !
3910 OFF KEY
3920 Comments
3930 GOTO Menu
3940 !-----------------------------------------------
3950 Quit: !
3960 OFF KEY
3970 Clear curr
3980 Ends"$W*$
3990 GOTO Sub_end
4000 !-----------------------------------------------
4010 Parameters: !
4020 OFF KEY
4030 Clear curr
4040 PRINT
4050 PRINT
4060 PRINT ! "PARAMETER CURRENT VALUE"
4070 PRINT ! "# OF TRACES/SET "Ntrace
4080 PRINT ! "# OF POINTS "Npts
4090 PRINT ! "VOLNE BINT Size (meters) "Bin_rng(1),Bin_rng(2),Bin_rng(3)
4100 PRINT ! "OUTPUT TYPE "Out_types
4110 PRINT ! "SOUND "Sound$"Debug$"
4120 PRINT ! "ON KEY 0 LABEL "OF TRACES "GOTO Trace
4130 PRINT ! "ON KEY 1 LABEL "OF POINTS "GOTO Points
4140 PRINT ! "ON KEY 2 LABEL "BIN SIZE "GOTO Bin_rng set
4150 PRINT ! "ON KEY 3 LABEL "OUTPUT TYPE "GOTO Output set
4160 PRINT ! "ON KEY 4 LABEL "SOUND "GOTO Sound set
4170 PRINT ! "ON KEY 5 LABEL "DEBUG MODE "GOTO Debug set
4180 PRINT ! "ON KEY 6 LABEL "MAIN MENU "GOTO Menu_Clear
4190 PRINT
4200 Trace: !
4210 GOTO Spin
4220 OFF KEY
4230 INPUT "INPUT THE # OF TRACES DESIRED (integer)",Ntrace
4240 GOTO Parameters
4250 Points: !
4260 OFF KEY
4270 INPUT "INPUT THE # OF SAMPLE POINTS DESIRED (integer 51,101,201,401)",Npts
4280 GOTO Parameters
4290 Bin_rng set: !
4300 OFF KEY
4310 INPUT "ENTER THE DESIRED BIN SIZE (ONE-WAY IN METERS)",Bin_rng(1)
4320 GOTO Parameters
4330 Bin_rng c: !
4340 OFF KEY
4350 INPUT "ENTER THE DESIRED BIN SIZE (ONE-WAY IN METERS)",Bin_rng(2)
GOTO Parameters
4440 Bin_rng x!
4440 GOTO Parameters
4450 OFF KEY
4450 ON KEY 0 LABEL " PRINT " GOTO out_pr
4450 ON KEY 1 LABEL " DISC " GOTO out_d
4450 ON KEY 2 LABEL " PRINT/DISC " GOTO out_pr_d
4450 GOTO Spin
4450 Out_pr: !
4450 OFF KEY
4450 Out_types="PRINT"
4450 GOTO Parameters
4450 Out_d:
4450 OFF KEY
4450 Out_types="DISC"
4450 GOTO Parameters
4450 Out_pr_d:
4450 OFF KEY
4450 Out_types="PRINT/DISC"
4450 GOTO Parameters
4460 Sound set:!
4460 OFF KEY
4460 IF Sounds="ON" THEN
4460 Sounds="OFF"
4460 Bell="*"
4460 ELSE
4460 Sounds="ON"
4460 Bell="**"
4460 END IF
4460 GOTO Parameters
4470 Debug set:!
4470 OFF KEY
4470 IF Debugs="ON" THEN
4470 Debugs="OFF"
4470 OUTPUT $Nwa:"DEBUOFF"
4470 ELSE
4470 Debugs="ON"
4470 OUTPUT $Nwa:"DEBUON"
4470 END IF
4470 GOTO Parameters
4470 !---------------------------------------------------------------------
4480 Calibrate: !
4480 OFF KEY
4490 MAX Cal_flag_old= Cal_flag
4490 MAX Cal_flag= (0)
4490 ON KEY 0 LABEL " L BAND " GOTO Cal l
4490 ON KEY 1 LABEL " C BAND " GOTO Cal_c
4490 ON KEY 2 LABEL " X BAND " GOTO Cal_x
4490 ON KEY 4 LABEL " BEGIN FULL CAL " GOTO Begin_cal
4490 ON KEY 5 LABEL " VV " GOTO Cal_vv
4490 ON KEY 6 LABEL " VH " GOTO Cal_vh
4490 ON KEY 7 LABEL " HV+VH " GOTO Cal_cross
4490 ON KEY 9 LABEL " CANCEL " GOTO Cancel
4500 GOTO Spin
4500 Cal l: !
4500 OFF KEY 0
4500 Cal_flag(1,1)=1
4500 GOTO Spin
4500 Cal c: !
4500 OFF KEY 1
4500 Cal_flag(1,2)=1
4500 GOTO Spin
4500 Cal x: !
4500 OFF KEY 2
4500 Cal_flag(1,3)=1
4500 GOTO Spin
4500 Cal_vv: !
4500 OFF KEY 5
4500 Cal_flag(2,1)=1
4500 GOTO Spin
4500 Cal hh: !
4500 OFF KEY 6
4500 Cal_flag(2,2)=1
4500 GOTO Spin
4500 Cal_cross: !
4500 OFF KEY 7
4500 Cal_flag(2,3)=1
4500 GOTO Spin
4500 GOTO Spin
4500 Begin cal: !
4500 OFF KEY
4500 Clear.crt
4500 Cal(Cal_flag(*),Npts)
4500 GOTO Menu_clear
4500 Cancel: !
OFF KEY
MAT Cal_flag = Cal_flag_old
GOTO Menu

Mode 1
OFF KEY
ON KEY 0 LABEL = POINT "GOTO Point"
ON KEY 1 LABEL = SURFACE "GOTO Surface"
ON KEY 2 LABEL = VOLUME "GOTO Volume"
ON KEY 3 LABEL = MATRIX "GOTO Matrix"
GOTO Spin
Point 1
OFF KEY
Mode = "POINT"
GOTO Menu
Surface 1
OFF KEY
Mode = "SURFACE"
GOTO Menu
Volume 1
OFF KEY
Mode = "VOLUME"
GOTO Menu
Matrix 1
OFF KEY
Mode = "MATRIX"
GOTO Menu
Display:
OFF KEY
Clear cbr
F_disp_old = F_disp
Fdisp_old = Fdisp
Fdisp = 0
ON KEY 0 LABEL = L "GOTO L_disp"
ON KEY 1 LABEL = C "GOTO C_disp"
ON KEY 2 LABEL = X "GOTO X_disp"
ON KEY 3 LABEL = DISPLAY "GOTO Display"
ON KEY 5 LABEL = D "GOTO Vv_disp"
ON KEY 6 LABEL = H "GOTO H_disp"
ON KEY 7 LABEL = V "GOTO Hv_disp"
ON KEY 8 LABEL = S "GOTO In_disp"
ON KEY 9 LABEL = CANCEL "GOTO Cab_disp"
GOTO Spin
L_disp:
IF F_disp = 0 THEN F_disp = 1
IF F_disp > 1 THEN GOTO Mess disp
OFF KEY 0
GOTO Spin
C_disp:
IF F_disp = 0 THEN F_disp = 2
IF F_disp = 2 THEN GOTO Mess disp
OFF KEY 1
GOTO Spin
X_disp:
IF F_disp = 0 THEN F_disp = 3
IF F_disp = 3 THEN GOTO Mess disp
OFF KEY 2
GOTO Spin
Vv_disp:
IF F_disp = 0 THEN P_disp = 1
IF F_disp = 1 THEN GOTO Mess disp
OFF KEY 3
GOTO Spin
H_disp:
IF F_disp = 0 THEN P_disp = 2
IF F_disp = 2 THEN GOTO Mess disp
OFF KEY 4
GOTO Spin
Hv_disp:
IF F_disp = 0 THEN P_disp = 3
IF F_disp = 3 THEN GOTO Mess disp
OFF KEY 5
GOTO Spin
Disp:
IF F_disp = 0 OR P_disp = 0 THEN
DISP "YOU MUST SET BOTH A FREQUENCY AND A POLARIZATION TO DISPLAY"
GOTO Spin
END IF
OFF KEY
Disp "WORKING"
OUTPUT $nw="USEPASC"
CALL Freq.set(F_disp)
OUT PUT $Nw,""TIMETRANON; LOGM; GTAOFF; CONT"
IF debug="OFF" THEN
OUT PUT $Nw,""DEBUGOFF"
OUT PUT $Nw,""TITL ""Freq$(F_disp)" BAND ""Pol$(F_disp)" **
ELSE
OUT PUT $Nw,""DEBUGON"
ENDIF
CALL Freq_sw(F_disp)
CALL Pol_sw(F_disp)
DISP **
GOTO Menu
Can disp:
OFF KEY
F disp=F disp_old
F disp=F disp_old
DSP **
GOTO Menu
Mess disp:
DISP **
ONLY ONE FREQ./POL. CAN BE DISPLAYED AT ONCE."
GOTO spin
---------
BEGIN
OFF KEY
Clear crt
Sub end: }
Messages="**
SUB Clear crt
OUTPUT KBD;CHR$(255)4CHR$(75);
SUBEND
---------
SUB Date_string(Brief_date$,Realtime)
This subroutine converts the time/date as produced by the computer
to a 10-digit number YYYYMMDDHHMM used for various purposes.

