AUTOMATION OF AN RCS MEASUREMENT SYSTEM AND ITS APPLICATION TO INVESTIGATE THE ELECTROMAGNETIC SCATTERING FROM SCALE MODEL AIRCRAFT CANOPIES

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AUTOMATION OF AN RCS MEASUREMENT SYSTEM
AND ITS APPLICATION TO INVESTIGATE
THE ELECTROMAGNETIC SCATTERING FROM
SCALE MODEL AIRCRAFT CANOPIES

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Preface

The purpose of this thesis was twofold. The first objective was to complete the development of the Air Force Institute of Technology (AFIT) Far-Field Radar Range with an automated and fully calibrated measurement process. The second objective was to use the range to investigate the scattering of metallic versus transparent canopies on the total Radar Cross Section (RCS) of fighter aircraft.

The first task was successfully completed, as the user can obtain calibrated and accurate RCS measurements from his or her seat in front of the Hewlett Packard computer and a copy of the AFIT RCS Measurement Software (ARMS) code, which is conveniently consolidated on one floppy disk. Investigative measurements were then taken of canopy models at the AFIT range and a similar, but more established facility at the Wright Research and Development Center. The results of the measurements simply quantify the relative level of the scattering from the cockpit/canopy area with respect to the total aircraft.

I owe many thanks to select people in completing this study. I could not have even begun this endeavor without the guidance and experience of my advisor, Capt Phil Joseph. His patience and skill in lessening the intimidation and frustration inherent in any topic dealing with electromagnetic scattering is noteworthy. I am grateful to Capt Cass Hatcher and his crew at the Air Force Orientation
Center, Defense Electronic Supply Center (DESC) for supplying me with crucial information and material for the low RCS test body. Thanks and much appreciation are also due to Dave Driscoll and Jack Tiffany of the AFIT Fabrication Shop for their design expertise and model-making prowess demonstrated in building the various models.

Finally, I would like to recognize Butch Porter and his co-workers at the Barn for their flexibility and willingness to measure my targets. Most importantly, however, I thank my wife, Kathy, for her support, patience, and understanding throughout our entire AFIT experience.

Scott A. Owers
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Abstract

The purpose of this study was twofold. The first objective was to complete the development of AFIT's Far-Field Radar Range with a fully automated measurement process. The second objective was to use the facility to investigate the scattering of metallic versus transparent aircraft canopies relative to the scattering of the total aircraft. The approach for the investigation was: first, to measure scale model aircraft to determine the effect of the RCS of the canopy/cockpit area on the RCS of the total aircraft, and second, to design and measure a test body which would isolate the canopy/cockpit area from the rest of the aircraft.

The result of the work on the first task is a software package called AFIT RCS Measurement Software (ARMS). The successful performance of the far-field range was validated by very favorable comparisons with the Wright Research and Development Center's anechoic chamber. The scale model measurements suggest at most a 5 dB difference between the scattering from the two extreme cases. The test body, however, clearly demonstrated differences up to 20 dB at certain frequencies.

This study documents the upper and lower bounds of the subject measurements in an indoor measurement range. The Air Force has expressed interest in steering the investigation to examine materials and/or canopy construction.
AUTOMATION OF AN RCS MEASUREMENT SYSTEM AND ITS APPLICATION TO INVESTIGATE THE ELECTROMAGNETIC SCATTERING FROM SCALE MODEL AIRCRAFT CANOPIES

Introduction

The Radar Cross Section (RCS) of a target has received much attention in recent years, fueled in part by the advent of stealth technology. RCS is an important parameter which describes the amount of radar energy that a target scatters back to a radar receiver. Knowledge of what causes the RCS of a target is an invaluable tool for the designer of military vehicles. Determining the RCS of even simple objects however, is a complex matter. In fact, the RCS of certain 'simple' geometries cannot be calculated by current methods. The military significance of the RCS teamed with the limitations of theory in calculating it places a great deal of importance on the measurement of a target's radar cross section. A good measurement system will not only find the total RCS of a target, but will also identify the major contributors.

To make an RCS measurement, ideally, the target must be illuminated by a plane wave. A plane wave can be approximated by placing the target at a large distance from the source, so that the spherical wavefronts transmitted by
the source are approximately planar by the time they reach the target. A measurement range that approximates a plane wave in this manner is known as a far-field, or spherical range. A rule-of-thumb for determining the minimum range separation, $R$, from source to target in a far-field range is given by

$$R \geq \frac{5D^2}{\lambda}$$

where $D$ is the crossrange extent of the target and $\lambda$ is the operating wavelength of the radar. For example, if a target is three meters wide and is to be measured at 10 GHz, the required range separation is 1.5 Km. Clearly, the measurement of large targets at operationally useful frequencies leads to large outdoor facilities, thus indoor ranges are restricted to measuring smaller targets. Outdoor facilities, however, suffer the disadvantages of external monitoring, interference from external sources, and bad weather. One study contributed as much as a 35 percent increase in operating hours for the indoor range due to the weather alone (4:383). Another method of approximating a plane wave is to use a range reflector to simulate the large range separation, $R$, in a relatively short distance. By utilizing this approach, the compact range is capable of increasing the size of targets to be measured in an indoor facility. This study will deal with an indoor far-field range.
Background

The radar cross section of a target is an indication of the amount of power in the incident field that is intercepted by the target and scattered back to the source. It is a fictitious area which can be thought of as the geometrical area required to produce the target's return if the energy intercepted by this geometric area were re-radiated isotropically. The formal definition of the RCS, \( \sigma \), is given by

\[
\sigma = \lim_{R \to \infty} 4\pi R^2 \frac{|E^s|^2}{|E^i|^2}
\]

where

- \( E^i \) = the electric field incident on the target
- \( E^s \) = the electric field scattered from the target
- \( R \) = the distance between the source and target

The definition is normalized so that it is independent of the range separation between the source and the target and the level of the incident field (6:157).

The far-field, or plane wave requirement is accounted for in the above definition by the limiting process as \( R \) approaches infinity. In an actual measurement range, tolerance standards are set for acceptable amplitude and phase variations of the wavefront. The far-field range relies on a large range separation to yield a plane wave with acceptable amplitude and phase variations.

The definition of RCS also assumes the target to be in free space, which is also an impossible condition to
perfectly duplicate in an actual measurement system. Radar returns from sources other than the target are unwanted signals and represent sources of error. With the indoor range, the unwanted returns are caused by scattering from the walls, the target support structure, the floor, and even coupling between the transmit and receive antennas. Add to these all the possible multiple interactions between these scatterers and the number of unwanted returns quickly becomes very large.

These unwanted returns can be partially removed in an indoor range by attenuation, vector subtraction, or hardware (range) gating. Applying Radar Absorbing Material (RAM) to the surfaces which are unwanted scatterers, such as the walls of the range, attenuates the undesirable energy and improves the approximation of free space. The other two techniques for improving the free space condition, vector subtraction and time gating, are indirect methods, and will be discussed later.

AFIT Far-Field Range

The heart of AFIT's RCS measurement facility is the Hewlett Packard Network Analyzer HP 8510B. This recently acquired piece of equipment measures the radar return (relative to a reference signal) and is used to control the associated hardware necessary for the RCS measurement. The range can accommodate measurements from 6 to 18 GHz, and is powered by an HP 8340B Synthesized Sweeper. The chamber is
lined with eighteen inch pyramidal absorber, and uses a conical ogive target support.

The radar cross section is a complex function of many variables, hence there are a number of ways to display it. The AFIT far-field range will be able to analyze a target's RCS in various ways. One of these, a common method known as a "pattern cut", is to rotate the target in some plane through $360^\circ$ at a fixed frequency. This measurement reveals the dependence of RCS on the aspect, or viewing angle. Another measurement which will be available is the "frequency response" of the target's RCS. This is a measurement through a range of frequencies at a fixed aspect angle, and yields both the amplitude and phase of the RCS as a function of frequency. The complex frequency domain data can be transformed to the time domain via an Inverse Fourier Transform to obtain a temporal view of the target's return. These techniques will be explained further in Chapter III.

**Problem statement**

The purpose of this thesis is twofold. The first objective is to complete the development of the AFIT far-field radar range; particularly to install the recently acquired equipment and automate the measurement process with proper calibration procedures. The chamber will then be used to investigate the effect of a metallic versus a transparent canopy on the total RCS of an aircraft.
Approach

The first task is to upgrade the instrumentation used in the AFIT chamber. This will involve writing the software necessary to fully utilize the measurement capabilities of the newly acquired network analyzer. These measurements include pattern cuts and target frequency responses. The ability to measure the amplitude and phase of the frequency response brings about the requirement to perform a complex calibration. The complex calibrated frequency response can then be used to compute the band-limited impulse response of the target (time domain view). These are all tasks which the software must accomplish. The software will also perform a vector background subtraction and implement a 'software range gate' to minimize the undesired signals.

This first task will include the software, validation tests of the system, and an assessment of system sensitivity, or noise floor.

The second task of this research is to examine the scattering from metallic versus transparent canopies. Measurements will first be made of small-scale models of fighters. These measurements will show the effect of metallic versus transparent canopies on the total aircraft RCS at a specific azimuth angle. The measured results of the scale models must be scaled in order to relate them to the full-size aircraft. For example, a 1/33 scale model
measured at 10 GHz is equivalent to the full-size aircraft measured at an effective operating frequency of .3 GHz.

Measurements will also be made on a test body which will physically isolate the cockpit/canopy effect from the aircraft. The test body, which will be discussed further in Chapter V, is intended to have a very low RCS so that the object of interest, in this case the cockpit/canopy, will be the only scatterer. In addition, the test body measurements will result in a higher effective operating frequency, since the cockpit/canopy can be as large as the entire scale model mentioned in the above example.

As mentioned earlier, in an ideal RCS measurement, a target would be in free space and would be illuminated by a perfect plane wave. One objective of the next chapter is to quantify how well the AFIT measurement range approximates these ideal conditions.
The AFIT Anechoic Chamber

This chapter describes the hardware and physical layout of the AFIT far-field RCS measurement range. Also discussed are the approximations of the conditions assumed in the definition of RCS. These conditions are that of an incident plane wave and of a target in free space. These conditions will be quantified to some extent.

Physical Layout

The RCS measurement range is part of AFIT's Advanced Technology Laboratories located in Area B at Wright-Patterson AFB. The range was built in the confines of Building 168, which presented the primary restrictions on the dimensions of the anechoic chamber. A sketch of the measurement range, shown in Figure 2-1, reveals the main features of the measurement chamber.

The most outstanding feature of the anechoic chamber is its tapered design. The chamber was constructed several years ago when such a taper was thought to suppress specular wall reflections. Measurements from Swarner (8) and calculations from Joseph (3), however, have shown that the pyramidal absorber material used to line the walls is not a specular scatterer. The question of optimum chamber design is outside the scope of this study.

The length of the room is 45 feet, while the crossrange distance varies from 16 feet at the front to 24 feet at the
rear of the chamber. The ceiling is canted upward from a height of 14 feet at the front to 26 feet at the back. The two entrances into the chamber are located on the right and left sides towards the front of the chamber. A cross-section of the measurement chamber is shown in Figure 2-2.

The center of the target mount, or pedestal, is 26.5 feet from the front wall and centered in the cross-range dimension. The pedestal is a conical ogive column made of metal and stands 7.5 feet high. Its shape and orientation with respect to the incident wave are designed to have a very low RCS while maintaining the ability to support and rotate a target.

The microwave energy is transmitted into the chamber by a pyramidal horn antenna, and the return signal is collected by an identical receiving antenna. The antennas are mounted
Figure 2-2

adjacent to one another and separated by two inches in a circular cavity on the front wall of the chamber. The antennas are centered in the cross-range dimension and are at a height of eight feet above the floor. The antennas are mounted such that the faces of the antennas extend two inches beyond the front wall of the chamber.

The walls, ceiling, and floor of the chamber (with the exception of the walk-way to the target pedestal) are lined with 18 inch pyramidal Radar Absorbing Material (RAM). A block of pyramidal absorber is shown in Figure 2-3.

This RAM is a carbon impregnated urethane foam. The 4'x 4' blocks are glued to the conducting ceiling and walls of the chamber, and placed on the tile floor of the chamber.
The RAM acts as a geometric transition from non-conducting free space to the conducting walls and ceiling. RAM is also placed to hide the base of the target support pedestal.

Pyramidal Radar Absorbing Material (RAM)
Figure 2-3 (6:252)

Hardware

The next task is to describe the instrumentation used to perform RCS measurements in the AFIT range. A schematic of the hardware set-up is provided in Figure 2-4.

Source/Amplifier. The transmitted signal for the RCS measurement is a continuous wave (CW) microwave radio frequency signal generated by the HP 8340B Synthesized Sweeper. The sweeper output is fixed at 0.0 dBm. The accuracy of the source at this output level is ±1.5 dB. The signal is passed through a directional coupler, and then sent to the HP 8349B Microwave Amplifier where the level is boosted to 24 dBm for all measurements. At this relatively
low power output level, the stability of the amplifier is rated at ±1.25 dB (2:Sec 1-11).

**Antennas.** The purpose of the antennas is to transmit the illuminating energy and receive the scattered energy. Because the source is producing a continuous signal (as opposed to a pulsed-CW system), separate transmit and receive antennas are required. The antennas used in this study cover the frequency range of 6 GHz to 18 GHz. The main lobe of the radiation pattern provides nearly uniform illumination of the target.

**Frequency Converter.** The role of the HP 8511A Frequency Converter is to convert the RF test and reference signals to IF while preserving the relative amplitude and phase of the two signals. This function is not performed perfectly; however, any frequency-dependent distortion introduced will later be eliminated in the calibration process. The frequency conversion of the RF signal is to an IF of 20 MHz which is then passed to the network analyzer for measurement.