INTEGER Month
Realdate$=DATE$(Realtime)
Brief_date$=Realdate$[10,11]
CASE "Jan"
Month=1
CASE "Feb"
Month=2
CASE "Mar"
Month=3
CASE "Apr"
Month=4
CASE "May"
Month=5
CASE "Jun"
Month=6
CASE "Jul"
Month=7
CASE "Aug"
Month=8
CASE "Sep"
Month=9
CASE "Oct"
Month=10
CASE "Nov"
Month=11
CASE "Dec"
Month=12
END SELECT
Month$=VAL$(Month)
IF LEN(Brief_date$)=1 THEN Brief_date$="0"4Brief_date$
Day$=VAL$(Brief_date$[1,2])
IF LEN(Day$)=1 THEN Day$="0"4Day$
Brief_date$=Brief_date$4Month$4Day$
Realtime$=TIME$(Realtime)
Brief_d ate$=Brief_date$4Realtime$[1,2]4Realtime$[4,5]
SUBEND
---------
GOTO_set(Gate_cen t,Gate_span,Angle,Range,Height,Beam,INTEGER F)
CASE "*"
This subroutine sets the time gate and returns the range distance.

SUB Set/Paths/ $Nw,$Nw data,$Npib,$Relay
COM/Constants/ Val,Zeros()
COM/Sys$1/Freq$(*)4Freq_cen t(*)4Freq_span(*)
COM/Sys$5/Target$,Versi ons$,Mode$,Out_types$,Sound$,Bell$,Debug$
G a te_cen t=1,50E-7
Gate_span=2,00E-8
OUT PUT $Nw,""TIMETRANON; LOGM;"
OUT PUT $Nw,""GATE0H""GATECENT "$VAL$(Gate_cent)" $;GATESPAN "$VAL$(Gate span)" $;GATECENT"
7080 OUTPUT $Wn;"OPC1;WAIT"
7090 ENTER $Wn;Reply
7100 LOCAL 716
7110 DISP "SET CENTER OF TIME GATE WITH KNOB OR KEYPAD <CONTINUE>";Bells
7120 PAUSE
7130 REMOTE 716
7140 DISP "WORKING"
7150 OUTPUT $Wn;"OUTPACTI;*
7160 ENTER $Wn;Gate_cent
7170 :1
7180 OUTPUT $Wn;"MARKI";Gate_cent
7190 LOCAL 716
7200 DISP "FIND RANGE WITH MARKER"
7210 PAUSE
7220 REMOTE 716
7230 OUTPUT $Wn;"OUTPACTI;*
7240 ENTER $Wn;Range
7250 Range=Range-0(0);Vel/2.0
7260 Height=Range*COS(Angle)
7270 Gate_span=2*(Height/Vel)*((1/COS(Angle)+Beam/2)-1/COS(Angle-Beam/2))
7280 Test=2.5*(1.92/Freq_span(F));1.299
7290 IF Gate_span<Test THEN Gate_span=Test
7300 OUTPUT $Wn;"GATESPAN"*VAL$;"Gate_span"" S"
7310 OUTPUT $Wn;"GATESPAN"
7320 OUTPUT $Wn;"OPC1;WAIT"
7330 ENTER $Wn;Reply
7340 LOCAL 716
7350 DISP "MODIFY GATE SPAN IF DESIRED <CONTINUE>";Bells
7360 PAUSE
7370 REMOTE 716
7380 DISP "WORKING"
7390 OUTPUT $Wn;"OUTPACTI;*
7400 ENTER $Wn;Gate_span
7410 IF Gate_span<0 THEN Gate_span=Gate_span
7420 OUTPUT $Wn;"GATESPAN"*VAL$;"Gate_span"" S"
7430 SUBEND : Gate set
7440 !*****************************************************************************
7450 SUB Cal(INTEGER Cal_flag(*),Npts)
7460 : This subroutine calibrates all frequencies and polarizations which
7470 : were selected from main menu after pressing the CALIBRATE softkey
7480 : (as recorded in the Cal_flag matrix).
7490 OPTION BASE 1
7500 COM /Patha/ $Wn,$Wn data,$Hpib,$Relay
7510 COM /Constants/ Vel,Zero(*)
7520 PAUSE
7530 SYs_1.Freq(*),Freq_cent(*),Freq_span(*)
7540 SYs_1.INT ENT F_disp,F disp
7550 SYs_1.4,Drive_dis,Drive dis,Drive cs,INT ENT preamble,By tes
7560 SYs_5.TARGET5,Version5,Mode,Ext types,Sound,bell,Debug$9
7570 SYs_1.Cal keep(*),Rcal(*),DONE cal(*)
7580 INTEGER F,K
7590 ALLOCATE COMPLEX Room(3,4,Npts),Referr(3,4,Npts),Room_ref,Room_ref(3,4,Npts)
7600 ALLOCATE Amp(Npts),Phase(Npts),Freq(Npts)
7610 ALLOCATE COMPLEX Sp(Npts),Kwv(Npts),Khv(Npts),Kw(Npts),Khv(Npts)
7620 ALLOCATE COMPLEX Ko(Npts),Kc(Npts),Kn(Npts),Kd(Npts)
7630 TO-TIME DATE
7640 Preamble=0025
7650 By tes-Npts=16
7660 MAT Referr= (COMPLEX(0,0))
7670 MAT Room_ref= (COMPLEX(0,0))
7680 MAT Room= (COMPLEX(0,0))
7690 : Begin stepping through frequency and polarization for
7700 : calibration.
7710 : FOR F=1 TO 3
7720 IF Cal_flag(1,F)=0 THEN 7910
7730 CALL Freq_set(F)
7740 CALL Freq_sw(F)
7750 CALL Pol sw(F,1)
7760 OUTPUT $Wn;"TDMANON;STAR 100 NS;STOP 400 NS"
7770 DISP "POSITION REFERENCE TARGET FOR "Freq(F)" BAND <CONTINUE>";Bells
7780 PAUSE
7790 DISP "WORKING"
7800 CALL Measure_cal(Room_ref(*),Cal_flag(*),Npts,F,"ROOM_REF")
7810 : Measure background
7820 : DISP "REMOVE REFERENCE TARGET (DO NOT REMOVE MOUNT!) <CONTINUE>";Bells
7830 PAUSE
7840 DISP "WORKING"
7850 CALL Measure_cal(Room(*),Cal_flag(*),Npts,F,"ROOM"
7860 NEXT F
7870 MAT Referr= Room_ref
7880 MAT Room_ref= Room
7890 : JUGGLE ARRAYS AND STORE CALIBRATION.
FOR F=1 TO 3
    IF Cal_flag(L,F)=0 THEN 8460
    DISP "ENTER CALIBRATION TARGET TYPE (SPH,SPH2) FOR ";Freq$(F);"=BAND;
    INPUT file refs

    Move file to RAM cache
    COPY FNPfileloc$$(File_ref,F,*/"LCK/SphTheor";) TO File_ref$4;Drive_c$;FORMAT OFF
    ASSIGN $Datafile TO File_ref$4;Drive_c$;FORMAT OFF
    ENTER $Datafile;1;File_ref,F,T;Bytes,Preamble,Npts
    ENTER $Datafile;Freq$(F),Ampl$(F),Phase$(F)
    ASSIGN $Datafile TO *

    Convert Theoretical Sphere Data to Real & Imaginary

    FOR K=1 TO Npts
        Sph re=Amp$(K) COS(Phase$(K))
        Sph im=Amp$(K) S IN(Phase$(K))
        Sph$(K)=CMP LX(Sph re,Sph im)
    NEXT K