**Network Analyzer.** The heart of the measurement system is the HP 8510B Network Analyzer (NWA). The HP 8510 is actually composed of two instruments which operate on the incoming data from the frequency converter. In the first step, the HP 85102 IF/Detector converts the 20 MHz signal to 150 KHz where the synchronous detectors determine the real and imaginary parts of the test signal relative to the
reference signal. The relative amplitude and phase data is then sent to the HP 85101 Display/Processor for data processing and conversion to one of the display formats.

The entire system can be controlled from the front panel of the network analyzer. The source, frequency converter, pedestal controller, and peripherals such as plotters can be linked to the NWA via the HP 8510 System Bus. In the
configuration used at the AFIT range, however, the measurement process is automated by a computer.

**System Controller.** The measurement procedure is directed by the HP 9000 Series 236 Computer. The computer controls the entire system either directly through the HP-IB or indirectly through the HP 8510 System Bus via the network analyzer. The computer and NWA share the processing and calibration functions as prescribed by the software. These tasks and the software will be discussed in Chapter III.

**Pedestal Controller.** The servo-mechanism which rotates the target pedestal is controlled by the Newport Corporation 855C Controller. This controller is directed by the HP computer.

**Peripherals.** There are several options for obtaining hardcopies of the RCS data. A printer is hardwired to the HP computer for obtaining program listings or screen dumps. A plotter is also hardwired to the HP computer to get formatted RCS plots. Another plotter is dedicated to the NWA to obtain a copy of whatever data is on the NWA screen. Finally, a personal computer is connected to the HP computer via an RS232 link so that data files can be sent to this second computer for off-line processing.

The final objective of this chapter is to evaluate how well the AFIT RCS range duplicates the conditions assumed in the definition of RCS of an incident plane wave and a target isolated in free space. While the software which directs
the measurement procedure is very much a part of AFIT's anechoic chamber, its impact on the final result will be addressed in Chapter III.

Target Zone

The definition for the RCS, \( \sigma \), assumes that the distance between the target and the source approaches infinity to enforce plane wave illumination. (The target is assumed to be a small scatterer in the far zone of the source.) One question to be answered, then, is how close is the incident field in the measurement chamber to a plane wave. The other assumption in the definition that the target is in free space prompts another question of how well the measurement simulates a target in free space. Both of these questions are addressed next.

Incident Plane Wave. In comparing our incident field to an ideal plane wave, three parameters are considered: crossrange amplitude variation, crossrange phase variation, and downrange amplitude variation. Ideally, all three are zero. In general, the allowable variation in these parameters depends on the type of target being measured, the required accuracy of the RCS data, and the type of processing to be performed on the RCS data. For this thesis effort (and commonly used in similar measurements), a 1 dB downrange and crossrange amplitude variation, and a \( \pi/16 \) radian crossrange phase variation will be chosen as allowed limits. These limits define a region in space called a
target zone, in which the incident wave is acceptably similar to a plane wave. The following paragraphs will use these three parameters to determine the target zone, or maximum size of the target.

First, consider the downrange amplitude variation. Let \( R \) be the distance from the amplitude and phase centers of the antennas to the target zone, and assume \( R \) is large enough so that the amplitude of the incident field varies as \( 1/R \) in the target zone (a very good assumption). This leads to the relationship

\[
D = \frac{R}{8.2}
\]

where \( D \) is the downrange extent of the target zone.

The next parameter to be considered is the crossrange phase variation. Assume that the source is a point source as shown in Figure 2-5. (A more rigorous analysis would consider the actual antenna used, but would yield virtually identical results.) Assume that \( E_i(L/2)/E_i(0) = Ae^{-i\phi} \), so that \( A \) and \( \phi \) are the crossrange amplitude and phase variation, respectively. By simply accounting for the different phase paths from source to target zone center and from source to target zone edge, one can show that \( \phi = \pi/16 \) radians leads to,

\[
L \leq \frac{\pi}{4} (\lambda R)^{1/2}
\]

where \( L \) is the crossrange extent of the target zone and \( \lambda \) is the operating wavelength. By the same argument, the
vertical extent of the target zone is also given by equation 2-2, hence the target zone can be visualized as a cylinder of diameter $L$ and length $D$ centered on the target mount.

Finally, when considering the crossrange amplitude variation, the point source model is inadequate. Its application would result in $L \approx R$. A more rigorous analysis where some antenna is chosen must be carried out. This would result in a limit on $L$ which is less restrictive than that set by the allowed crossrange phase variation. The dimensions of the target zone, therefore, are determined from equations 2-1 and 2-2. More information on this subject can be found in (5:920-928).

Recalling the fixed range separation in AFIT's chamber of 26.5 feet, equation 2-1 yields a value of 3.2 feet for the downrange extent of the target zone. Figure 2-6 displays $L$ versus frequency for a range of 26.5 feet.
The maximum crossrange extent of the target zone is clearly limited by the highest operating frequency. Currently, the maximum frequency of operation in AFIT's range is 12.4 GHz, which restricts the crossrange extent of the target zone to 0.725 feet, or 8.7 inches. The crossrange extent of the target zone is 0.6 feet, or 7.2 inches if the upper frequency is 18 GHz. Now that the target zone is fully specified, the front and side views of the target pedestal and the cylindrically-shaped target zone are shown in Figure 2-7.

**Target in Free Space.** To accurately produce the RCS of a target, the range must be able to measure the return from the target as if it were in free space. Any returns from other than the target will incorrectly affect the result.
Target zone dimensions for upper frequency of 12.4 GHz
Figure 2-7

The goal of the AFIT far field range, then, is to minimize these erroneous returns. A parameter used to evaluate how well a chamber reduces the unwanted returns is called the noise floor.

The noise floor is the noise level remaining after range gating and vector subtraction have been performed. It determines how accurately, if at all, low RCS targets can be measured. In a well designed measurement system, receiver noise is below the "noise floor", so that receiver noise is not the overriding source of noise in the measurement system. The measured noise floor of the AFIT range is at least -60 dBsm between 8 GHz and 12.4 GHz. The accuracy of the amplitude of a measurement, however, is directly related to the Signal to Noise Ratio (SNR). This means, for
example, if a measurement accuracy of ± 0.5 dB is desired, the target should have a minimum RCS at least 10 dB higher than the measured noise floor, or -50 dBsm.

In summary, the target zone of the chamber was identified as a 3.3 foot cylinder with a diameter of 0.72 feet. The noise floor of the chamber was measured at -60 dBsm between 8 GHz and 12.4 GHz. The next chapter discusses the software which automates the measurement process. In addition to describing the structure of the program and the options it offers the user, Chapter III will explain how the measurements are taken and show that these are valid RCS measurements.
AFIT RCS Measurement Software

An integral component of the AFIT far-field measurement range is a software package called AFIT RCS Measurement Software (ARMS). The code was written in HP BASIC to run the HP Q36 computer which serves as the controller for the measurement range. Although the most obvious purpose of ARMS is to automate the range instrumentation, the software also directs the measurement procedures and, more significantly, calibrates the raw data and performs vector background subtraction. There is also a post-processing option via the network analyzer. The purpose of this chapter is to explain these capabilities and provide a brief description of ARMS.

ARMS Structure

The ARMS program is a compilation of three major subroutines. The first two perform pattern cuts and frequency responses, respectively, while the third subroutine handles processing and plotting of previously measured data. A significant portion of the processing/plotting subroutine is composed of existing code written recently by AFIT faculty and staff members. More detailed information regarding the architecture and operation of the software may be obtained from the flow charts provided for each subroutine (listed in Appendix A),
or from the code itself (listed in Appendix B). The flow charts provided in this chapter are extremely simplified in order to aid in the discussion of the measurement procedure.

The overall organization of ARMS is shown in Figure 3-1. The motivation behind this structure is to separate the measurement activity from the plotting and processing activity. This organization was selected in part because of the ability and preference to transfer the calibrated data files from the HP computer to a Zenith computer, whose plotting and processing options are not nearly as limited. This approach will also save time since it frees the range for further measurements.

**Calibration**

This section will explain the formula used in ARMS to produce the calibrated RCS of a target for a pattern cut or frequency response. A discussion of the limitations of the formula and how it applies to the two measurements will follow.

In order to determine the RCS, the formula must produce the quantity $r(E_s/E_i)$, where $E_s$ is the scattered field of the target, $E_i$ is the incident field at the target, and $r$ is the range separation from antennas to target. This quantity, which is the basis of the definition of RCS (reference equation 1-1), assumes a plane incident wave and, for now, neglects the $4\pi$ constant.
Consider the exact solution of the scattering from a sphere, $E_{SE}^s$. The solution can be written in terms of the incident field and the range separation as shown below

$$E_{SE}^s = E^i \frac{F}{r}$$

where $F$ is some known complex scattering function. Note that two of the elements in the definition of RCS, $r$ and $E^i$, are present in the exact solution of the sphere, but are inverse to the same elements in the desired quantity. Solving for $F$ corrects the inverse problem, and since it is known exactly, $F$ will be used to calibrate the desired
result. Finally, multiplying $F$ by the quantity $E_s^s/E_{SM}^s$ results in a very good approximation to the desired quantity in the definition of RCS. As will be shown later in this chapter, since the measured sphere return, $E_{SM}^s$, is close enough to the exact solution of the sphere, $E_{SE}^s$, the two quantities will cancel to result in the expression shown in equation 3-1.

\[
\left( \frac{E_{SE}^s}{E^i} \right) \times \left( \frac{E_s^s}{E_{SM}^s} \right) = r \frac{E_s^s}{E^i} \quad 3-1
\]

where $E_s^s =$ the measured scattered field from the target (with the background subtracted)

$E_{SM}^s =$ the measured scattered field from the sphere (with the background subtracted)

The formula, then, used in ARMS to calculate the calibrated RCS in the frequency domain is given by

\[
\sigma = 4\pi \left| \frac{E_s^s}{E_{SM}^s} \right|^2 \quad 3-2
\]

which, ideally is equivalent to

\[
\sigma = 4\pi r^2 \left| \frac{E_s^s}{E^i} \right|^2
\]

The quality of the measured sphere and target returns dictates the accuracy of the measurement. The software performs complex vector background subtraction on these returns in an attempt to duplicate the free space condition inherent in the definition of RCS. (Recall that the far-field condition has already been assumed, and is
approximated by imposing limitations on the permitted phase and amplitude variations of the incident field.) The subtraction, however, cannot include the interactions between the target and the target mount, or between the sphere and the sphere mount, and so on, because these interactions are not present in the background measurement.

Note that the formula for the calibrated RCS given in equation 3-2 can be used for a single frequency, as in a pattern cut, or used repeatedly through a range of frequencies, as in a frequency response.

The next task is to describe the procedure for performing the two measurement options available to the user: the pattern cut and the frequency response. A pattern cut is a representation of the RCS of a target as a function of aspect angle. The data is taken at a single frequency while the target is rotated through 360 degrees. A frequency response shows the RCS of a target as a function of frequency at a fixed azimuth angle. This allows for the calculation of a bandlimited impulse response, which is a time domain view of the target scattering. For both options, there are four measurements required to compute the RCS. They are the reference sphere background, the reference sphere, the target background, and the target. Also, an appropriate amount of averaging is used for each type of measurement, and the user can select the width of a pre-measurement gate which defines the range gate for which
data is collected. The pattern cut is the first measurement option to be discussed.

Pattern Cut Procedure

For the pattern cut, ARMS directs the network analyzer to record the magnitude (in dBsm) of the complex return for all measurements. For this discussion, refer to the flow chart of the measurement procedure for the pattern cut which is shown in Figure 3-2.

First, the user is prompted to input information needed for the pattern cut, such as the operating frequency, gate width, and polarization. The user then measures the return of the reference sphere background. This background is composed of the room and the mount which supports the sphere. The network analyzer places this return in the network analyzer memory. The next measurement needed is the return from the reference sphere. After this measurement is made, the network analyzer subtracts the sphere background return from the sphere measurement to come up with the free-space measurement of the reference sphere. As explained earlier, the background subtraction is performed to comply with the free space condition in the definition of RCS. Note that the sphere and sphere background measurements are taken at one position only.

The third measurement is of the target background. If the target background is identical to the reference sphere background, the measurement can be skipped, as ARMS will
substitute the sphere background return for the target background return upon subtraction. If the target background is different, care should be taken that the target background, or mount, is symmetrical in the azimuthal plane since the mount will be rotated in a pattern cut. As before, the target background return is placed in the network analyzer memory where it will be subtracted from the target return.
When the target background option is resolved, the first measurement is of the return from the target. At each degree, the target return is measured and sent to memory where the target background is subtracted. The free-space target return is then stored in the first row of a 1 x 360 dimensioned array. The positioner then rotates the target mount to the next position and the process is repeated until the array is filled. This sequence of measurements is intended to minimize the possibility of moving something in the chamber once it has been measured, hence introducing error in the measurement procedure.

The final step in producing a pattern cut is to calculate the RCS for each of the 360 data points. The formula which calculates RCS for a pattern cut uses an approximation which makes it slightly different from the formula given in equation 3-2. The high frequency approximation for the return of a sphere, \( \pi a^2 \), (\( a \) is the radius of the sphere), is used instead of the exact solution for the scattering from a sphere. The effect of this simplification on the pattern cut, however, is simply a uniform shift in the magnitude of the data. The formula used by the HP computer to calculate the magnitude of the return in decibels, is shown in equation 3-3.

\[
\sigma_{\text{pattern cut}} = 10\log(\pi a^2) + \left[ \text{Target-Target background} \right] - \left[ \text{Sphere - Sphere background} \right] \text{ (dBsm)} \tag{3-3}
\]
After the pattern cut is complete, the result is displayed on the HP 9236 computer, with a menu which offers several options. The user can align or shift the pattern cut to a desired angle, save the result, perform another pattern cut, or return to the main menu. An example plot of a pattern cut is shown in Figure 3-3. The target is a trihedral corner reflector oriented so the maximum open face occurs at 180°. The RCS is given in dBsm, and the angular resolution of the data is one degree. The header information provided at the bottom of the plot includes the
width of the software gate selected at the beginning of the measurement.

Frequency Response Procedure

A frequency response measurement displays the RCS of a target as a function of frequency at a fixed azimuth angle. For each of the four required measurements, the network analyzer samples the bandwidth of the sweep at 801 equal intervals, and records the real and imaginary components of the return in a 801 x 2 dimensioned array. ARMS implements trace averaging, where the displayed trace is a weighted average of previous traces, instead of the single frequency point averaging technique used in the pattern cut, to obtain consistent data. Figure 3-4 provides a flow chart of the measurement procedure for a frequency response.

As with the pattern cut, the first step taken by ARMS is to obtain the necessary input from the user. For a frequency response, the required information is the start and stop frequency, antenna polarization, range gate width, averaging factor, and the sweep mode of the source generator (ramp or step). The first two measurements are of the returns from the reference sphere and the reference sphere background. The network analyzer writes the complex data to arrays called Reference, and Ref_background, respectively. Next, the user is prompted to measure the target background. As with the pattern cut, if the backgrounds are the same, ARMS provides the user an option to substitute the reference
sphere background return stored in the array Ref_background, for the measured target background return to be stored in an array called Target_background. Finally, the target is measured and the data stored in the array named Target.

For the frequency response, ARMS performs complex vector background subtraction for the sphere and target measurements. The calibration is performed using the exact solution of the reference sphere, as indicated in equation 3-2.
A sample of a frequency response plot is shown in Figure 3-5. Note that a software gate can be applied to the calibrated frequency response data, in addition to the pre-measurement range gate, labeled 'soft gate' on the plot. The plot designates the center of the software gate, labeled 'gate center', and the width of the gate, labeled 'gate width', which is symmetric about the center. ARMS utilizes the processing capability resident in the network analyzer to set the location and width of the secondary gate.

![Example plot of a frequency response](image)

Example plot of a frequency response
Figure 3-5

The target in the example frequency response in Figure 3-5 is a five inch sphere. The dominant contributor to the
RCS of a sphere is the specular return, which is shown in the plot to be approximately -19 dBsm. The variation of the RCS about this level indicates the presence of the creeping wave which adds in and out of phase with the specular return.

**Time Domain**

As mentioned earlier, the network analyzer has a feature which produces a temporal view of the RCS by transforming the frequency response data to the time domain via an inverse Fourier Transform. This view of RCS gives an indication of the downrange position of the scatterers on the target. Figure 3-6 is an example plot of the time domain view of RCS. The target is the same sphere whose frequency response is shown in Figure 3-5, but the specular and creeping wave are now isolated in time. Notice the same header information is provided for the frequency response plot and time domain view of RCS. The alias free range, impulse width, and range resolution are useful parameters which describe the time domain view and quantify the limitations due to the band-limited processing and the sampling technique used to obtain the RCS versus time data.

**Alias Free Range.** The alias free range, or measurement range, is the downrange distance in which a measurement can be made without encountering aliasing, which is a repetition of the response. Aliasing is a consequence of the manner in which the frequency domain data is collected. An
The network analyzer effectively converts continuous frequency spectrum data into a discrete set of data due to the sampling process at the uniform frequency points. The effect of this sampling process is that the time domain response becomes a periodic function with a period, $T$, of $1/\Delta f$ seconds, where $\Delta f$ is the frequency spacing between samples. The frequency spacing is determined from the bandwidth of the frequency response and the number of samples taken. The alias free range, $R_{\text{alias free}}$, is found by multiplying the period of the repeating time domain
response, \( T \), by the velocity of the wave in the medium, \( c \), which is taken here as the speed of light in free space. Because an RCS measurement is a reflection measurement, the actual downrange distance of the target cannot exceed half of the alias free range.

\[
R_{\text{alias free}}(\text{meters}) = \frac{1}{\Delta f (\text{Hz})} \times c(\text{m/sec})
\]

At the AFIT measurement facility, the downrange distance before aliasing is encountered is 89.5 feet for a frequency range of 8 to 12.4 GHz and 801 sampling points.

**Range Resolution.** This parameter defines the minimum distance required to separate two responses of equal
magnitude which are close together in time. Sometimes called response resolution, the range resolution is directly related to the impulse width. The impulse width depends on the frequency range and the window selected, and is defined as the width between the half power points. For reflection measurements such as for RCS, the relationship for the impulse width is

\[
\text{Impulse Width} = \frac{0.96}{f_{\text{range}}(\text{Hz})}
\]

where \( f_{\text{range}} \) is the bandwidth of the frequency response, and the constant 0.96 is associated with a 'normal' window as defined in the network analyzer (1:Sec 3.5-16). (Note the difference between this definition and the approximation of the impulse width for a typical radar, which is \( 1/(2B) \), where \( B \) is the bandwidth of the pulse.) For a frequency response from 8 to 12.4 GHz, the impulse width is 0.22 nsec. This width will be wider for responses of different magnitudes.

The range resolution is found by multiplying the impulse width by the velocity of the wave, taken again as \( c \), the speed of light. For the frequency response example given above, the range resolution is 2.6 inches. For a frequency response from 6 to 18 GHz, the range resolution improves to slightly less than one inch.

**Display Resolution.** The display resolution determines the ability to determine the location of a response in the
time domain. This parameter depends on the time span on the display and the number of data points as shown below,

\[
\text{Display Resolution} = \frac{t_{\text{span}}}{(\text{no. of points} - 1)}
\]

where \( t_{\text{span}} \) is the time span on the display. For measurements made at the AFIT range, the bandwidth for a frequency response will always be sampled 801 times, and the time domain display will go from -5 to 5 nsec, so a time domain response can be located with a resolution of 12.5 picoseconds on the display. Obviously, the time domain display resolution can be improved by simply narrowing the time span on the display.

**Software Gate**

A time gate can be applied to the time domain data of a frequency response measurement. This is accomplished from the Plotting and Processing branch of ARMS. The gate acts like a time bandpass filter which mathematically eliminates responses outside the gate. ARMS allows the user to select the position of the center of the gate and a symmetric gate width. After the gate is activated in the time domain, the network analyzer performs a Fourier Transform of the gated time domain data to obtain the new frequency response data.

It is noted here that the automated processing available via ARMS represents a fraction of the processing options that exist in the network analyzer. (For more information, see reference (1:Sec 3.6).)
Performance Validation

The purpose of this chapter is to validate the performance of the AFIT far-field measurement range, and demonstrate the analytical procedure and type of information obtainable using the ARMS software. The first step is to evaluate the measurement procedure and the performance of equation 3-2, which ARMS uses to determine the RCS of a target. This could be accomplished by comparing measurements of simple objects, such as flat plates or a cylinder, with the theoretical RCS of the target. Obviously, the inherent limitations of a measurement made in an indoor measurement range (due to the imperfection of the far field and free space approximations) are not considered in the theoretical predictions. However, with proper attention to measurement and processing details, one can achieve agreement (to within graphical accuracy) between measured and predicted RCS. Another way to assess the performance of the AFIT far-field range is through comparison with measurements and processing from an established indoor RCS measurement facility. To verify the proper operation of the AFIT facility, measurements were repeated at the Wright Research and Development Center's (WRDC) anechoic chamber. This measurement facility will be briefly described later in this chapter. The presence of signals from other than the target in a measurement is a
source of error, and prompts questions regarding the effect of the noise floor.

Noise Floor

The noise floor of a measurement range is defined here as the maximum level of all unwanted signals in the measurement procedure after processing. In addition to the noise introduced by the hardware, the chamber is a significant source of noise in the form of undesirable scatterers. Ideally, the return from the empty chamber (no target present) is zero, as stated in the free-space condition. In the real world, however, the empty chamber, even when carefully lined with RAM, scatters the incident field. The dominant scatterers in the AFIT chamber can be seen by viewing the scattering of the chamber in the time domain as shown in Figure 4-1.

The most dominant return seen in Figure 4-1 is actually not a scatterer, as alluded to in this discussion, but represents cross-coupling energy between the transmit and receive antennas. The next significant return may be caused by two smoke detectors whose mount and location, unfortunately, were driven by safety, as opposed to scattering considerations. Located near the center of the figure and the chamber, the target pedestal structure and associated RAM are the cause for the second largest return. Also, the interactive scattering between the target pedestal, ceiling, and walls is a source of noise. Finally,
direct scattering from the rear wall is seen to be a significant scatterer.

The unwanted signals can be partially removed by attenuation, vector subtraction, and hardware/software range gating. The chamber is lined with RAM which attenuates the energy as discussed in Chapter II. ARMS also utilizes vector subtraction and software range gating to reduce all unwanted signals. The scattering from stationary objects is very repeatable, hence vector subtraction does a good job of negating their impact on the measurement. A further means of reducing the unwanted signals is to apply a filter in the

![Time domain view of chamber scatterers](Figure 4-1)
time domain which passes only the energy corresponding to the downrange position of the desired target. Note that this technique, called time (or range) gating, also passes energy scattering from the target support structure. The effectiveness of these techniques can be determined by measuring the noise floor.

The noise floor, shown in Figure 4-2, is measured by performing a frequency response where the target measurement is actually a measurement of the empty chamber. The target background, of course, is also the same empty chamber. The

![Graph showing noise floor measurement](image)

Noise floor of AFIT range using 8-12.4 GHz antennas; soft gate of 7 nsec, averaging factor of 16, and horizontal polarization

Figure 4-2
figure shows the RCS of the empty chamber between 3 to 12.4 GHz, and represents the minimum level of a target return which can be discerned from the returns of the noise sources in the measurement procedure.

Some measurements in this thesis were taken between 6 to 18 GHz, as opposed to 8 to 12.4 GHz, because antennas with a greater bandwidth became available late in the research phase of this study. Preliminary measurements indicate that the new antennas concentrate more energy on the target and thus yield an improved noise floor. Regardless of the antennas used to make the measurements, to obtain results accurate to within ±0.5 dB, the return from the target should be 10 dB higher than the noise floor. Figure 4-3 shows the noise floor measured using the new, broadband antennas. The noise floor at the WRDC Anechoic Chamber is claimed to be -70 dBsm (7). A brief description of this facility follows.

WRDC Anechoic Chamber ("The Barn")

There are many physical differences between the AFIT chamber and the Barn (a local name for the facility). The primary consideration is how these differences affect the plane wave and free space conditions. The Barn's measurement range is housed in a very large building (shaped like a barn) which allows for a large chamber; approximately twice the size of AFIT's chamber. The measurement facility is a compact range, meaning a parabolic reflector is used to
Noise floor of AFIT range using 6-18 GHz antennas; soft gate is 7 nsec, averaging factor is 16, horizontal polarization

simulate a plane wave. One benefit of the large room and parabolic reflector is a target zone of nearly 10 feet in downrange length. The large room also causes greater spatial attenuation of various error signals, thus improving the free space approximation. The hardware configurations which drive the compact ranges are also different.

The Barn's range is built around a Lintek system instead of the Hewlett Packard Network Analyzer used at AFIT's range. The sources used in each chamber are identical, however the Barn has the capability to simulate a pulsed
system by utilizing hardware gates. This is a key factor regarding the free space condition, because only the scattering from objects in the desired downrange location are passed and detected. In addition, only one antenna is required at the Barn which eliminates the cross-coupling energy between antennas which occurs at the AFIT facility. Another difference is the bandwidth of the antennas. The Barn can collect data between 2 to 18 GHz, as opposed to 6 to 18 GHz at AFIT. Some other general comments are the relative easy access to the target pedestal, and the data processing which is independent of the measurement procedure. The above is a fundamental description at best. Questions regarding the capability of the Barn's measurement ranges should be directed to WRDC/SN.

The last notable difference between the two measurement ranges is in the presentation of the product. The scale of the bandlimited impulse response (time domain) is presented in a linear, dimensionless scale as opposed to the dBsm scale used in the AFIT system.

Validation Measurements

The first validation measurement is a frequency response with a vertically polarized incident field on a cylinder of length 12.25 inches and radius 1.5 inches. The cylinder's orientation is shown in Figure 4-4; note that it is broadside to the incident field.
The high frequency approximation for the RCS of a cylinder at broadside is given as,

\[ \sigma \approx 2\pi \frac{l^2a}{\lambda} \]

where \( a \) = radius of the cylinder
\( l \) = length of the cylinder
\( \lambda \) = wavelength

and predicts a value of approximately -2 dBsm at 8.5 GHz. The frequency responses taken at the AFIT and WRDC measurement ranges are shown in Figure 4-5a and Figure 4-5b, respectively. Both measurements show a slightly lower RCS than the predicted value. The AFIT measurement is slightly lower than the Barn measurement due to a difference in the azimuthal orientation rather than a flaw in the measurement procedure, while the general pattern of the frequency response is very similar for both measurements. In the time domain, the plots are harder to compare because the
Frequency response from 8 to 12.4 GHz of a cylinder of length 12.25 inches and radius 1.5 inches at broadside and vertical polarization at a) AFIT and b) the Barn

Figure 4-5
vertical scales are different. The scattering phenomena are plain to see in the AFIT plot (shown in Figure 4-6a), while more difficult to see in the Barn plot (shown in Figure 4-6b). The scattering consists of a reflection and a creeping wave. The longer path length of the creeping wave, referenced to the specular path length, corresponds to a 0.65 nsec roundtrip delay, which is evident in the AFIT plot. The AFIT plot also shows the return due to the double diffraction mechanism which includes the opposite edges. This scattering mechanism has a roundtrip path length corresponding to 1 nsec. In the time domain plot of the Barn's measurement, one is interested in the envelope of the trace (due to their processing). The reflection is evident in Figure 4-6b, while the other mechanisms are not; this is due to the linear scale.