    Calculating Calibration Constants

    FOR P=1 TO 3
        IF Cal_flag(L,P)=0 THEN 8320
        MAT RC= Refe[2,P,*]
        IF P=1 THEN MAT Kvr= Sph/Nc
        IF P=2 THEN MAT Kkh= Sph/Nc
        IF P=3 THEN
            MAT K= Refe[F,4,*]
        FOR K=1 TO Npts
            Km(K)=SORT(Kvr(K) Kkh(K))
            Kd(K)=SORT(Kc(K) Kc(K))
        NEXT K
        MAT Kvh= Km/Kd
    END IF

    END P

    Realtime=TIMEDATE

    Storing Calibration Constants

    CALL Date string(Cal_keep$(F),Realtime)
    Cal_keep$(F)=Freq$(F)Cal keep$(F)[2,10]
    Bytes per rec=256+(4*16*NCt)

    CREATE BDAT FNPfileloc$(Cal_keep$(F),"LCK/CAL";Drive_a$),1,Bytes_per_rec
    ASSIGN $Keep TO FNPfileloc$(Cal_keep$(F),"LCK/CAL";Drive_a$)
    OUTPUT $Keep,Cal keep$(F),Npts,RCal(F)
    OUTPUT $Keep,Kvr$(K),Kkh$(K),Kvr$(K)
    ASSIGN $Keep TO *
    Donecal(F)=1

    NEXT F

    CALL Freq_sw(F disp)
    CALL Pol_sw(F disp,P disp)
    Time=TIME DATE
    T= (T1-T0)/60
    DISP "CALIBRATION TOOK ";DROUND(T,5);" MINUTES"
    WAIT 5

    SUBEND Cal

    IF file refs

    SUB Measure call (COMPLEX Array(*), INTEGER Flag(*), Npts,F,Title$(F))

    This subroutine measures the call target and background.

    It is called from Cal subroutine.

    OPTION BASE 1
    COM /Path$: <Nwa>, <Nwa data>, <Pb1>, <Relay>
    COM /Sys 1/ : Freq$(F), Freq scan $(F), Freq span$(F)
    COM /Sys2/ : Pol$(F), Polw$(F)
    COM /Cal1/ Cal keep$(F), RCal$(F), Donecal$(F)
    INTEGER F

    ALLOCATE COMPLEX Dummy(Npts)

    FOR P=1 TO 4
        IF Flag(L,P)=0 THEN 8870
        CALL Pol_sw(F,P)
        IF Title$(F)="YOM REF" THEN
            Do the co-poles first
        IF P=3 THEN
            DISP "POSITION CROSS-POL TARGET FOR ";Freq$(F);" BAND <CONTINUE>";Bells
            PAUSE
        END IF
        CALL Gate set(Gate cent$(F,P),Gate span$(F,P),Angle$(F),Range$(F),Height$(F),Beam$(F),F)
        RCal(F)=Range(F)
        PRINT "Range=", RCal(F)
        OUTPUT Nwa," TIME OFF:";
        WAIT;
        END IF
        OUTPUT Nwa," DECA4VALS(F1)="; WAIT;
        OUTPUT Nwa,"POL2 AUTO: AVERFACT 17;"
        OUTPUT Nwa,"AVE ROON; NIMG 17;"
CALL Get_form3(Dummy(*),Npts,F)
MAT Arrs(F,P,"="Dummy
OUTPUT $Nw="AVEROFF; LOGM; TIMEDTRANON; WAIT; CONT"
NEXT P
SUBEND Measure cal

CALL Point_target

OPTION BASE 1
COM /Paths/ $Nwa,$Nwa_data,$Nplb,$Relay
COM /Constants/ Vel,2Rho(*)
COM /Sys_1/ Freq(*),Freq_cent(*),Freq_span(*)
COM /Sys_2/ PolS(*),Polsw(*)
COM /Sys_3/ INTEGER_Pdisp,Fdisp
COM /Sys_4/ Drive_s5,Drive_RB,Drive_c5,INTEGER F_preamble,Bytes
COM /Sys_5/ TargetS,VarialefS,ModeS,Out_typeS,SoundS,BellS,DebugS
COM /Sys_6/ Angle,AngleS,Bin_roq(*),Beam(*),INTEGER Npts,Ntrace
COM /Sys_7/ INTEGER Cal_flag(*),Meas flag(*)
COM /Cal7 Cal keeps(*),Rcal(*),DoneCal(*)
DIM OutZlis(10)
INTEGER F,P,K,Fig

ALLOCATE memory space.

ALLOCATE COMPLEX Room(3,4,Npts),Refer(3,4,Npts),Room ref(3,4,Npts)
ALLOCATE COMPLEX Rcal(3,4,Npts),Subcal(Npts),Dummy(Npts)
ALLOCATE COMPLEX Data(3,4,Npts)
ALLOCATE Magdata(3,4,Npts),Phasedata(3,4,Npts)
ALLOCATE Range(3)
ALLOCATE Gate cent(3),Gate_span(3)
ALLOCATE Tlm(3,4)
MAT Refer= (CMPLX(0,0))
MAT Room ref= (CMPLX(0,0))
MAT Room= (CMPLX(0,0))
CALL Load cal(Rcal(*),Fig)
IF Fig=1 THEN SUBEXIT

BEGIN target measurement (step thru frequency & polarization).
FOR P=1 TO 3
IF Meas_flag(1,F)=0 THEN 11450
CALL Freq set(F)
CALL Freq sw(F)
Fig=0
FOR P=1 TO 4
IF Meas_flag(2,P)=0 THEN 11250
CALL Pol_sw(F,P)
IF Fig=0 THEN
  DISP "POSITION TEST TARGET FOR "$Freq(F)" BAND <CONTINUE>";BellS
  PAUSE
END IF
CALL Gate set(Gate cent(F),Gate_span(F),Angle,Range(F),Height,Beam(F),F)
Rcal(F)=Range(F)
PRINT "Range",Rcal(F)
OUTPUT $Nwa=" TIMEDTRANOFF;"
OUTPUT $Nwa="$SAV"; "AVERTARGET;"
OUTPUT $Nwa="$POLA; AUTO; AVERAGE 17;"
OUTPUT $Nwa="$AVER"; N Marg 17;"
CALL Get_form3(Dummy(*),Npts,F)
MAT Room ref(F,P,"="Dummy
Fig=1
OUTPUT $Nwa="AVEROFF; LOGM; TIMEDTRANON; WAIT; CONT"
NEXT P

FOR P=1 TO 4
IF Meas_flag(2,P)=0 THEN 11440
CALL Pol_sw(F,P)
IF Fig=0 THEN
  DISP "REMOVE TEST TARGET (DO NOT REMOVE MOUNT!) <CONTINUE>";BellS
  PAUSE
END IF
OUTPUT $Nwa="$RECA="AVALS(F)"; WAIT;"
OUTPUT $Nwa="$POLA; AUTO; AVERAGE 17;"
OUTPUT $Nwa="$AVER"; N Marg 17;"
CALL Get_form3(Dummy(*),Npts,F)
MAT Room(F,P,"="Dummy
Fig=1
OUTPUT $Nwa="AVEROFF; LOGM; TIMEDTRANON; WAIT; CONT"
NEXT P

BACKGROUND measurement
FOR P=1 TO 4
IF Meas_flag(2,P)=0 THEN 11440
CALL Pol_sw(F,P)
IF Fig=0 THEN
  DISP "REMOVE TEST TARGET (DO NOT REMOVE MOUNT!) <CONTINUE>"; BellS
  PAUSE
END IF
OUTPUT $Nwa="$RECA="AVALS(F)"; WAIT;"
OUTPUT $Nwa="$POLA; AUTO; AVERAGE 17;"
OUTPUT $Nwa="$AVER"; N Marg 17;"
CALL Get_form3(Dummy(*),Npts,F)
MAT Room(F,P,"="Dummy
Fig=1
OUTPUT $Nwa="AVEROFF; LOGM; TIMEDTRANON; WAIT; CONT"
NEXT P

BACKGROUND measurement
Data correction

Magdata is in voltage

MAT Ref= Room_ref
MAT Room_ref= RSum
MAT Data= Real_ref.Refer
MAT Data= Real
MAT Magdata= ABS(Data)
MAT Phasedata= ARG(Data)

Realtime=TMEDATE

CALL Data_string(Outfile, Realtime)

CALL Catalog(Outfile, Modes, Target$, Angle)

Write output to printer if this output type is set.