Analysis Technique

The purpose of the next validation measurement is to demonstrate the analytical procedure used in the time domain to isolate separate scatterers. The target for this measurement is a pair of circular flat plates which are different sizes and separated in the crossrange and downrange directions. The configuration of the plates is shown in Figure 4-7, and the incident field is vertically polarized.
Time domain view of cylinder at a) AFIT and b) the Barn

Figure 4-6
The frequency response provided in Figure 4-8 shows an interference pattern caused by the constructive and destructive phase relationship as the frequency changes. While this information is useful, it is often beneficial to know the frequency response of a single scatterer, or in this example, the frequency response of just one plate. This is accomplished by applying a bandpass filter in the time domain centered over the scatterer of interest. The time domain view of the RCS of the two plates is shown in Figure 4-9. Note that the scattering from each plate is shown by the two peaks, located at -0.71 nsec and 1.34 nsec, and that the temporal separation is the roundtrip time. The temporal path length between these peaks is 2.05 nsec, and indicates the plates are separated by 30.75 cm. Also, the
Frequency response of circular flat plates with vertical polarization

Figure 4-8

amplitudes of the returns confirm that the 4 inch plate was in front of the larger 6 inch plate.

A bandpass gate (from -1.36 nsec to -0.06 nsec) is applied around the return from the first plate; the resulting gated time domain is shown in Figure 4-10a. This is then transformed to the frequency domain via a Fast Fourier Transform (FFT). The frequency response of the first plate alone is shown in Figure 4-10b.

The RCS of a flat plate is dependent on the angle of incidence and wavelength of the incident wave. According to the high frequency prediction formula, \( \sigma = 4\pi A^2/\lambda \), where \( A \) is the area of the plate and \( \lambda \) is the wavelength, the RCS of a
A circular flat plate at normal incidence varies from -2.3 dBsm to 1.5 dBsm as the frequency increases from 8 GHz to 12.4 GHz.

As can be seen from Figure 4-10b, the effects of the processing are evident at the edges of the bandwidth, near 8 GHz and 12.4 GHz. When these effects are excluded, the frequency response exhibits the proper trend regarding the frequency dependence, namely, the RCS of a flat plate increases as the frequency is increased at normal incidence.
Gated RCS of 4 inch circular flat plate a) time domain and b) frequency response

Figure 4-10
Measurement Results

The improvements and new capabilities of the AFIT far-field measurement range have been fully described and verified. The next phase of the research is to use the facility to investigate the effect of a metallic versus a transparent canopy on the total RCS of an aircraft. The approach for the investigation is based upon measurements of scale model aircraft and measurements of a test body specifically designed to isolate the cockpit/canopy area.

The organization of this chapter mirrors the major chronological events of the research. The foundation of the measurement process was a sufficiently bounded measurement test matrix which would ensure appropriate data to accomplish the identified objective of the research. The next task was the judicious selection of a scale model aircraft which would maximize the benefits for the intended research, but not violate the physical limits of the chamber. Measurements of the scale models were then taken in three configurations (specified later in this chapter) to determine the relative magnitude of the scattering of the canopy and cockpit with respect to the scattering from the entire aircraft. The measurement results for the scale model aircraft were then analyzed and the conclusions documented. The next logical step to investigate the scattering from the subject area was to isolate the cockpit/canopy from the aircraft. To achieve this, a test
body was designed, again, with the chamber limitations in mind. After the measurement of the test body, the final task was to analyze the data and draw conclusions from the results.

**Measurement Matrix**

The objective of the measurements is to investigate the scattering from the cockpit/canopy area relative to the scattering from the entire aircraft. The following paragraphs discuss the measurement conditions which were either required by the ARMS measurement procedure and/or appropriate for the research.

A thorough investigation of the angular dependence of the scattering is outside the scope of the study, therefore all frequency response measurements were nose-on and at a zero degree elevation angle. All measurements were taken with both a vertically and horizontally polarized incident field. The frequency dependence of the scattering was within the scope of this study, however, the availability of the transmit and receive antennas determined the frequency range with which the targets could be measured. Frequency responses of the scale model aircraft performed at the AFIT range were only measured between 8 and 12.4 GHz, while similar measurements taken at the Barn of any target could be in any bandwidth between 2 and 18 GHz. Frequency responses of the test body were taken from 6 to 18 GHz at both facilities, because wider bandwidth antennas became
Two target configurations were used to simulate a perfectly metallic and a perfectly transparent canopy. The metallic canopy was modeled by painting the canopy with the same metallic paint used to cover the target such that the cockpit of the target was completely shadowed from the incident field. The transparent canopy was modeled by simply removing the canopy from the target. In this configuration, the cockpit was totally illuminated. The measurement conditions are summarized in the test matrix shown in Figure 5-1.

Scale Model Selection

The first step in selecting a scale model aircraft was to define the requirements which would fully describe the perfect target to be measured. The next step was to conduct a tradeoff between the perfect target and the practical considerations of readily available but less-than-perfect targets.

The two main criteria in selecting the scale model aircraft were the size and type. The type of aircraft was selected from modern fighters, because their requirement for situational awareness is typically satisfied via an exposed, bubble-shaped canopy. The F-16A and F-15E fighters were then chosen. The size of the fighter model is clearly
limited by the dimensions of the target zone of the chamber. The target zone was defined in chapter II as the area in the measurement chamber in which the incident wave approximated a plane wave within designated phase and amplitude variation standards. The target zone of the AFIT range is centered on the target pedestal, and is cylindrically shaped with a length of 3.2 feet and a diameter of eight inches. In the case of the fighters, the wing span was the limiting factor.

The largest scale model which could properly occupy the target zone was calculated to be approximately 1/46 of the full size of the target. The 1/46 scale model was deemed
insufficient to achieve the desired objective because of the following reasons: the length of the cockpit/canopy on this size was only 2.75 inches, a model of this particular scale was not commonly available, and the range resolution for a frequency response between 8 to 12.4 GHz was 2.6 inches. Based on the above reasons, it was decided to measure a 1/32 scale model of the F-16A and F-15E fighter aircraft.

The scaled targets were built from plastic model kits, and assembled in an airborne configuration without any external stores or weapons. The cockpit of the aircraft contained a removable seat and the normal features found in a plastic model kit, including the Heads-Up Display (HUD). If necessary, the kit was modified so the canopy/fuselage interface was smooth, and the canopy was easily removable from the fuselage. Finally, all surfaces of each fighter, including the cockpit, were painted with metallic copper paint so that the targets were highly conductive. The test for conductivity was a resistance of less than 3 ohms between any two points on the target.

Before showing the measurement results of the scale model fighters, the following paragraphs briefly describe the measurement procedure and decode the abbreviated titles of the plots. Although the conditions of each measurement are documented in the writing, the explanation is intended to aid the reader in examining the data.
The ARMS code requires one array to be filled for each of the following: reference target, reference target background, target, and target background. (Recall the option to skip the target background measurement if the target background is identical to the reference target background.) For the scale model measurements, the reference target background and the target background was a six inch styrophoam column, so the above-mentioned option was used. The option was very important because it allowed the target configuration to be changed without moving the entire aircraft. For example, a measurement run is the consecutive measurement of the three target configurations (without re-measuring the target background) by altering, but not moving, the model in the following manner. First, the model was measured with the canopy, then the canopy carefully removed (yielding the cockpit with a seat), and finally, the seat removed. All measurements were taken with a RAM cap over the target pedestal.

Due to the limited space available for labeling the plots, the filename is encoded. The first two letters designate the target; the third letter designates the polarization of the incident field; the fourth, fifth, and sixth letters represent the target configuration; and the seventh and eighth letters designate the measurement set number. The targets are coded as follows: TA (1/32 scale model F-16), TB (1/32 scale model F-15), and TC (test body).
The target configuration codes are: CAN (aircraft with canopy on), SET (canopy off; cockpit with seat), and COC (cockpit without seat). For example, the filename TAVCAN2B is a measurement of target TA (the 1/32 scale model F-16) with a vertically polarized incident field and the CANopy on.

**Measurement Results**

Although the performance and accuracy of the AFIT range was demonstrated with validation measurements, some questions were raised concerning the performance of the system when the target was a complex, low level scatterer, such as a small model aircraft. In particular, a significant concern was the consistency of the results, and the repeatability of the measurement procedure.

An extensive number of frequency response measurement runs were performed to resolve this concern, and all target configurations produced the same conclusions. Figure 5-2 shows the RCS for two independent measurements of the F-16 without the canopy or seat in the time domain and frequency domain. The incident field is horizontally polarized. The frequency domain plot shows the general patterns are very similar, as the RCS is within 2.5 dB except where the nulls are slightly shifted at 11.3 GHz. This amount is representative of the error associated with the placement and mounting of the target.
Two independent RCS measurements of the 1/32 scale model F-16; cockpit without seat, horizontal polarization:
a) time domain and b) frequency response

Figure 5-2
The data in the time domain also shows the repeatability of the measurement procedure. As can be seen from Figure 5-2a, however, the traces begin to diverge as the number and complexity of the scatterers which compose the return increases. For example, the traces are almost identical up to 0 nsec, which corresponds to approximately 65 percent of the length of the model. Towards the rear of the target, the number of scatterers increases which results in minor deviations between the traces. The canopy/cockpit area, incidentally, is well within the forward half of the model F-16. The dominant scatterers on the target are always in close alignment, even beyond 0 nsec, as can be seen at 0.5 nsec on Figure 5-2a. Target alignment is chiefly responsible for the minor differences in the time domain traces.

The next logical step is to identify the scatterers which are evident in the time domain plot of the RCS. To aid in the analysis, a template of the target is overlayed on the time domain plot of the target's RCS. The template is, of course, scaled and positioned to correspond to the target's actual downrange position in the chamber. A time gate from -2.0 to 1.0 nanoseconds is applied to the F-16 data to eliminate the returns not caused by the target. The template, shown in Figure 5-3, indicates the scattering from the nose of the F-16 occurs at -1.85 nsec with respect to the center of the reference target, and similarly,
scattering from the tail of the F-16 corresponds to 1.05 nsec from the center of the reference target.

**F-16, 8 to 12.4 GHz, horizontal polarization, AFIT.** The first target to be analyzed is the 1/32 scale F-16 (TA) with a horizontally polarized incident field. The next three figures (Figures 5-4 through 5-6) show the RCS for each of the three target configurations in the time domain and frequency domain. The following paragraphs refer to the time domain plots for each target configuration.

The first scatterer in all three measurements is unmistakenly due to the nose of the target. The -55 dBsm level of the return is comparable to the RCS of a similarly
dimensioned cone, and the time of the return, -1.75 nsec, closely corresponds to the downrange location of the nose.

The next resolvable return for each configuration is close in temporal location but different in magnitude. The return does not occur at the calculated location of the front of the canopy, -1.3 nsec, as one might expect. Instead, the return, occurring at -1.0 nsec for the CAN configuration, -0.97 nanoseconds for the COC configuration, and -0.9 nsec for the SET configuration, is most likely due to the engine inlet which is located directly beneath the center of the canopy. Because the range resolution for a frequency response from 8 GHz to 12.4 GHz is only 2.6 inches (see page 36), the temporal differences in the target configurations cannot be resolved from the dominant scattering of the engine inlet. The result is that the subject return for each configuration is slightly skewed about the temporal location of the scattering from the engine inlet. The magnitude of the returns are the only distinguishing feature of the three target configurations.

The configuration which caused the highest return, not surprisingly, was SET (the cockpit with the seat), because the seat was directly illuminated by the incident field. A notable observation, however, is that the canopy caused a larger return than the empty cockpit. The RCS at roughly the center of the canopy for the SET, CAN, and COC
RCS of 1/32 scale F-16 with canopy, horizontal polarization; a) time domain and b) frequency response

Figure 5-4
RCS of 1/32 scale F-16, cockpit with seat, horizontal polarization; a) time domain and b) frequency response

Figure 5-5
RCS of 1/32 scale F-16, cockpit without seat, horizontal polarization; a) time domain and b) frequency response

Figure 5-6
configurations are -35 dBsm, -37 dBsm, and -39 dBsm, respectively. The trend of the magnitude of the returns for the three configurations was not discernible from the frequency response plots.

The final return of interest occurs at -0.45 nanosec with a magnitude of -32.5 dBsm. This return is independent of the target configuration and is believe to be a result of the scattering from the end of the engine inlet cavity.

In summary, for a horizontally polarized incident field, little information regarding the scattering from the canopy/cockpit area of the F-16 model was gained. This is primarily because the electric field was aligned with and scattered from the horizontally oriented and oblong-shaped engine inlet, thus obscuring the electromagnetic view of the subject area. Also, the range resolution of the AFIT chamber was inadequate to separate the scatterers in the different target configurations. It was confirmed, however, that the cockpit with the seat is a dominant scatterer, while it was learned that the canopy scattered more (2 dB) than the empty cockpit. Although little was learned about the scattering from the canopy/cockpit, the conclusion is useful information in the context of the entire model aircraft.

The next task was to perform an identical set of measurement runs at the AFIT far-field measurement range to investigate the scattering from the subject area with a vertically polarized incident field. In the same format as
with the preceding horizontally polarized measurements, the data is provided in a series of six plots (Figure 5-7 through 5-9). As before, the nose of the aircraft is the first resolvable scatterer based on the temporal location and magnitude of the response. The level is almost 4 dB lower than the same measurement with a horizontally polarized field. The difference is caused by the asymmetry in the nose of the aircraft.

An interesting observation is that the discontinuity caused by the intersection of the fuselage and the front of the canopy is now apparent. The peaks which occur at approximately -1.3 nanoseconds in all three configurations correspond to this point. As in the previous case, the seat configuration is the dominant scatter, but the empty cockpit now scatters more than the canopy by at least 6 dB, as one might expect. Figure 5-10 shows the time domain returns for the three target configurations on one plot.

Another unexpected result occurs at -0.7 nsec which corresponds to the discontinuity caused by the intersection between the back of the canopy and the fuselage. Significant scattering occurs with the canopy, possibly via a traveling wave propagating from the front of the canopy to the back. Also, the scattering from the end of the engine inlet cavity, which was so dominant with the horizontally polarized field, is not present.
RCS of 1/32 scale F-16 with canopy, vertical polarization; a) time domain and b) frequency response

Figure 5-7
RCS of 1/32 scale F-16, cockpit with seat, vertical polarization; a) time domain and b) frequency response

Figure 5-8
RCS of 1/32 scale F-16, cockpit without seat, vertical polarization; a) time domain and b) frequency response

Figure 5-9
The effect of the polarization of the incident field is significant and beneficial to the objective of this thesis. The benefit is two-fold. Not only is the scattering from the canopy/cockpit area more apparent, but the undesirable scatterers on the model, such as the engine inlet and cavity, appear to scatter less. The measurement runs of the other targets in this effort are only analyzed for the case of a vertically polarized incident field based on the merits of this conclusion.

One solution to the problems associated with measuring the relatively small scale model aircraft at the AFIT range was to measure an aircraft with a larger canopy/cockpit,
such as the F-15E. The results and conclusions, however, were very similar to those for the F-16, with one exception. The difference in the magnitude of the scattering between either cockpit configuration and the scattering from the canopy configuration at the temporal location of the seat was significantly higher than the same location on the F-16. Nearly a 20 dB difference is very clear in the time domain plot shown in Figure 5-11.

Time domain view of RCS of 1/32 scale F-15, three target configurations, vertical polarization

To further investigate the scattering of the canopy/cockpit area, the 1/32 scale F-16 and F-15 models were measured at the Barn, which is capable of a broader
frequency coverage and better time domain resolution. Given the information obtained thus far, the scenario measured at the Barn was selected to produce the best opportunity to observe scattering from the subject area. Based on the lessons learned from the scale model measurements taken at the AFIT chamber, it was decided to concentrate on measurements of the F-15 from 2 GHz to 18 GHz with a vertically polarized incident field. (Measurements were also taken from 8 GHz to 12.4 GHz for validation purposes; these yielded the same results obtained at AFIT).

F-15, 2 to 18 GHz, vertical polarization, the Barn. As before, the three target configurations were measured, and the time domain and frequency response plots for each configuration are provided in Figure 5-12 through Figure 5-14. A template of the model is overlayed on selected plots to aid in viewing the data.

The general conclusions are the same as those drawn from the AFIT measurements; the SET configuration yields the strongest scattering, followed by the COC and CAN configurations, respectively. The difference, however, is that the range resolution of the Barn facility provides more detailed information on which to base and defend the conclusions. Recall that the AFIT time domain measurement of the F-15 (Figure 5-11) yielded only one peak which distinguished the three target configurations. As can be seen from the time domain plots, there are many scatterers
which contribute to the overall return and can be isolated for further analysis.

The first task is to identify the causes of the major peaks which occur in the region of interest. The front and back of the cockpit define this region, which extends from -1.8 nsec to -0.9 nsec, respectively. By observing the effect that changing the target configuration has on the amplitude of a peak, and knowing the temporal location which corresponds to the physical position of suspect scatterers, the significant contributors can be identified. For a complex target such as an aircraft, care must be exercised. A radar return could be the result of multiple reflections, resulting in a time domain peak that does not correspond to the downrange position of a specific scatterer.

There are five scatterers which produce significant returns in the region of interest. The first scatterer is the discontinuity formed by the front of the canopy. The return from this scatterer is identical for the SET and COC configurations, but is significantly reduced in the CAN configuration. The next two scatterers share the same downrange distance which corresponds to -1.6 nanoseconds. The first of these occurs in the CAN configuration and is due to the discontinuity caused by the junction between the
Barn measurement of RCS of 1/32 scale F-15, with canopy, vertical polarization; a) time domain and b) frequency response

Figure 5-12
Barn measurement of RCS of 1/32 scale F-15, cockpit with seat, vertical polarization: a) time domain and b) frequency response

Figure 5-13
Barn measurement of RCS of 1/32 scale F-15, cockpit without seat, vertical polarization; a) time domain and b) frequency response

Figure 5-14
two pieces which compose the canopy. The other scatterer at -1.6 nsec occurs in either cockpit configuration and is the most dominant scatterer on the model. In both configurations, the Head Up Display (HUD), is illuminated. The peak from the HUD is very clear in Figures 5-13 and 5-14 at -1.6 nsec. The next contributor is the seat. Clearly, the negative and positive peaks at approximately -1.3 nsec of Figure 5-13 and 5-14 are directly influenced by the presence (or absence) of the seat. Finally, the back of the cockpit scatters in much the same way as the front of the cockpit. (Note that the amplitude of the impulse response is dimensionless. This is a result of the processing.)

The frequency response plots of complex targets are much more difficult to analyze and identify meaningful trends because the RCS of a complex target is a complicated function of frequency. For example, by comparing the frequency responses for the SET and COC configurations, it is almost impossible to determine which configuration scatters the most. The correct answer for this complex target, which is demonstrated in the data, is that either can be the stronger scattering configuration depending upon the frequency. One conclusion which could be determined from the frequency response data is that the SET configuration scatters more than the CAN configuration, as the SET magnitude is always greater or equal to the
magnitude from the CAN configuration. The difference in magnitude and the amount contributed by a specific contributor, however, cannot be precisely determined from the total aircraft's frequency response.

To summarize the measurements of the 1/32 scale models, the F-16 and F-15 were measured as described in the test matrix shown in Figure 5-1. The models were first measured at the AFIT range from 8 GHz to 12.4 GHz, where it was discovered that a vertically polarized incident field scattered from the canopy/cockpit area more than a horizontally polarized incident field. The limited success at the AFIT facility was due to the limited bandwidth and small target size. Based on that experience, and to increase the probability of obtaining better data, it was decided to emphasize measurements of the larger model (F-15) with the widest possible bandwidth (2 GHz to 18 GHz) and a vertically polarized incident field.

Test Body Approach

This phase of the study examines the scattering from the canopy/cockpit area by physically isolating the subject area via a test body. There were two reasons and benefits for doing this. First, the size of the canopy/cockpit would be larger than that of the scale model because only the canopy/cockpit needed to fit in the target zone. This reduces the limitations imposed by the range resolution. Another benefit of increasing the size of the test area is
an increased effective illuminating frequency. The effective illuminating frequency is the frequency which would illuminate a full scale target in the 'real world' if the ratio between the length of the test wavelength and test target is maintained. The second reason is that the purpose of the test body is to physically isolate the canopy/cockpit, thus eliminating other scattering mechanisms which are not of interest.

The three major design criteria for the test body were that it: 1. have a very low monostatic RCS (forward direction only), 2. accurately model the canopy and canopy/fuselage interface of the F-16 or F-15 aircraft, and 3. allow the test area (canopy/cockpit area) to fit within the confines of the quiet zone of the AFIT chamber. The canopy had to be removable so a cockpit could be measured. The following paragraphs address the design criteria in further detail.

In anticipation of the acquisition and installment of the broadband antennas (6 GHz to 18 GHz), the test area had to fit in the quiet zone for a frequency of 18 GHz. (The highest frequency dictates the target zone.) The target zone was defined in Chapter II for this frequency as a cylinder of length 3.2 feet and diameter 7.22 inches centered on the target pedestal. Since the cross-range extent of the target zone was obviously the dimension which would limit the size of the test area, the maximum width of
the canopy was also restricted by this dimension. The actual dimensions of an F-16 canopy were obtained and it was determined that a 1/5 scale canopy would just fit. A canopy of this scale was not readily available; however, a spare canopy from a 1/10 scale model F-16 was obtained from the Air Force Orientation Group (AFOG) at the Defense Electronic Supply Center (DESC) in Kettering OH. Regarding the third design criteria, the task was reduced to simply building a test body which would allow the canopy/cockpit area to fit in the target zone. Since the target zone and canopy are oblong shapes, it was natural to shape the test body in a similar fashion. In fact, the shape of the test body was designed from the actual dimensions of the fuselage of an F-16. (This is explained further in the discussion of the second design criteria.) The baseline test body was then modified to meet the low RCS design criteria.

The first design criteria was that the test body have a very low frontal RCS. This meant that edges, rough surfaces, discontinuities, changes in the radii of curvature, and other sources of scattering had to be kept to a minimum, especially near the canopy. The front of the cylindrically-shaped test body was smoothed to a pointed cone, and the back of the test body was rounded to a hemisphere. The radius of the test body was designed as small as possible without forcing a drastic change in the curvature of the surface at some other point on the test
body. The surface of the test body immediately surrounding the canopy was kept as smooth and consistent as possible. Only at a distance of several wavelengths from the front and back of the canopy did the shape begin to change to the cone, and hemisphere, respectively. The entire test body was painted with conductive silver paint which was acquired from Spray Lat Corporation in Mount Vernon, NY. An ohmmeter was used to make sure the surface was uniform and never above two or three ohms between any two points on the test body.

The second criteria was that the shape of the canopy and the canopy/fuselage interface be as accurate as possible. As previously mentioned, the canopy for the test body was an actual canopy from a 1/10 scale model (very accurate), and the test body was designed from the fuselage dimensions of an F-16, and then altered. The accuracy of the shape of the canopy/fuselage interface was maintained within a perimeter surrounding the canopy for as long a distance as the test body would permit. The top and side views of the test body are shown in Figure 5-15.

The dashed line indicates the perimeter in which the shape of the F-16 fuselage was maintained. Beyond the perimeter, the shape was altered to meet the other design criteria of the test body. Ideally, at the lowest frequency, the shape of the F-16 fuselage should be accurate for at least several wavelengths all around the
canopy/fuselage interface. This distance was achieved at the front and back of the canopy. However, the narrow width of the target zone did not permit the same distance for the perimeter at the sides of the canopy. At the sides, the perimeter extends one inch beyond the canopy/fuselage interface, which, at 6 GHz, is approximately half of a wavelength. The discontinuity caused by the removable canopy was minimized.
On the other hand, no attempt was made to duplicate the cockpit of the F-16, and the SET configuration was not required to be measured. The cockpit was a simple cavity with the same gross dimensions as the actual cockpit.

There were also considerations driven by measurements which affected the design. The test body was to be mounted with a sting mount, which supports the target from the rear and projects the test body in front of the target pedestal. The benefit of this mounting scheme is that a time gate can be used which passes the return from the target while omitting the scattering from the target pedestal. Because the target was in front of the target pedestal, the test body had to be under ten pounds.

**Measurement Results**

For the test body measurements, there are two target configurations. These simulate the extreme cases of a metallic and transparent canopy. The SET configuration is not considered. All measurements presented in this section use a vertically polarized incident field (for the same reasons cited for the scale models), although the test body was measured with a horizontally polarized incident field at both facilities. The frequency range was 6 GHz to 18 GHz.

The test body measurements taken at the Barn of the CAN and COC configurations are shown in Figure 5-16 and Figure 5-17, respectively. The benefits alluded to earlier of measuring the test body are now apparent. The relatively
sparse returns attest to the success of isolating the canopy/cockpit. The spikes in Figure 5-16a correspond to the discontinuities shown by the template. The peak at -4.0 nsec, however, is not associated with any discontinuity. It is due possibly to a flaw, or non-uniformity in the paint job. Another benefit of the test body is the larger magnitude of the returns. It is apparent by viewing the frequency response data that the COC configuration is approximately 5 dB to 10 dB higher than the CAN configuration. Of course, these frequency response plots contain many undesired signals. A time gate can easily be applied to isolate the desired canopy/cockpit scattering from the undesired signals. (This isolation was not possible in the measurements of the F-16 and F-15 models.) A time gate from -6.0 nsec to -2.0 nsec is applied to the data, and the resulting time domain and frequency response data is provided in Figure 5-18 and Figure 5-19 for the CAN and COC configurations, respectively.

At the lower frequencies, the COC configuration is scattering up to 20 dB more than the CAN configuration. The disparity lessens as the frequency is increased, but is at least 10 dB until about 14 GHz, or approximately two thirds of the plot.

To investigate this further, the CAN configuration was measured from 2 GHz to 18 GHz. The time domain and
Barn RCS measurement of test body: with canopy, vertical polarization; a) time domain and b) frequency response

Figure 5-16
Barn RCS measurement of test body; cockpit, vertical polarization; a) time domain and b) frequency response

Figure 5-17
Barn RCS measurement of test body with a time gate (-6 to -2 nsec), canopy, vertical polarization; a) time domain and b) Frequency Response

Figure 5-18
Barn RCS measurement of test body with a time gate (-6 to -2 nsec); cockpit, vertical polarization, a) time domain and b) frequency domain

Figure 5-19
frequency response of this measurement are shown in Figure 5-20. Notice the significant amount of energy between 2 GHz and 6.5 GHz. The cause of the low frequency energy appears to be the large spike which occurs at approximately 0.25 nsec in the time domain plot. (In comparing the same measurement from 6 to 18 GHz (Figure 5-16a), the scattering at 0.25 nsec is present, but not nearly as strong.) This scatterer occurs well beyond the temporal location of the test body, and is therefore not caused by any direct scattering from the test body. The next concern is to identify the reason for this scattering. Based on the temporal location, the scattering may be a direct return from the sting mount, or could be related to energy creeping around the rear of the test body. This energy could proceed directly back to the observer, or intercept the target pedestal which would cause additional scattering. Whatever the cause of the return, it is of absolutely no interest to this study.