IF TRIM$(Out_types)$= "PRINT" OR TRIM$(Out_types)$= "PRINT/DISC" THEN
PRINT VERSION: "; Version$; 
# OF POINTS = "; Npts
PRINT
PRINT
PRINT TAB(4); "FREQ$"; TAB(12); "GATE_CENT$"; TAB(25); "GATE_SPAN$";
PRINT TAB(36); "R_CAL$"; TAB(47); "RANGE$"; TAB(56); "CAL_FILE$"
PRINT
FOR F=1 TO 3
IF Meas_flag(1,F)>0 THEN 11750
PRINT TAB(6); Freq$(F); TAB(12); DROUND(Gate_cen$(F),5); TAB(25); DROUND(Gate_span$(F),5);
PRINT TAB(33); DROUND(Ral$(F),4); TAB(46); DROUND(Range$(F),4);
PRINT TAB(45); Cal_kee$(F)
NEXT F
PRINT
PRINT
PRINT TAB(4); Freq$(F); TAB(11); Pol$(F); TAB(20); Magnitude$(F); TAB(34); Phase$
PRINT
FOR F=1 TO 3
IF Meas_flag(F,1)>0 THEN 11960
FOR P=1 TO 4
IF Meas_flag(2,P)>0 THEN 11940
FOR K=1 TO 3
PRINT TAB(4); Freq$(F); beq$(F); TAB(11); Pol$(F); TAB(19);
PRINT DROUND(Magdata(F,P,1,1),5);
PRINT TAB(4); Freq$(F); miz$(F); TAB(11); Pol$(F); TAB(19);
PRINT DROUND(Magdata(F,P,Npts-1/2,5); TAB(30); DROUND(Phasedata(F,P,Npts-1/2,5),5)
NEXT K
NEXT F
NEXT P
PRINT
NEXT F
PRINT
IF Printer is CRT THEN END IF

Create an output filename based on the current date and time.

Then output important processing parameters and sigma zero data.

IF TRIM$(Out_types)$= "DISC" OR TRIM$(Out_types)$= "PRINT/DISC" THEN

Bytes per Rec=64*(10+12+7+30+3*1+*4+*8+2*2+5+7+5)+(*8)+Npts*2*8

CREATE DOUT FNFil$ou$(Outfile$, "LOCK\DATA\Drive a\1. Bytes per rec

ASSIGN DOUT TO FNFil$ou$(Outfile$, "\LOCK\DATA\Drive a\1.

OUTPUT #Disc; Outfile$, Version$, Modes$, Target$, Cal_kee$(F), Angle, Range$(F), Meas_flag$(F)

OUTPUT #Disc; Gate_cen$(F), Gate_span$(F), Npts, Ntrc$

OUTPUT #Disc; Magdata$(F), Phasedata$(F)

ASSIGN #Disc TO *

END IF

Place radar in default mode.

CALL Freq_sw(FDisp)

CALL Pol_bw(FDisp, PDisp)

SUBEND | Point Target

*******************************************************************************

Subroutine treats all targets as surfaces.

It averages the sigma-zero and std dev of it.

It averages each frequency trace and then averages over Nrace traces.

OPTION BASE 1

COM /Paths/ $Nwe,$Nwe_data,$Hplb,$Relay

COM /Constants/ Val,$zero$(*)

COM /sys$1/ Freq$(*) Freq_cen$(*)

COM /sys$2/ Pol$(*) Polsw$(*)

COM /sys$3/ INTEGER P_disp, P Disp

COM /sys$4/ Drive a$ Drive BS, Drive CS, INTEGER Preamble, Bytes

COM /sys$5/ Target$ Version$, Modes$, Out_types$, Sound$, Bell$, Debug$

COM /sys$6/ Angle, Angies$, Bin_rog$(*) Beam$(*) INTEGER Npts, Nrace
COM /Sys/ 7/ INTEGER Cal_flag(*), Mes_flag(*)
COM /CfCal Keep$(*) , Rcal$(*) , DoneCal$(*)
DIM OutilS$(10)
INTEGER P,F,K,Flg, SkyFlg

ALLOCATE Complex Sky(3,4, Npts), Subsky(Npts), DataL(Npts)
ALLOCATE Complex Kcal(3,4,Npts), SubKcal(Npts), Dummy4(Npts)
ALLOCATE Pwr_mag(Ntrace, Dummy5(Npts), Dummy6(Npts)
ALLOCATE Sig_zro(3,4), Sig_zro_sd(3,4)
ALLOCATE Range(3)
ALLOCATE Gate_cent(3), Gate_span(3)
ALLOCATE Tim(3,4)
MAT Sky= (CMPLX(0,0))
SkyFlg=0

CALL Load_cal(Kcal$(*) , Flg)
IF Flg=1 THEN SUBEXIT
CALL Angle_set(Angle)
IF FNAME("DO SKY MEASUREMENT") THEN
FOR P=1 TO 3
CALL Freq_set(F)
CALL Freq_sw(F)
CALL Pol_sw(1,1)
CALL Gate_set(Gate_cent(F), Gate_span(F), Angle, Range(F), Height, Beam(F), F)
OUTPUT $Nwa; "GATECENT *=VALUES(Gate_cent(F))" $;
OUTPUT $Nwa; "GATESPAN *=VALUES(Gate_span(F))" $;
CALL Measure_sky(Sky$(*) , Mes_flag$(*) , Npts , F)
SkyFlg=1
NEXT F
END IF

FOR P=1 TO 3
IF Mes_flag(1,F)=0 THEN 13350
CALL Freq_set(F)
CALL Freq_sw(F)
IF SkyFlg=0 THEN
CALL Gate_set(Gate_cent(F), Gate_span(F), Angle, Range(F), Height, Beam(F), F)
END IF
OUTPUT $Nwa; "GATECENT *=VALUES(Gate_cent(F))" $;
OUTPUT $Nwa; "GATESPAN *=VALUES(Gate_span(F))" $;
OUTPUT $Nwa; "POLE;ENTO:"; Polar form for Re/Im pairs.
OUTPUT $Nwa; "AUTO;OPTC;WAIT"
OUTPUT $Nwa; "Reply"
OUTPUT $Nwa; "END"
END IF
FOR P=1 TO 4
IF Mes_flag(2,P)=0 THEN 13330
MAT Subsky= Sky(F,P)
MAT SubKcal= Kcal(F,P)
CALL Pol_sw(F,P)
DISP "READY FOR MEASUREMENT <CONTINUE>"; Bells
PAUSE
DISP "WORKING"
TIm(F,P)=TImDATE
time of measurement.
DISP number of traces remaining in this set.
PRINT TABXY(1,5);"Traces remaining = "
FOR K=1 TO Ntrace:
LOOP through Ntrace traces
GET a trace, consisting of Npts complex values, from the
HP753 using form3. Poin1 can be used, if faster data
transfer is required.
CALL Get_form(Dummy$(*) , Npts , F)
MAT Detail= Dummy-Subsky
MAT Dummy= DataL SubKcal
MAT Dummy5= ABS(Dummy)
MAT Dummy6= Dummy5 . Dummy5
I Sum the power over Npts points and divide by Npts to get
average power.
Pwr_mag(K)=SUM(Dummy6)/Npts
WALT 2
PRINT TABKY(20,50);
PRINT USING "DDD;Ntrace=K"
NEXT K
DISP "Scale the data according to the calibration and illum integral.
Then generate stats on the sigma zero measurement.

SUM=0
SUM=SUM + Pwr_mag(K) * (PHIIL(Height, Angle, F, P) * Rcal(F)^4)
CALC the ill intg ratio
FOR K=1 TO Ntrace
; Scale each trace by the illumination integral and sum.
; Sum=sum*Pwr_mag(K)*Fx
; Also sum the squares.
; SumX=Sum*Pwr_mag(K)*Pwr_mag(K)*Fx

NEXT K
; Sigma-zero is the average scaled power.
Sig_zro(F,P)=Sum/Ntrace
; Also compute the std dev of the Ntrace values of sig_zro.
; Sig_zro_sd(F,P)=SQRT((Ntrace*SumX-Sum*Sum)/(Ntrace*(Ntrace-1)))
; Sig_zro_sd(Sig_zro(F,P))

NEXT F

OUT#rew "TIMEDATE: WAIT;"

NEXT F

Realtime=TIME&DATE
; Put current time in Realtime variable.
CALL DateTime(Outfile,Realtime)

CALL Catalog(Outf1,Mode6,Target6,Angle)

; Write output to printer if this output type is set.
IF TRIMS(Out_type$)="PRINT" OR TRIMS(Out_type$)="PRINT/DISC" THEN

PRINT
PRINT "VERSION = ";Version$;
; # OF POINTS = ";Npts;
; # OF TRACES = ";Ntrace

PRINT
PRINT
PRINT
PRINT TAB(4);"FREQ";TAB(12);"GATE CENT";TAB(25);"GATE SPAN";TAB(38);
PRINT TAB(38);"R_CAL";TAB(47);"RANGE";TAB(56);"CAL_FILE"