The measurements of the test body were also taken at the AFIT chamber, with both polarizations and a frequency range of 6 GHz to 18 GHz. Despite the relative complexity of the target and the data processing, the results are amazingly similar, as seen in Figure 5-21. This figure shows the frequency responses taken at each facility of the test body without a canopy. (Figure 5-21a is a repeat of Figure 5-19b.) The patterns and levels are virtually identical.
Barn measurement of test body with canopy, 2 to 18 GHz, vertical polarization; a) time domain and b) frequency response

Figure 5-20
Frequency response of test body without canopy, 5 to 18 GHz, vertical polarization: a) the Barn and b) AFIT

Figure 5-21
The only difference between the measurements is the depth of the nulls, which is greater at the Barn because of the greater sensitivity. Target alignment, however, is always a possible source of error.

The 1/10 scale factor of the test body can be used to approximate the level of scattering from a full scale canopy/cockpit. The level of scattering from a full-scale target is roughly \(-20\log(\text{scale factor})\) dB higher than the scaled target. Thus, for a scale factor of 1/10, the full scale vehicle would scatter 20 dB higher than the 1/10 scale model. For example, Figure 5-16b indicates the magnitude of the return for the 1/10 scale canopy at slightly past 12 GHz is -35 dBsm. The magnitude of the return from a full scale canopy, then, would be -15 dBsm. As previously mentioned, the COC configuration is scattering 10 to 20 dB higher than the CAN configuration. Obviously, the difference in scattering between the same configurations on a full scale aircraft would still be 10 to 20 dB. Of course, the full scale vehicle is a much more complicated geometry than the relatively simple geometry of the test body.
Conclusion

The problem statement for this thesis was twofold; consequently, observations and recommendations for each task are given separately.

AFIT Chamber Upgrade

As stated earlier, the first task was to complete the automation of the AFIT RCS measurement range. New software was needed to control recently acquired microwave hardware. The new hardware had certain new capabilities which the controlling software exploited. A software package, called ARMS (AFIT Radar Cross Section Measurement Software) was generated which not only achieved the objectives defined at the onset of the thesis, but was flexible enough to allow for continual change and improvement. The measurement procedure produces excellent results, as evidenced by the strong comparison with measurements from the WRDC anechoic chamber. As with any project involving software, however, the number of possible improvements is seemingly endless.

Most of the recommendations for improving the ARMS code involve features; that is, the ability to process and display the data. For a pattern cut, a relatively easy improvement would be to let the user select the start and stop angles, and the resolution of the data. A convenient (and legitimate) improvement would be to permanently store
the background measurement in a file which could be retained at any time. Another improvement would be to allow the user to set the start and stop times of the gate, as opposed to selecting a gate center and gate span.

Canopy/Cockpit Measurements

The second task was the investigation of the effect of a metallic versus a transparent canopy on the total RCS of an aircraft. The scattering from these extreme canopies was investigated by measuring a scaled version of a realistic canopy which was removable from the target.

The scale model measurements revealed a small but measurable difference in the RCS of the two configurations. The metallic canopy scattered less than a transparent canopy, which was simulated by an exposed cockpit. In the context of the entire aircraft, the frequency responses of the aircraft models were close, as each may be higher or lower depending on the frequency.

The secondary objective was to investigate the scattering from just the canopy/cockpit, without the complications of the scattering from the rest of the aircraft. As expected, the difference in the RCS between the two configurations was demonstrated more clearly. There was a 10 to 20 dB change between the CAN and COC configuration. Obviously, the difference in RCS of these two configurations on a full-scale version of this test canopy would still be 10 to 20 dB.
There is interest and value in learning more about this subject. While the results of the measurement portion of the thesis effort may or may not be surprising, they do define the upper and lower bounds on the scattering, and present the limitations and benefits of the various approaches. Further work should investigate materials and emphasize different levels of conductivity of the canopy, as opposed to the two extreme cases studied here. Other possibilities include determining the effect of different canopy constructions on the RCS of the canopy.
APPENDIX A: Flow Charts of Subroutines in ARMS Code

ARMS
MAIN PROGRAM

START

Preset Commands

Sub Start

END
Sub Fr

Set Nwa
Instrument State

Collect
User Data

send data to
Nwa

Sub Measure
(Sphere)

Reference(*)

Bkgdr(*)

Target(*)

Sub Measure
(Sphere Background)

Bkgdr(*) → Bkgdt(*)

separate
Target bkgdr

Sub Measure
(target bkgnd)

Sub Measure
(Target)

calculate RCS

Sub Fr menu

New Frequency
Response

SUBEND

back to
Main Menu

Instrument State 2
381 points

bandwidth
gate span
sweep node
Sub Measure

turn on Averaging

wait

801 freq points

Data(*)

turn off Averaging

SUBEND

back to Sub Fr

*Each frequency point is a real/imaginary data pair.
Data(*) = (801, 2)
Sub Pc

Collect User Data

Set Nwa

Sub Background_meas

Sub Ref_meas

Sub Tgt_meas

calculate RCS

Sub Show_crt

New Pattern Cut

SUBEND

back to Sub Start

Is there a target bgd?

no

yes

frequency
gate span
Sub

Background_meas

Assign Nwa

turn on
Averaging

wait

data trace → Memory

turn on
trace subtraction

turn off
Averaging

SUBEND

back to
Sub Pc
Sub Ref_meas

Assign Nwa

turn on
Averaging

wait

Data → Memory

trace value
Sphamp

"Sphamp = Ref - Sphbkgrnd"

turn off
Averaging

SUBEND
Sub Tgt_meas

ASSIGN Nwa

Set Controller

velocity
step increment

Pattern Cut loop

for i=1 to 360
trace value → Pdata(1)
rotate positioner

SUBEND

wait

back to Sub Pe

107
Sub Show_crt

Display Pattern Cut on CRT

Present Menu

select option

Shift Data

Dump to Printer

New Pattern Cut

Main Menu

SUBEXIT

back to Sub Pe

PRINT Screen

PRINT IS "printer"

View(361)=Freq
View(362)=Pol

Save Data

Sub Store

shift data right or left

PRINT IS "crt"
Sub Stre

INPUT Name$

Open BDAT file
NAME$

Data(382) → NAME

close file

Open BDAT file
name$

Date → name
Pregate → name

close file

SUBEND
Choose data type

Input data file from disk

Present data on CRT

options:
- change domain
- specify gate
- plot
- new data
- exit

Input data file from disk

Present data on 8518

options:
- change domain
- specify gate
- plot
- new data
- exit

Plot

options:
- choose line type
- draw grid
- draw data
- exit

(Will return to where Plot was called from)
Appendix B: ARMS Code

10: 'AFITRCS version 1.2, May '79
20: 'NAME; so you are the MAIN program
30: 'PRINT BASE
40: 'INTEGER Premap, etc. so pointers visible
50: 'PASS STORAGE IS "INTERNAL...
60: 'NEXT
70: 'CALL Clear_magic
80: 'PRINT "You are now back in BASIC."
90: 'END

120: 'THIS SUBROUTINE IS THE MAIN MENU FOR 'AFITRCS'.
130: 'B Start(Dates)
140: 'PRINT "...
150: 'CALL Clear_magic
160: 'PRINT Enter the day's date...Dates
170: 'Start (ISP CHR$(129)
180: 'CALL Clear_magic
200: 'PRINT "...
210: 'PRINT "<0 - frequency response"
220: 'PRINT "<1 - "
230: 'PRINT "<2 - Pattern Cut"
240: 'PRINT "<4 - Process/Plot stored files"
250: 'PRINT "<7 - Back to BASIC"
260: 'PRINT "...
270: 'PRINT "...
280: 'PRINT "...
290: 'PRINT "...
300: 'PRINT "...
310: 'ON KEY 0 LABEL "Freq. Response" GOTO C_tr
320: 'ON KEY 1 LABEL "Pattern Cut" GOTO C_pc
330: 'ON KEY 4 LABEL "Plot / Proc." GOTO C_pc
340: 'ON KEY 7 LABEL "Back to BASIC " GOTO C_exit
350: 'ON KEY 1 GOTO Idle
360: 'ON KEY 3 GOTO Idle
370: 'ON KEY 5 GOTO Idle
380: 'ON KEY 6 GOTO Idle
390: 'ON KEY 3 GOTO Idle
400: 'ON KEY 9 GOTO Idle
410: ' Đi the appropriate sort key.
420: 'CALL Pr Date
430: 'CALL F Tr
440: 'CALL Start
450: 'CALL Off Key
460: 'CALL Pr (Dates)
470: 'CALL Start
480: 'CALL Off Key
490: 'CALL Pr (Dates)
500: 'CALL Start
510: 'CALL Off Key
520: 'CALL Pr Magic
530: 'CALL Start
540: 'CALL Off Key
550: 'CALL Clear_magic
560: 'CALL SEND
570: 'THIS SUBROUTINE IS THE MAIN MENU FOR THE FREQUENCY RESPONSE.
..."value:'ZEEQ: \"PRESS..."
420  2:  ..."  example5.3..i.ai,2, No points.
430  2:  ..."  example5.3..i.ai,2, No points.
440  2:  ..."  example5.3..i.ai,2, No points.
450 (T:  ..."  example5.3..i.ai,2, No points.
460  2:  ..."  example5.3..i.ai,2, No points.
470  2:  ..."  example5.3..i.ai,2, No points.
480  2:  ..."  example5.3..i.ai,2, No points.
490  2:  ..."  example5.3..i.ai,2, No points.
500  2:  ..."  example5.3..i.ai,2, No points.
510  2:  ..."  example5.3..i.ai,2, No points.
520  2:  ..."  example5.3..i.ai,2, No points.
530  2:  ..."  example5.3..i.ai,2, No points.
540  2:  ..."  example5.3..i.ai,2, No points.
550  2:  ..."  example5.3..i.ai,2, No points.
560  2:  ..."  example5.3..i.ai,2, No points.
570  2:  ..."  example5.3..i.ai,2, No points.
580  2:  ..."  example5.3..i.ai,2, No points.
590  2:  ..."  example5.3..i.ai,2, No points.
600  2:  ..."  example5.3..i.ai,2, No points.
610  2:  ..."  example5.3..i.ai,2, No points.
620  2:  ..."  example5.3..i.ai,2, No points.
Start frequency is "Min": Hz.
Stop frequency is "Max": Hz.
Polarization is "Pol1":
The oscillator is in "Sweep": mode.
The gate width is "Negt": sec.
The averaging is "Aver":

ARE THE CORRECT ANTENNAS INSTALLED?

? s

Did you want to change anything? (Enter Y. or Default is NO).

? s

END THE INPUT INFORMATION TO THE HP 8510.

? s

Is "Antenna":

PLEASE WAIT

? s

OUTPUT Inua:"STAR";Min:"GHI:STOP";Max:"GHI:"?

? s

IF Sweeps="RAMP" "EN

? s

ELSE

? s

END IF

? s

WAIT 5

? s

THE FOLLOWING LINES CALL THE HEADER AND MEASUREMENT SUBROUTINES. THE DATA COMES IN 80I REAL/IMAGINARY DATA PAIRS.

? s

Measurement$="f:");

? s

CALL Ref_cnr(Pol1,Measurements)

? s

CALL Measure(Reference(,+),Aver.Sweeps)

? s

CALL Ref_bkgnd_nrt(Pol1,Measurements)

? s

CALL Measure(Bkgnd(,+),Aver.Sweeps)

? s

PRINT " meetings"

? s

DO you want to measure a separate target background?

? s

INPUT "Enter Y or N: default is no.";bck$

? s

CALL Ref_cnr(...;bck$="y" THEN

? s

CALL Measure(Bkgnd(,+),Aver.Sweeps)

? s

PRINT " meetings"

? s

ARE THE CORRECT TARGETS INSTALLED?

? s

Measure(Reference(,+),Aver.Sweeps)

? s

The following lines subtract the reference and target backgrounds from reference and target measurements, respectively.

? s

Please wait while the system is number crunching.

113
!THE FOLLOWING LINES CALCULATE (Target-Bkgd)/(Reference-Bkgd).

FOR L = 1 TO No_points
  Den=Reference(L,1)*Reference(L,2)/2
  Cal_tgt(L,1)*Target(L,1)-Reference(L,1)*Target(L,1))/Den
  Cal_tgt(L,2)*Target(L,2)-Reference(L,2)*Target(L,2))/Den
NEXT L

IF E_data(1)<0 THEN 2070
  ASSIGN @Dt TO Dis
  ENTER #dt:E_data(*)
  ASSIGN @Dt TO *
FOR J = 1 TO No_points
  Ex_sphere(I,1)*E_data(J)
  Ex_sphere(I,2)*E_data(J+No_points)
NEXT J

!THE FOLLOWING LINES READ IN THE EXACT SOLUTION FOR THE 5" INCH SPHERE.

!THE NEXT LINES CALCULATE (exact_sphere-sub_fields)

FOR K = 1 TO No_points
  Cal_tgt2(K,1)=Cal_tgt(K,1)*Ex_sphere(K,1)-Cal_tgt(K,2)*Ex_sphere(K,2)
  Cal_tgt2(K,2)=Cal_tgt(K,1)*Ex_sphere(K,2)-Cal_tgt(K,2)*Ex_sphere(K,1)
NEXT K

!END ANSWER TO THE HP 8510. "E*(Target-Bkgd)/(Reference-Bkgd)

OUTPUT @Nua:"FORM3:OUTPUT"
ENTER @Nua: @Preamble:Size.Bkgd(*)
OUTPUT @Nua:"AVEROFF:GATEOFF"

OUTPUT @Nua:"HOLD!"
OUTPUT @Nua:"FORM3:INPUTRAW"
OUTPUT @Nua: @Preamble:Size.Cal_tgt2(*)

BEEP CALL @mnu:menu(min:Max:Pol:Cal_tgt2(*),Date$,.Pre_gate$).Return
  IF Return = THEN:Go:<>0
  IF Return = "EN": Go:<>0
  RETURN: "Clear:cran"
SEND

!END

THE FOLLOWING ROUTINE IS A HEADER FOR BOTH THE FREQUENCY RESPONSE AND PATTERN BKG OF DETECTED BACKGROUND MEASUREMENTS.