PRINT
PRINT FOR F=1 TO 3
IF Mass_flag(1,F)=0 THEN 13570
PRINT TAB(6);Freq(F);TAB(12);DROUND(Gate_cent(F),5);TAB(25);DROUND(Gate_span(F),5);
PRINT TAB(37);DROUND(Ron(F),4);TAB(46);DROUND(Range(F),4);
PRINT TAB(55);Cal_keepp(F)
NEXT F
PRINT
PRINT
PRINT TAB(4);"FREQ";TAB(11);"POL";TAB(20);"SIG_ZRO";TAB(34);"STD. DEV.";TAB(51);"TIME"
PRINT
PRINT FOR F=1 TO 3
IF Mass_flag(1,F)=0 THEN 13700
PRINT FOR P=1 TO 4
IF Mass_flag(2,P)=0 THEN 13860
PRINT TAB(6);Freq(F);TAB(11);Pol(F);TAB(19);DROUND(Freq(Sig_zro(F,P)),5);
PRINT TAB(33);DROUND(Sig_zro_sd(F,P),5);TAB(49);TIMES(Tim(F,P));
NEXT P
PRINT
NEXT F
PRINT
NEXT F
PRINT
PRINT
PRINT
PRINT
END IF

; Create an output filename based on the current date and time.
; File will be stored in Directory: /LIXC/DATA_
; The output important processing parameters and sigma zero data.

IF TRIMS(Out_type$)="DISC" OR TRIMS(Out_type$)="PRINT/DISC" THEN

Bytes_per_rec=64+{10+12+7+30+3+104*ES+7*ES+7+4+8*8}+{24*8}

CREATE OUT file=Outfile$(/LIXC/DATA$Outfile$)

BYTES (Outfile$)

ASSIGN #Disc TO Out_file$(/LIXC/DATA$Outfile$)

OUTPUT #Disc;Outfile$,Version$,Mode$,Target$,Cal_keepp$,Angle,Range,Mass_flag(*)

OUTPUT #Disc;Gate_cent$(F),Gate_span$(F),Npts,Ntrace

ASSIGN #Disc TO *

END IF

; Place radar in default mode.

CALL Freq_ev(F.disp)
CALL Pol_Bw(F.disp,P.disp)

SUBEND ; Surface

*****************************************************************************

SUB Volume

*****************************************************************************

OPTION BASE 1

COM /Paths/ $Mwa,$Mwa_data,$Spib,$Relay
COM /Constants/ Val,zero(*)
COM /Sys/ 1, Freq1(*), Freq_cent(*), Freq_span(*)
COM /Sys/ 2, Pol2(*), Polsw2(*)
COM /Sys/ 3, INTEGER F disp, P disp
COM /Sys/ 5, Target8,Version$,Mode$,Out_type$,Sounds,Bell3,Debug$
COM /Sys/ 6, Angle,Angles, Bin_ranq(*), SelS(*) INTEGER Npts,Ntrace
COM /Sys/ 7, INTEGER Cal_flag*, Mass_flag(*)
COM /Cal/ Cal keeps(*), Real(*), Doncal(*)
REAL Delms(3), Tim(3, 6), Start_int(3), Stop int(3)
REAL Start_time(3), Stop_time(3), No_bytes
REAL Bin_rng_old(3)
INTEGER F,F,R,L,Fig,Ichk, Istep,Nbins(3),Ibeg,end,N,Nbins_max

! Allocate memory space.

MAT Bin_rng_old= Bin_rng
ALLOCATE COMPLEX Kcalm(3,4),Kcal(3,4,Npts)
ALLOCATE COMPLEX Block(4,Npts)
ALLOCATE INTEGER Binary(Npts,0:2),Bin(Ntrace,Npts,0:2)
ALLOCATE SIGV att(3,4,Npts)
ALLOCATE SIGV att ad(3,4,Npts)
ALLOCATE SIGV Ero(3,4)
ALLOCATE SIGV zro ad(3,4)
ALLOCATE PW r_nmag(Ntrace,Npts)
ALLOCATE SUM(3,4,Npts)
ALLOCATE SUMmag(3,4,Npts)
ALLOCATE Range(3)
ALLOCATE range ax(3,4,Npts)
MAT Kcalm= (COMPLEX(0,0))
MAT SigV att = (0)
MAT SigV att ad = (0)
MAT SigV Ero = (0)
MAT SigV zro ad = (0)
MAT PW r_nmag= (0)
MAT SUM= (0)
MAT SUMmag= (0)

! Read in calibration data.
CALL Load cal(Kcal(*),Fig)
IF Fig=1 THEN SUBEXIT

! Begin measurement sequence (step thru frequency and polarization).

FOR F=1 TO 3
IF Meas_flag(1,F)=0 THEN 15460
CALL Freq sw(F)
Ichk=0
FOR F=1 TO 4
IF Meas_flag(2,P)=0 THEN 15450
CALL Pol sw(F,P)
! Average the Calibration constants.
FOR N=1 TO Npts
Kcalm(F,P)= Kcalm(F,P)+Kcal(F,P,N)
NEXT N
MAT Kcalm= Kcalm(1/Npts)
OUTPUT *#W#="MARKDISC"
! Set start and stop integration times (and other necessary
! parameters) for each new frequency.
! Prompt user for readiness.
! IF Ichk=0 THEN
! CALL Integ set(Start Int(F),Stop Int(F))
! Start Time(F)=Start Int(F)
! Delm(F)=-(Stop Int(F)-Start Time(F))/Npts-1
! Inte=ROUND(T2*Bin_rng(F)/Vel)/Delm(F),0
! Bin time=Inte*Delm(F)
! Nbins(F)=INT((Stop Int(F)-Start Int(F))/Bin time)
! Start Time(F)=Start Int(F)+Nbins(F)*Bin Time+Delm(F)
! Delm(F)=-(Stop Int(F)-Start Time(F))/Npts-1
! Inte=ROUND(T2*Bin_rng(F)/Vel)/Delm(F),0
! Bin time=Inte*Delm(F)
! Nbins(F)=INT((Stop Int(F)-Start Int(F))/Bin time)
IF Nbins(F)*Inte> Npts THEN
Stop time(F)=Stop time(F)+Bin time
! DISP "READJUSTING STOP_TIME"
GO TO Loop
END IF
STOP time(F)=Start Int(F)+Nbins(F)*Bin Time+Delm(F)
Bin_rng(F)=Bin_time*,S*Vel
Ichk=1
END IF

Output *#W#="MARKDISC"
OUTPUT *#W#="STAR *AVAL\$[Start time(F)]*4*$
OUTPUT *#W#="STOP *AVAL\$[Stop time(F)]*4*$
OUTPUT *#W#="POL/\$AUTO\$ENTO" ! Smith chart form for Re/Im pairs.
OUTPUT *#W#="GET/\$WAIT"
ENTER *#W#;Reply
! DISP "READY FOR MEASUREMENT? CONTINUE*";Bells
PAUSE
DISP "WORKING"
PAUSE
! Transfer data using the binary form1 and convert to form3.
! Integrate the power in each bin for each of the (Ntrace)
! number of traces.
! Timing(F,P)=TIME DATE  time of measurement.
FOR K=1 TO Ntrace
CALL Get_form1(Binary(*))
MAT Bin(K, *, *) = Binary
PRINT K
NEXT K
FOR K=1 TO Ntrace
MAT Bin= Bin(K, *, *)
CALL Convert(Block(*), Binary(*), Npts)
! Creating the sum & sum of the raw trace to store on disc
FOR N=1 TO Npts
Pwr=ABS(Block(N))**2
Sum(F,N,F,N)=Pwr
Sumq(F,N,F,N)=Pwr*Pwr
NEXT N
! Determining the average power of each bin
FOR L=1 TO Nbins(F)
Ibeg=L-(L-1)*istep
Iend=Ibeg+L
FOR M=Ibeg TO Iend
Pwr_mag(K,L)=Pwr_mag(K,L)+ABS(Block(M)*Kcal_m(F,P))**2
NEXT M
NEXT L
NEXT K
! Scale the data according to the calibration and illum integral.
! Then generate stats on the sigma zero (volume attenuated) for
! each range bin and the volume as a whole.
VAR tot=0
FOR L=1 TO Nbins(F)
Sum al=
Sum al=Sum al=Sum al=Sum al=Sum al=(Ntrace*Sum al/Sum al)/(Ntrace=Ntrace-1)
Sigv_att(F,P,L)=Sum al/Ntrace
Sigv_att_sd(F,P,L)=SQR(Var al)
Sig_zro(F,P,L)=Sig_zro(F,P,L)+Bin rng(F)*COS(Angle)*Sigv_att(F,P,L)
Var tot=Var tot+(Bin rng(F)*COS(Angle))**2*Var al
NEXT L
NEXT F
Sig_zro_sd(F,P,L)=SQR(Var tot)
NEXT F
REAL Time=TIME_DATE
CALL Date_string(Outils, Realtime)
CALL Catalog(Outfits, Mode, Target, Angle)
IF TRIMS(Out_type$)="PRINT" OR TRIMS(Out_type$)="PRINT/DISC" THEN
PRINT
VERSION = ";Version$;"  # OF POINTS = ";Npts;"  # OF TRACES = ";Ntrace
SPS=" 
FOR F=1 TO 3
IF Meas_flag(1,F)=0 THEN 18800
PRINT
FREQ(F)=" Band"
PRINT SPS="START TIME: ";DROUND(Start_time(F),5);" STOP TIME: ";DROUND(Stop_time(F),5)
PRINT SPS="START INT: ";DROUND(Start_int(F),5);" STOP INT: ";DROUND(Stop_int(F),5)
PRINT SPS="DELM: ";DROUND(Delm(F),5);" RCL: ";DROUND(Rcal(F),5);" BIN SIZE: ";DROUND(Bin_rng(F),5)
FOR F=1 TO 4
IF Meas_flag(2,F)=0 THEN 18790
PRINT
PRINT
PRINT Pol2(F);" POLARIZATION"
PRINT SPS=" TIME OF MEAS: ";DROUND(Time,5)
PRINT
PRINT SPS=";BIN NO.+;TAB(21);";RANGE=";TAB(41);";SIGV_ATT=";TAB(61);";STD. DEV; "
NEXT F
FOR N=1 TO Nbins(F)
PRINT TAB(7);N;TAB(20);DROUND(Range_al(F,P,N),5);TAB(34);DROUND(FNbrd(Sigv_att(F,P,N),5)
NEXT F
NEXT N
PRINT
PRINT
PRINT SPS=";SIG ZRO; ";DROUND(FNbrd(Sig_zro(F,P),5)
PRINT SPS=";STD. DEV; ";DROUND(Sig_zro_sd(F,P),5)
NEXT F
NEXT N
NEXT F
NEXT F
END IF
15830 !
CALL Angle_set(Angle)

FOR F=1 TO 3
IF Meas_flag(1,F)=0 THEN 17860
OUTPUT $nw;"GATSOFF"
OUTPUT $nw;"LOGOFF"
CALL freq_set(F)
CALL freq_sw(F)
INCH=0

| Take $race measurements of all 4 polarizations for frequency F. |
| Store individual measurements in a larger array. |

OUTPUT $nw;"OPC7:WAIT"
ENTER $nw;Reply
FOR $K=1 TO $race
OUTPUT $nw;"FORM1"
IF F=1 THEN
OUTPUT $Relay;"B56"

PAUSE
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnv(*)
OUTPUT $Relay;"A5"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnh(*)
OUTPUT $Relay;"A6"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnv(*)
OUTPUT $Relay;"B5"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnh(*)

Tim(f,K)=TME_DATE
END IF

IF F=2 THEN
OUTPUT $Relay;"B34"

PAUSE
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnv(*)
OUTPUT $Relay;"A3"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnh(*)
OUTPUT $Relay;"A4"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnv(*)
OUTPUT $Relay;"B3"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnh(*)

Tim(f,K)=TME_DATE
END IF

IF F=3 THEN
OUTPUT $Relay;"A34"

PAUSE
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnv(*)
OUTPUT $Relay;"B3"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnh(*)
OUTPUT $Relay;"B4"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnv(*)
OUTPUT $Relay;"A3"
WAIT .07
OUTPUT $nw;"SING;OUTPAM1"
ENTER $nw_data;Preamble,Bytes,Blnh(*)

Tim(f,K)=TME_DATE
END IF

MAT Binary(1,K,*) = Blnv
MAT Binary(2,K,*) = Blnh
MAT Binary(3,K,*) = Blnv
MAT Binary(4,K,*) = Blnh

PRINT K
NEXT K
| Load calibration for the specified polarization and reload |
| (only-one) the Ntrace measurements. Gate the first trace |
| and output the voltage mag & phase at the center frequency. |
| NOTE: The gate changes for each new frequency but remains the |
| same regardless of polarization for all Ntrace measurements. |

FOR F=1 TO 4
FOR K=1 TO Ntrace
MAT Dummy=Binary(F,K,*,*)
OUTPUT $Nwa;"FORM1;INPRAW1;" OUTPUT $Nwa;data=Preamble,Bytes,Dummy(*)
IF (chk=0) THEN CALL Gate_set(Gate_cent(F),Gate_span(F),Angle,Range(F),Height(F),Beam(F),F)
IGIN=1 ELSE
OUTPUT $Nwa;"GATECENT " &LABELS(Gate_cent(F))&" S"
OUTPUT $Nwa;"GATESPAN " &LABELS(Gate_span(F))&" S"
ENDIF IF (K=1) THEN OUTPUT $Nwa;"TMS3RANOFF;GATEON" OUTPUT $Nwa;"POLA:AUTO;MARK; " &LABELS(freq_center(F))&" GHz" OUTPUT $Nwa;"POLA:OUTMARK" ENTER $Nwa;Data1(F,P,K)
OUTPUT $Nwa;"OPC7;WAIT" OUTPUT $Nwa;"OPC7;WAIT" END IF
NEXT K
NEXT F

IF FNAsk("DO SKY MEASUREMENT?") THEN
FOR F=1 TO 3
FOR L=1 TO 180000
CALL Freq_set(F)
CALL Freq_sw(F)
CALL Pol_sw(F,l)
OUTPUT $Nwa;"GATECENT " &LABELS(Gate_cent(F))&" S"
OUTPUT $Nwa;"GATESPAN " &LABELS(Gate_span(F))&" S"
CALL Measure_sky(Sky(*),Meas_flag(*),Npts,F)
MAT subkey=Sky(*,*,MaidIndex) NEXT F
ENDIF

IF Meas_flag(1,F)=0 THEN 18190
IF Meas_flag(1,F)=1 THEN 18390
IF Meas_flag(1,F)=2 THEN 18250
IF Meas_flag(1,F)=3 THEN 18350
IF Meas_flag(1,F)=4 THEN 18120
IF Meas_flag(1,F)=5 THEN 18200
IF Meas_flag(1,F)=6 THEN 18330
ENDIF