IF (measurement) = "F:" THEN
  "sphere measurement is complete."
ELSE
  "go ready to measure the sphere background."
ELSE
PRINT "Put out the sphere background."
PRINT "Are the antennas aligned for \"pois\" polarization?"
PRINT ""
The subroutine presented after the frequency response is complete:

SUB FR_menu(Fmin,Fmax,Pol,Cal tgt,2(*),Date3,Pre_gate5,Return)

OPTION BASE

ASSIGN #wa TO 716

DIM S_data(3105)

CALL Clear_off

DM=1

Menu: PRINT "Please select an option from the menu."

PRINT "

PRINT "X0 - View the other domain."

PRINT "X2 - Store the frequency response data."

PRINT "X4 - Continue frequency response with a new target."

PRINT "X6 - Completely new frequency response."

PRINT "X8 - Back to the main menu."

PRINT "

ON KEY 0 LABEL "Toggle Domain" GOTO C_td

ON KEY 2 LABEL "Store Data" GOTO C_store

ON KEY 4 LABEL "New Target" GOTO C_same

ON KEY 6 LABEL "New Resp" GOTO C_new

ON KEY 8 LABEL "Main Menu" GOTO Cstrt

ON KEY 1 GOTO Again

ON KEY 3 GOTO Again

ON KEY 5 GOTO Again

ON KEY 7 GOTO Again

ON KEY 9 GOTO Again

Again: DISP "Please hit the appropriate soft key."

GOTO Again

C_off: OFF KEY

DM=1

If DM=1 THEN OUTPUT #wa:"FREQ:"

If DM=1 THEN OUTPUT #wa:"TIME:LOGM:"

CALL Clear_off

GOTO Menu

C_same: OFF KEY

return

CALL Clear_off

If yx="y" THEN GOTO C_store

If x="x" THEN GOTO C_off

If yx="y" THEN GOTO C_new

If yx="y" THEN GOTO C_same

GOTO Menu

Again
This subroutine stores a frequency sweep file.

SUBROUTINE Store(Sdata(-),Dates,Pre_gate$)
OPTION BASE 1
CALL Clear_crt
PRINT
PRINT
PRINT
PRINT...
PRINT "Insert storage disk into the right-hand disk drive."
PRINT...
PRINT "Press ":CHR$(129):" CONTINUE";CHR$(123):" when you are ready."
PRINT
CALL Clear_crt
Name:=PRINT "The file name must have at least one upper case letter."
PRINT...
INPUT ": Enter the file name for the current set of data.";Dt_fileS
File_name1S=LHS(Dt_fileS)
Disk:=CREATE BOAT Dt_fileS,1,1294
ASSIGN @Dt_fileS TO Dt_fileS
OUTPUT @Dt_fileS: Sdata(-)
ASSIGN @Dt_fileS TO *
CREATE BOAT File_name1S.2,30
ASSIGN @File_name1S TO File_name1S
OUTPUT @File_name1S: Dates
OUTPUT @File_name1S: File_gate$
ASSIGN @File_name1S TO *
SUBEND

This subroutine is the main "Menu for the pattern cut.

SUB Proc(Gates)
OPTION BASE 1
DIM A(2),Procgot(65,2),Prior_tree(65,2),Plot_size(65,1),Pcolor(373)
DIM TVview(65),View(165),Fmask_data(165),Fdata(312)
ASSIGN Nuwa TO 176
ASSIGN Nuwa data TO 176;FORMAT OFF
CALL Proc#name;DataS
Neu:=CALL Clear_crt
PRINT "At present, only the 160 degree option is active."
"Input the parameters for the pattern cut."

"Operating frequency? (Between 2 and 18 GHz)".Freq

"What gate do you want (ns)? (Default is 7 ns)".Negte

"Polarization? (Enter V or H; Default is horizontal)".Pols

"Starting aspect angle?".Angle1

"Ending aspect angle?".Angle2

"Angular resolution? (Default is 1 degree)".Resolution

"Target rotation rate .....".Speed

"Do you want to change anything? (Enter 1 or "No"; Default is no)".Ans

THE FOLLOWING LINES SEND THE INPUT INFORMATION TO THE HP 8510.

OUTPUT $Var: "MARK!"; Freq: "Freq"; Negte: "Negte"
THE NEXT SECTION CALLS THE HEADER AND MEASUREMENT SUBROUTINES.

Measurement$="PC"
CALL Refbkgnd_hdr(PolS,Measurements$)
ReoS=""
CALL Background_meas(ReoS)
CALL Ref_hdr(PolS,Measurements$)
CALL Ref_meas(Sphamp)

PRINT IF THERE IS A DIFFERENT TARGET BACKGROUND
PRINT Do you need a separate target background?
PRINT 
IF RepS="Y" THEN GOTO 5050
IF RepS<="N" THEN GOTO 4920
CALL Clearcrt
CALL Tgtbkgnd_hdr
CALL Background_meas(ReoS)
CALL Tgt_hdr
CALL Tgt_meas(Pdata(.).No_incrmts.Speed)

THE FOLLOWING LINES CALCULATE THE RCS OF THE TARGET.

Plot_dt(J) ....... RCS of the target (dBsm)
Rcs .............. exact RCS of the 6 inch sphere (dBsm)
Pdata(J) ........... target - target background (dBsm)
Sphamp .............. reference target - reference target background (dBsm)

Diam$=
Rcs=10*LOG(PI*(Diam$.0254/2)2)
FOR J=1 TO 360
Plot_dt(J)=Rcs+Pdata(J)-Sphamp
NEXT J

THIS SUBROUTINE DISPLAYS THE PATTERN CUT ON THE CRT.
CALL Show_crt(Freq,Pola,Date5,PreGate5,Choice,Plot_dt(*))
IF Choice<1 THEN GOTO 4950
CALL Clear_crt
SUBEND

THIS SUBROUTINE PERFORMS THE PATTERN CUT TARGET MEASUREMENT.
CALL Tgt_meas(Pdata(.).No_incrmts.Speed)
ASSIGN Nuwa TO 748
! THIS SUBROUTINE IS A HEADER FOR THE PATTERN CUT TARGET MEASUREMENT.

1. SUB Tgt_hdr
2. CALL ClearCRT
3. PRINT "Get ready to measure the target."
4. PRINT "Has the controller been assigned to the HP 3510?"
5. PRINT "(Enter 'QUIT' on the handbox.)"
6. PRINT "Hit CONTINUE when the target is in place."
7. PAUSE
8. CALL ClearCRT
9. SUBEND
10. ! THIS SUBROUTINE PERFORMS THE PATTERN CUT REFERENCE AND TARGET BACKGROUND MEASUREMENTS.

13. SUB Background_meas(Rep$)
14. ASSIGN @Nwa TO 716
15. OUTPUT @Nwa:"DISPDATA:AVERON32:""MEASURING":CHR$(126);" the target
16. FOR I=1 TO 360
17. OUTPUT @Nwa:"OUTMARK:"
18. ENTER @Nwa:DATA(I).8
19. OUTPUT 709 USING "K":"IA"
20. WAIT Speed
21. NEXT I
22. CALL ClearCRT
23. PRINT ""! THIS SUBROUTINE PERFORMS THE PATTERN CUT REFERENCE AND TARGET MEASUREMENT.
24. SUB Ref_meas(Sphamp)
25. ASSIGN @Nwa TO 716
26. OPTION BASE 1
27. OUTPUT @Nwa:"AVERON32:""MEASURING":CHR$(126);" the target
28. WAIT 6
29. OUTPUT @Nwa:"DATI:MINU:DISPMATH:AVEROFF:""MEASURING":CHR$(126);" the target
30. ENTER @Nwa:DATA(I).8
31. CALL ClearCRT
32. END
33. ! THIS SUBROUTINE IS A HEADER FOR BOTH THE FREQUENCY RESPONSE AND PATTERN CUT REFERENCE TARGET MEASUREMENTS.
34. SUB Ref_hdr(PolS,Measurement)
35. CALL ClearCRT
IF "measurement$"="PC" THEN GOTO 5270
5240 PRINT "Are the antennas aligned for";Pols." polarization?"
5250 PRINT 
5260 PRINT "Put out the reference target;"
5270 PRINT "Hit CONTINUE when you are ready."
5280 PAUSE
5290 CALL Clear_crt
5300 CALL Clear_crt
5310 PRINT ":CHR$(130):";CHR$(126):"the sp
5320 SUBEND
5330 
5340 
5350 : THIS SUBROUTINE STORES A PATTERN CUT FILE.
5360 SUB Str(Date$,Pregate$.View(*))
5370 OPTION BASE 1
5380 CALL Clear_crt
5390 PRINT 
5400 PRINT 
5410 PRINT 
5420 PRINT 
5430 PRINT 
5440 PRINT "Insert storage disk into the right-hand disk drive;"
5450 PRINT 
5460 PRINT "Press ";CHR$(129):"CONTINUE":CHR$(129):" when you are ready."
5470 PAUSE
5480 CALL Clear_crt
5490 CALL Clear_crt
5500 NAME=PRINT "The file name must have at least one UPPER CASE letter;"
5510 PRINT 
5520 INPUT ": Enter the file name for the current set of data;";Dt_file$2
5530 File_name2$=LW$(Dt_file$2)
5540 Disk1;CREATE;Dt_file$2.1.2
5550 ASSIGN #Dt_file2 TO Dt_file$2
5560 OUTPUT #Dt_file2;View(*)
5570 ASSIGN #Dt_file2 TO 
5580 CREATE BDAT File_name2$1.2
5590 ASSIGN #File_name2 TO File_name2$1
5600 OUTPUT #File_name2.1;Dates
5610 OUTPUT #File_name2.1;Pre_gateS
5620 ASSIGN #File_name TO 
5630 CALL Clear_crt
5640 SUBEND
5650 
5660 
5670 1 THIS SUBROUTINE MAKES SURE THE USER HAS REMEMBERED TO SAVE THE DATA.
5680 SUB Check(Ch$)
5690 PRINT "You have saved your data. It will be lost if you haven't;"
5700 PRINT 
5710 PRINT "Press ";CHR$(129):"CONTINUE":CHR$(129):" when ready."
5720 PAUSE
5730 
5740 1 THIS SUBROUTINE DISPLAYS THE PATTERN CUT ON THE CRT.
5750 SUB Plot(Freq,$,Date$,Pre_gate$,Choice,View(*))
5760 Start: CALL Clear_crt
6520 :INIT
6530 :CUTTER IS 3."INTERNAL"
6540 "view(i)" 
6550 "max"="min"
6560 FOR i=1 TO 361
6570 IF view(i)<"min" THEN view(i)="min"
6580 IF view(i)>"max" THEN view(i)="max"
6590 NEXT i
6600 "max"="max+10"
6610 "max"=ROUND("max")
6620 "min"="min-10"
6630 "min"=ROUND("min")
6640 range="max"="min"
6650 GRAPHICS ON
6660 MOVE 0.85
6670 COSE 2
6680 LABEL name
6690 SIZE 5
6700 LOG 6
6710 FOR i=1 TO .3 STEP .3
6720 "MOVE 70+1.100"
6730 "LABEL ""N OBSERVABLES"
6740 NEXT i
6750 LOG 1
6760 COSE 4
6770 MOVE 0.62
6780 Labels="RCS"
6790 FOR i=1 TO 3
6800 "LABEL Label[i]"
6810 NEXT i
6820 "MOVE 58.15"
6830 "LABEL "ASPECT ANGLE"
6840 VIEWPORT 15.125.40.90
6850 FRAME
6860 = = "N 0.250.0.0.0.8"
6870 = = "= 5.20.0.0.5.5"
6880 SIZE 3
6890 LOG 6
6900 CLIP OFF
6910 FOR i=0 TO 360 STEP 45
6920 "MOVE i.""min-1"
6930 "LABEL i"
6940 NEXT i
6950 LOG 1
6960 LOG 6
6970 FOR i="min" TO "max" STEP 10
6980 "MOVE ""i"
6990 "LABEL "
7000 NEXT i
7010 FOR i=3 TO 359
7020 "PLOT i.""view(i)
7030 NEXT i
7040 if KEY 9 LABEL "SHIFT DATA" GOTO Shift
7050 if KEY 0 LABEL "STORE THE PC" GOTO Store
7060 if KEY 6 GOTO Idle
7070 if KEY 4 LABEL "NEW PC" GOTO New
7080 if KEY 5 LABEL "DUMP TO PRNTR" GOTO DUMP
7090 if KEY 7 GOTO Idle
7100 if KEY 8 GOTO Idle
7110 if KEY 9 LABEL "MAIN MENU" GOTO L
7120 ON KEY 0 LABEL "MAIN MENU" GOTO L
7130 ON KEY 1 LABEL "MAIN MENU" GOTO L
7140 ON KEY 2 LABEL "MAIN MENU" GOTO L
7150 ON KEY 3 LABEL "MAIN MENU" GOTO L
7160 ON KEY 4 LABEL "MAIN MENU" GOTO L
7170 ON KEY 5 LABEL "MAIN MENU" GOTO L
7180 ON KEY 6 LABEL "MAIN MENU" GOTO L
7190 ON KEY 7 LABEL "MAIN MENU" GOTO L
7200 ON KEY 8 LABEL "MAIN MENU" GOTO L
7210 ON KEY 9 LABEL "MAIN MENU" GOTO L
7130 "N KBD GOTO Bottom
7140 Idle:DISP CHR$(131):"";CHR$(129):"";"";TIMES(TIMEDATE)
7150 WAIT
7160 GOTO Idle
7170 Dount:PRINTER IS 701
7180 INPUT "KBD:"" Y"":
7190 PRINTER IS CRT
7200 GOTO Idle
7210 Shift: OFF KEY
7220 GRAPHICS OFF
7230 CALL Clear_crt
7240 "";VIEW(361);PLOT_AT(365)
7250 INPUT "How many degrees should the data be shifted (-- for shift left)"
7260 IF Shift<360 OR Shift>360 THEN GOTO 7...
7270 IF Shift>0 THEN
7280 Shift=Shift
7290 ELSE
7300 Shift=-Shift+(-1)
7310 END IF
7320 FOR I=1 TO 360-Shift
7330 View2(I)=View(I+Shift)
7340 NEXT I
7350 FOR I=1 TO Shift
7360 View2(360-Shift+I2)=View(I2)
7370 NEXT I2
7380 FOR I=1 TO 360
7390 Plot_at(I3)=View(I3)
7400 View(I3)=View2(I3)
7410 NEXT I3
7420 GOTO Start
7430 C_strt: OFF KEY
7440 CALL Clear_crt
7450 GRAPHICS OFF
7460 "";View(361);FREQ
7470 "";View(362);POL
7480 CALL Sitre(Date$);Pre_gate$;View(*)
7490 CALL Clear_crt
7500 GOTO Start
7510 C_next: OFF KEY
7520 GRAPHICS OFF
7530 CALL Clear_crt
7540 Choice=1
7550 CALL Check(Chk$)
7560 IF Chk$=""Y"" THEN GOTO C_strt
7570 SUBEX:
7580 C_strt: GRAPhICS OFF
7590 CALL Clear_crt
7600 Choice=0
7610 CALL Check(Chk$)
7620 IF Chk$=""Y"" THEN GOTO C_strt
7630 SUBEX: GOTO:GRAPHICS OFF
7640 "";CALL Clear_crt
7660 SUBEND
7670 ;
7680 ;
7690 SUB Proc_choice
7700 Critten by Dana J. Sergey, May 1989
7710 CALL Clear_crt
7720 Choice= PRINT
**WHAT TYPE OF FILE DO YOU WISH TO PROCESS?**

```
7740 PRINT
7750 PRINT "FREQUENCY/TIME DATA OR PATTERN DATA"
7760 IF KEY 0 = 1 THEN GOTO FreqTim
7770 IF KEY 1 = 1 THEN GOTO Idle
7780 IF KEY 2 = 1 THEN GOTO Pattern
7790 IF KEY 3 = 1 THEN GOTO Idle
7800 IF KEY 4 = 1 THEN GOTO Idle
7810 IF KEY 5 = 1 THEN GOTO Idle
7820 IF KEY 6 = 1 THEN GOTO Idle
7830 IF KEY 7 = 1 THEN GOTO Idle
7840 IF KEY 8 = 1 THEN GOTO Exit:
7850 IF KEY 9 = 1 THEN GOTO Idle
7860 IF KEY 9 = 1 THEN GOTO Exit:
7870 DISP "PRESS APPROPRIATE SOFT KEY"
7880 GOTO Idle
7890 FreqTim: CALL Clr_scr
7900 PRINT "Please":CHR$(130):"wait":CHR$(123):" while the syst
m is being configured."
7910 OFF KEY
7920 CALL Procplot
7930 GOTO Choice
7940 Pattern: CALL Clr_scr
7950 OFF KEY
7960 CALL ar_procplot
7970 GOTO Choice
7980 Exit: CALL Clr_scr
7990 OFF KEY
8000 SUBEND
8010 Input:
8020 SUB Procplot
8030 'Written by Dana J. Bergey, May 1989
8040 OPTION BASE 1
8050 ASSIGN #wa 10, 716
8060 DIM Trace_data(801), Plot_at(801), Data(801, 2)
8070 OUTPUT #wa: "RECA: POINTS?"
8080 WAIT !
8090 CALL Clear_crt
8100 Input: CALL Input(Trace_data(1), Data(1), File_name, Fr1, Fr2, Polarity, Pre_ga"
8110 CALL Present_data(Fr1, Fr2, Trace_data(1), Data(1), File_name)
8120 OUTPUT #wa: "GATECENT 0:ENTO:"
8130 ON 1
8140 INPUT #wa: "Date="
8150 CALL Clear_crt
8160 Menu: CALL
8170 PRINT
8180 PRINT "---------------------------------------------------------------------"
8190 PRINT
8200 PRINT "---------------------------------------------------------------------"
8210 PRINT "---------------------------------------------------------------------"
8220 PRINT "---------------------------------------------------------------------"
8230 IF 1 THEN "YES"
8240 PRINT "---------------------------------------------------------------------"
8250 IF 1 THEN "NO"
8260 PRINT "---------------------------------------------------------------------"
8270 IF 1 THEN "FREQUENCY"
8280 IF 1 THEN "TIME"
8290 ELSE "NEW DATA"
```