IF (F=1) THEN

RETRIEVE TIMEDATE
CALL Date_string(Outfile,Realtime)
CALL Catalog(Outfile,Mode,Target,Angle)
WRITE output to printer if this output type is set.
IF TRIMs(Out_type$)="PRINT" OR TRIMs(Out_type$)="PRINT/DISC" THEN
IF Printer IS FP
PRINT
PRINT "VERSION =";Version$;" # OF POINTS =";Npts;" # OF TRACES =";Ntrace
PRINT
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PRINT
IF Meas_flag(1,F)=0 THEN 18450
18460 PRINT
18470 PRINT
18480 PRINT Fees(F);:" CANN:";TAB(12);":MAGNITUDE IS THE SQ ROOT OF SIGMA ZERO (REAL #)"
18490 PRINT TAB(12):"PHASE IS THE RELATIVE PHASE WITH RESPECT TO VV POL.";
18500 PRINT
18510 PRINT TAB(12);"MAGV":;TAB(27);"MAGH":;TAB(42);"MAGV":;TAB(57);"MAGH"
18520 PRINT
18530 FOR K=1 TO Ntrace
18540 PRINT TAB(11):DROUND(Sqsiq0(F,1,K),5);;TAB(26):DROUND(Sqsiq0(F,2,K),5);
18550 PRINT TAB(41):DROUND(Rephs(F,3,K),5);;TAB(56):DROUND(Rephs(F,4,K),5)
18560 NEXT K
18570 PRINT
18580 PRINT TAB(12);"PH_HH":;TAB(27);"PH_HV":;TAB(42);"PH_VH":;TAB(58);"TIME"
18590 PRINT
18600 PRINT
18610 FOR K=1 TO Ntrace
18620 PRINT TAB(11);DROUND(Rephs(F,2,K),5);;TAB(26):DROUND(Rephs(F,3,K),5);
18630 PRINT TAB(41):DROUND(Rephs(F,4,K),5);;TAB(56);"TIME":;TIM(F,K)
18640 NEXT K
18650 NEXT F
18660 PRINT : PRINTER IS CRT
18670 END IF
18680 : IF TRMS(Out_type$)="DISC" OR TRMS(Out_type$)="PRINT/DISC" THEN
18690 Bytes_per_Fac=64*(10+127+30+10+4*67+12+7+4)*8*15+15)*13*Ntrace*8
18700 CREATE BOAT FN$Filelooc(Outfil$);"\\ICN\DATA\Drive_a$\ICN\DATA\Drive_a$\ICN\DATA\Drive_a$\ICN\DATA\Drive_a$"
18710 ASSIGN @Disc TO Outfil$;Version$;Mode$;Target$;Cal_keep$[N];Angle$;Range$;Meas_flag$[N];
18720 OUTPUT @Disc;Outfil$;Version$;Mode$;Target$;Cal_keep$[N];Angle$;Range$;Meas_flag$[N];
18730 OUTPUT @Disc;Get_times($);Npts;Ntrace
18740 OUTPUT @Disc;TIM($);Real$[N]
18750 CALL Array_pcm(Sqsiq0(F),@Disc;Meas_flag$[N];Ntrace,0)
18760 CALL Array_pcm(Rephs(F),@Disc;Meas_flag$[N];Ntrace,1)
18770 ASSIGN @Disc TO * : END IF
18780 : IF Place radar in default mode.
18790 CALL Freq_sw(F Disp)
18800 CALL Pol_sw(P幡ap,P Disp)
18810 SUBEND : Polarimetry
18820 :*******************************************************************************
18830 SUB Measure_sky(COMPLEX Sky$[*],INTEGER Flag[*],Npts,F)
18840 : This subroutine measures sky for frequency F. It checks Flag(2,F)
18850 : to measure the corresponding polarization. It uses form3 to
transfer data and stores it in Sky$[*].
18860 :*******************************************************************************
18870 OPTION BASE 1
18880 COM /Paths/ #Nwa,#Nwa data,#Hplb,#Relay
18890 COM /sys_3 INTEGER F,Disp,P Disp
18900 COM /sys_5/ Target$,Version$,Mode$,Out_type$,Sound$,Bell$,Debug$
18910 INTEGER F
18920 ALLOCATE COMPLEX Dummyn(2,Npts)
18930 DSEP "POSITION FOR SKY MEASUREMENT <CONTINUE>;Bell$
18940 PAUSE
18950 DSEP "WORKING"
18960 OUTPUT #Nwa;"TIMKTRANON; POLA; AUTO;"
18970 FOR F=1 TO 4
18980 IF Flag(2,F)=0 THEN 19140
18990 CALL Pol_sw(F,P)
19000 OUTPUT #Nwa;"AVERFACT 17;"
19010 OUTPUT #Nwa;"AVERNO; NDM 17;"
19020 CALL Get_form3(Dummyn[*],Npts,F)
19030 MAT Sky(F,P)= Dummyn
19040 NEXT F
19050 OUTPUT #Nwa;"AVEROFF; LOGSN; TIMKTRANON; WAIT; CONT"
19060 CALL Pol_sw(F,P)
19070 SUBEND : Measure sky
19080 :*******************************************************************************
19090 SUB Integ_set($Start_int,Stop_int)
19100 : This subroutine is called by Volume to set the integration start
19110 : and stop points.
19120 :*******************************************************************************
19130 COM /Paths/ #Nwa,#Nwa data,#Hplb,#Relay
19140 COM /sys_5/ Target$,Version$,Mode$,Out_type$,Sound$,Bell$,Debug$
19150 OUTPUT #Nwa;"MAK1"
19160 LOCAL 716
19170 DSEP "SET INTEGRATION START POINT WITH KNOB OR KEY PAD <CONTINUE>;Bell$
19180 PAUSE
19190 REMOTE 716
19200 OUTPUT #Nwa;"OUTFACT1"
19210 ENTER #Nwa;Start int
LOCAL 716

DISPLAY *SET INTEGRATION STOP POINT WITH KBND OR KEY PAD <CONTINUE>*;Rels
PAGE

REMOTE 716

OUTPUT &Nwa:"OUTPACT1"

ENTER &Nwa;Stop Int

SUBEND ; Integ_set

******************************************************************************

SUB Freq_sw(INTEGER Ifreq)

; This subroutine sets the relay actuator to Ifreq frequency.

COM /Paths/ &Nwa,&Nwa_data,&Hplb,&Relay

SELECT Ifreq

CASE 1

OUTPUT &Relay:"?&A1B2"

CASE 2

OUTPUT &Relay:"?&A2B1"

CASE 3

OUTPUT &Relay:"?&B12"

END SELECT

WAIT 1

SUBEND ; Freq_sw

******************************************************************************

SUB Table_def

; This subroutine creates a look-up table used in the Convert subroutine,

which converts formt data to form3.

******************************************************************************

COM /Table/ Exp_tbl(0:255)

Exp_tbl(0)=2*[-15]

FOR i=0 TO 126

Exp_tbl(i)=2*Exp_tbl(i)

NEXT I

Exp_tbl(128)=2*[-143]

FOR i=128 TO 255

Exp_tbl(i)=2*Exp_tbl(i)

NEXT I

SUBEND

******************************************************************************

SUB Conv(COMPLEX Block(*),INTEGER Binary(*),Npts)

; This subroutine converts binary (formt) to complex base-10 numbers.

******************************************************************************

COM /Table/ Exp_tbl(*)

FOR i=1 TO Npts

Exp=Exp_tbl(BINAND(Binary(i),255))

Block(i)=Binary(i,1)*Exp*COMPLEX(1,0)+Binary(i,0)*Exp*COMPLEX(0,1)

NEXT I

SUBEND

******************************************************************************

SUB Get_form(INTEGER Binary(*))

******************************************************************************

COM /Paths/ &Nwa,&Nwa_data,&Hplb,&Relay

INTEGER preamble,Byte

preamble=9025

Bytes=Npts+6

OUTPUT &Nwa:"FORM;OUTFORM"

ENTER &Nwa_data;preamble,Bytes,Binary(*)

******************************************************************************

SUBEND

******************************************************************************

SUB Get_form3(COMPLEX Arrays(*),INTEGER Npts,1)

******************************************************************************

COM /Paths/ &Nwa,&Nwa_data,&Hplb,&Relay

INTEGER preamble,Byte

ALLOCATE COMPLEX Dummy3(Npts)

OUTPUT &Nwa:"WAIT; FORM3;GATEOFF; WAIT; OUTFORM;"()

ENTER &Nwa_data;preamble,Bytes,Dummy3(*)

SUBEND

******************************************************************************

SUBEND ; Get_form3
This subroutine loads the calibration constants into Kcal(*).
If calibration has not been done in this run, it prompts the user
to use an old calibration file. The file should be located in
directory "/LCX/CAL".

OPTION BASE 1

DIM Outfil(10)

INTEGER F,P

FOR F=1 TO 3

IF Meas_flag(1,F)>0 THEN 20610

IF DoneCal(F)=1 THEN

ASSIGN $Keep To FNFilelnloc3(Cal_Keep$,(F),"/LCX/CAL"&Drive_s$)

ENTER $Keep,Cal_Keep$(F),Npts,Rcal(F)

PRINT **FILE COMPLEX Subkcall(Npts),Subkcall2(Npts),Subkcall3(Npts),Subkcall4(Npts)

ENTER $Keep,Subkcall$(,Subkcall2$,Subkcall3$,Subkcall4$

ASSIGN $Keep To *

MAT Kcal(F,1)= Subkcall

MAT Kcal(F,2)= Subkcall2

MAT Kcal(F,3)= Subkcall3

MAT Kcal(F,4)= Subkcall4

DEALLOCATE Subkcall$(,Subkcall2$(,Subkcall3$(,Subkcall4$

ELSE

IF FNAK("USE OLD CALIBRATION FILE?",Then

INPUT "ENTER CALIBRATION FILENAME",Cal_Keep$(F)

DoneCal(F)=1

GOTO 20400

ELSE

Figs=1

SUBEXIT

END IF

END IF

NEXT F

SUBEND 'Load_cal'

******************************************************************************

Catalog(Filename$,Mode$,Target$,Angle)

******************************************************************************

SUB Array_pr(Array$(,),$Disc,Integer Meas_flag$(,),Num)

******************************************************************************

This subroutine is used by the Volume subroutine to store
Array$(),* on $Disc if corresponding Meas_flag is set.

******************************************************************************

OPTION BASE 1

INTEGER F,P,N

ALLOCATE Dummy$(Num)

FOR Fix TO 3

IF Meas_flag(1,F)>0 THEN 20980

FOR P=1 TO 4

IF Meas_flag(2,P)>0 THEN 20970

FOR N=1 TO Num

Dummy$(F)=Array$(F,P,N)

NEXT N

OUTPUT $Disc;Dummy$(*

NEXT F

SUBEND 'Array_pr'

******************************************************************************

SUB Array_prm(Array$(,),$Disc,Integer Meas_flag$(,),Num,Ph)

******************************************************************************

This subroutine is used by the Polarimetry subroutine to store
Array$(F,*,*) on $Disc if Meas_flag(1,F) is set.

IF Array$(F,*,*) contains the phase measurements (Ph=1), it does
not store Array$(F,1,*)

OPTION BASE 1
INTEGER F

ALLOCATE Dum1 (Num), Dum2 (Num), Dum3 (Num), Dum4 (Num)

FOR F=1 TO 3
 IF flag(1,F)=0 THEN Next_freq
 MAT Dum1= Array (F,1,4)
 MAT Dum2= Array (F,1,4)
 MAT Dum3= Array (F,3,4)
 MAT Dum4= Array (F,4,4)
 IF FP=0 THEN
 OUTPUT @Disc: Dum1(*)
 END IF
 OUTPUT @Disc: Dum2(*), Dum3(*), Dum4(*)
 Next freq:
 NEXT F

SUBEND | Array_prm

******

DEF FM11 (H, Ang, INTEGER F, P)
 COM / illum/ C(*)
 A=Ang*PI/180
 RAD
 I=I+2*PI (F,P,1)+(F,P,2)*H*(C(F,P,8)+1/3)*C(F,P,9)*SQR (H)
 I=I+I+2*PI (F,P,3)+(F,P,4)*H)*SQR (H)
 I=I+I+2*PI (F,P,4)+(F,P,4)*H)*SQR (H)
 I=I+I+2*PI (F,P,10)*A+2*C(F,P,11)+1/10)
 DSG
 RETURN I

FNEND | I11

*******

DEF FMDB(Number)

| This function converts a number to "decibals".
| |
| |
| |
| DB=10*LOG(Number)
| |
| |
| RETURN DB

FNEND

*******

DEF FMPhase_norm(Theta)

| This subroutine normalizes Theta to -180<Theta<180, if out of range.
| |
| WHILE ABS(Theta)>180
| |
| IF Theta>180 THEN
| |
| Theta=Theta-360
| |
| ELSE
| |
| Theta=Theta+360
| |
| END IF
| |
| END WHILE

RETURN Theta

FNEND | Phase_norm

*******

| This subroutine displays Prompts the user. If answer is "Y" it returns
| |
| |
| |
| RETURN 1
| |
| |
| RETURN 0
| |
| |
| CASE ELSE
| |
| RETURN 0
| |
| END SELECT

FNEND | Ask

*******

| This function locates ":=" in Dir$ and inserts File$ string between
| |
| |
| |
| RETURN TRIM$ (File$ & Dir$)

SUB Fileloc

| Generate Theoretical calibration files.
| |
| |
| OPTION BASE 1

COM / Sys4 / Drive_a5, Drive_b5, Drive_c5, INTEGER Preamble, Bytes
COMPLEX A,B,C,E
REAL Delta,Inc,Frequency,Radius,Val,X
REAL Fatart,Fatop,Fadls
INTEGER I,J,K,T,Nponts,Recor,Tempalte_flg

M_sphere: Conducting sphere RCS.

Clear_crt

GOSUB Get_sphere_params

SUBEXIT

M_spk: B=CMPLX(1,0)
C=CMPLX(1,0)
E=CMPLX(0,0)
T=0

LOOP
T=T+1
A=B
B=C
C=A*B*CMPLX(0,(1-2*T)/X)
E=E-CMPLX(0,T+.5)/(B+C*CMPLX(0,-T/X))
EXIT IF ABS(REAL(G))>.1.E+10
END LOOP

Am_ref(I)=ABS(S81)+2*PI*Radius

Am_ref(I)=SQRT(Amp_ref(I)) Square root of sigma for polarimetry.

DISP 20*GOT(Amp_ref(I))

Phase_ref(I)=ASD(X)

RETURN

Get_sphere_params: Gets relevant sphere parameters.

Val=2.993E+8

INPUT "Starting frequency in GHz",Fatart

INPUT "Stopping frequency in GHz",Fatop

INPUT "Number of points?",Nponts

INPUT "Sphere diameter in inches?",Radius

Radius=Radius/2

Radius=Radius/25.4/1000 Now in meters

ALLOCATE Freq_ref(Nponts),Am_ref(Nponts),Phase_ref(Nponts)

Fdelta=(Fatop-Fatart)/(Nponts-1)

I=0

DISABLE

FOR J=I+1 TO Nponts STEP 1

Frequency=Fatart+I*Fdelta

I=I+1

X=2*PI*Frequency*10^9/Val*Radius

GOSUB M_spk

Freq_ref(I)=Frequency

PRINT 1,Freq_ref(I),Am_ref(I),Phase_ref(I)

NEXT J

BUILD

ENABLE

END

NEW_FILE=1

INPUT "Store metal sphere RCS data as (eg.SPH12C).",File_refl

ALLOCATE TS(80)

LINPUT "Enter file title.",TS

Bytes_per_rec=256+3*8*N

CREATE BOAT File_refl$Drive cs.1,Bytes per rec

ASSIGN @Datafile TO File_re$Drive cs$FROMAT OFF

OUTPUT @Datafile,1,File_re$TS,Byr$#,Preamble,Nponts

OUTPUT @Datafile,Freq_ref(*) Am_ref(*),Phase_ref(*)

ASSIGN @Datafile TO

COPY File_re$Drive cs TO FNFlileloc$File_refl$* //X/Sphtheor*Drive_a$3

DELETECATE TS,Freq_ref(*),Am_ref(*),Phase_ref(*)

Clear_crt

RETURN

QUIT:SUBEXIT

SUBEND: Sphere_response

***至此结束***

SUB Set_clock

SUBEND

| This subroutine asks the user for date & time and sets the HP clock.

OPTION BASE 1

DIM Chronos$[12],Month$[12][3]

Eexec key$=CHR$(135)$&CHR$(134)$

READ Month$[*]

DATA "JAN","FEB","MAR","APR","MAY","JUN","JUL","AUG","SEP","OCT","NOV","DEC"

OUTPUT KBD$SCRATCH KEY*Eexec_key$;

Clear_crt

PRINT "Current system date:

PRINT "Current system time:

IF Chronos$=" AND DATES(TERDATE)=" 1 Mar 1900" THEN

Clear_crt

SUBEXIT
22850 END IF
22860 Year$=VAL$(1900+VAL$(Ch chrono$[1,2]))
22870 IF (VAL$(Ch chrono$[3,4])<0 OR VAL$(Ch chrono$[3,4])>12) THEN
22880 BEEP
22890 PRINT "Incorrect month value."
22900 GOTO Ask
22910 END IF
22920 Year$=Month$=VAL$(Ch chrono$[3,4])
22930 Year$=Ch chrono$[5,6]"*""tYear$5
22940 SET TIMEDATE (DATE$(Year$))
22950 IF (VAL$(Ch chrono$[7,8]))>23 THEN
22960 BEEP
22970 PRINT "Incorrect hour value."
22980 GOTO Ask
22990 END IF
23000 Days=Ch chrono$[7,8]"
23010 IF VAL$(Ch chrono$[9,10])>59 THEN
23020 BEEP
23030 PRINT "Incorrect minute value."
23040 GOTO Ask
23050 END IF
23060 Days=Days=Ch chrono$[9,10]"
23070 IF (LEN$(Ch chrono$)>10 AND LEN$(Ch chrono$)=12) THEN
23080 IF VAL$(Ch chrono$[11,12])>59 THEN
23090 BEEP
23100 PRINT "Incorrect seconds value."
23110 GOTO Ask
23120 END IF
23130 Days=Days=Ch chrono$[11,12]
23140 ELSE
23150 Days=Days="00"
23160 END IF
23170 SET TIME TIME$(Days)
23180 CLEAR_CRT
23190 SUBEXIT
23200 SUBEND | Set clock
23210 !********************************************************************************
23220 SUB Fix_error
23230 ! This is the error correction subroutine. Certain errors, such as
23240 ! a disc full error, can be fixed without stopping the program.
23250 !********************************************************************************
23260 !
23270 SELECT ERRN
23280 CASE ERR
23290 P RINTER = CRT
23300 PRINT "ERROR "; ERRN
23310 PRINT ERRMS
23320 PRINT "THE PROGRAM IS PAUSED. FIX ERROR, IF POSSIBLE, AND CONTINUE."
23330 PAUSE
23340 END SELECT
23350 SUBEND
23360 !********************************************************************************
WARNING ***

These were too long and were wrapped.
WARNING ***