---
---
---
3300 PRINT " :CHR$(129);" "YOU ARE NOW VIEWING THE TIME DOMAIN":CHR$(129)
3310 ON KEY 7 LABEL "FREQ. DOMAIN" GOTO Domain
3320 ON KEY 5 LABEL "SPECIFY GATE" GOTO Gate
3330 END
3340 PRINT
3350 IF Gate = THEN PRINT " :CHR$(129);" "A TIME GATE HAS BEEN APPLIED TO
THE DATA":CHR$(129)
3360 ON KEY 7 LABEL " PLOT" GOTO Plot
3370 ON KEY 9 LABEL " EXIT" GOTO Exit
3380 ON KEY 9 LABEL " GATE OFF" GOTO Exit
3390 ON KEY 7 LABEL " EXEC"
3400 ON KEY 7 LABEL " ENTER" GOTO Exit
3410 IF Gate THEN OUTPUT #Nua:"FREQ:";
3420 ELSE OUTPUT #Nua:"TIME LOG CH;
3430 END IF
3440 ON KEY 7 LABEL " ENTER APPROPRIATE SOFT KEY.
3450 GOTO Idle
3460 IF Gate THEN Gate: Gate =
3470 ON KEY 7 LABEL " ENTER APPROPRIATE SOFT KEY:
3480 GOTO Gate
3490 GOTO Plot
3500 IF Gate THEN GOTO GateOFF;
3510 END IF
3520 GOTO GateOFF;
3530 INPUT #Nua:"GATE OFF:";
3540 GOTO GateOFF;
3550 GOTO GateOFF;
3560 IF Gate THEN Gate:
3570 GOTO GateOFF;
3580 END IF
3590 GOTO GateOFF;
3600 GOTO GateOFF;
3610 GOTO GateOFF;
3620 INPUT #Nua:"GATE OFF:";
3630 GOTO GateOFF;
3640 INPUT #Nua:"GATE CENT:";
3650 INPUT #Nua:"GATE OFF:";
8890   PRINT
8900   PRINT
8910   PRINT
8920   PRINT " USE KNOB ON 95:0 TO CENTER GATE. THEN PRESS CONTINUE."
8930   PAUSE
8940   OUTPUT #wua: ENTR:
8950   GOTO Gate
8960   Goto CALL Clr_scr
8970   IF Gate=1 THEN OUTPUT #wua: "IMB:LOGM:"
8980   Goto PRINT
8990   IF Gate=1 THEN OUTPUT #wua: "IT:"
9000   Goto Gate
9010   OUTPUT #wua: "GATESPAN:"
9020   LOCAL #w2: Gate
9030   PRINT
9040   PRINT
9050   PRINT " USE KNOB ON 85:10 SET GATE SPAN. THEN PRESS CONTINUE."
9060   PAUSE
9070   OUTPUT #wua: ENTR:
9080   GOTO Gate
9100   Plot: CALL Clr_scr
9110   PRINT " Please "CHR$(13)"AT"CHR$(16)"
(128):
9120   OFF KEY
9130   ASSIGN #wua.data2 TO 716:FORMAT ON
9140   OUTPUT #wua: "FORMA:OUTPUT Form:"
9150   ENTER #wua.data2: Data(*)
9160   FOR I=1 TO 801
9170   Plot dt(I)=Data(I,1)
9180   NEXT I
9190   IF Gate=1 THEN
9200   OUTPUT #wua: "GATECENT:OUTPUT CT:"
9210   ENTER #wua.data2: Gate_cent
9220   OUTPUT #wua:"GATESPAN:OUTPUT SPAN:"
9230   ENTER #wua.data2: Gate_span
9240   OUTPUT #wua: "ENT:"
9250   ELSE
9260   Gate_span=0
9270   END IF
9280   Gate_cent=Gate_cent*10.9
9290   Gate_span=Gate_span*10.9
9300   IF Gate=2 THEN Bandwidths=7.2-13 GHz:
9310   IF Gate=3 THEN Bandwidths=19.5 GHz:
9320   IF Gate=4 THEN Bandwidths=34 GHz:
9330   Plotmenu: CALL Clr_scr
9340   NEXT I
9350   NEXT I
9360   NEXT I
9370   NEXT I
9380   NEXT I
9390   NEXT I
9400   NEXT I
9410   NEXT I
9420   NEXT I
9430   NEXT I
9440   NEXT I
9450   NEXT I
9460   NEXT I
9470   NEXT I
9480   NEXT I
126
9490 PRINT "LINE TYPE DESCRIPTION"
9500 PRINT "") - Solid line"
9510 PRINT "' - Short dashed line"
9520 PRINT "- Progressively longer dashes"
9530 ON KEY 0:LABEL "GoTo Zero"
9540 ON KEY 1:LABEL "GoTo One"
9550 ON KEY 2:LABEL "GoTo Two"
9560 ON KEY 3:LABEL "GoTo Three"
9570 ON KEY 4:LABEL "GoTo Four"
9580 ON KEY 5:LABEL "GoTo Five"
9590 ON KEY 6:LABEL "GoTo Six"
9600 ON KEY 7:GOTO Lable
9610 ON KEY 8:GOTO Lable
9620 ON KEY 9:GOTO Lable
9630 Lable:DISP "SELECT LINE TYPE"
9640 GOTO Lable
9650 Zero: Lin_typ=0
9660 GOTO Plotmenu
9670 One: Lin_typ=1
9680 GOTO Plotmenu
9690 Two: Lin_typ=2
9700 GOTO Plotmenu
9710 Three: Lin_typ=3
9720 GOTO Plotmenu
9730 Four: Lin_typ=4
9740 GOTO Plotmenu
9750 Five: Lin_typ=5
9760 GOTO Plotmenu
9770 Six: Lin_typ=6
9780 GOTO Plotmenu
9790 Plot_grid: CALL Cir_scr
9800 PRINT "Please "CHR$(130):"wait";CHR$(130):" while the da
ta is being entered"
9810 OFF KEY
9820 CALL Scale_cnttYmax,Ymin,Plot_dt(*)
9830 CALL Cir_scr
9840 IF Dm=-1 THEN CALL Draw_plt(Ymax,Ymin,T1,T2,Fr1,Fr2,Dm,Num_traces)
9850 IF Dm=1 THEN CALL Draw_plt(Ymax,Ymin,T1,T2,Fr1,Fr2,Dm,Num_traces)
9860 GOTO Plotmenu
9870 Plo: Plot_data: CALL Cil_scr
9880 PRINT "insert disc containing data files into unit and disc
ta"

127
10650  OUTPUT nua;"STAR";F:1;"GHz:"
10660  WAIT 1
10670  OUTPUT nua;"STOP";F:2;"GHz:"
10680  WAIT 1
10690  OUTPUT nua;"HOLD;GATEOFF:
10700  OUTPUT nua;"FORM3;INPURAT:
10710  OUTPUT nua_data;Preamble.Size.Trac...*
10720  SUBEND
10730  SUB
10740  !
10750  !
10760  SUB Scale_ct(fmax,frnin,Plot_ott(*))
10770  ! Written by Dana J. Sergey. May 1989
10780  ! OPTION BASE 1
10790  ! 'minPlot_ott(1)  INITIALIZE
10800  'maxFrnin
10810  'FOR J=1 TO 801
10820  IF Plot_ott(J)<Ymin +EN Ymin +Plot_ott(J)
10830  IF Plot_ott(J)>Ymax THEN Ymax =Plot_ott(J)
10840  NEXT J
10850  CALL Clear_crt
10860  PRINT " scaling choices"
10870  PRINT " ****************
10880  PRINT " *
10890  PRINT " **********
10900  PRINT " The maximum value of the current data is " ;"max";(dBsn)."
10910  PRINT " The minimum value of the current data is":"min";(dBsn)."
10920  PRINT " AUTO SCALE";"CHR$(129)";"MENUTCUR'T SCALE";"CHR$(128)";
10930  PRINT " AUTO SCALE";"CHR$(128)";"USER";"CHR$(128)";
10940  PRINT " USER defines scale."
10950  PRINT " " ;"CHR$(128)";"MAIN MENU";"CHR$(128)";"Main menu."
10960  PRINT " Enter appropriate sort key."  
10970  IN KEY 5 LABEL " AUTO SCALE" GOTO Auto
10980  IN KEY 6 LABEL " USER" GOTO User
10990  IN KEY 1 LABEL " MAIN MENU"  GOTO Main
11000  ON KEY 2 LABEL " ONE OF THE SCALE"
11010  ON KEY 7 LABEL " USER"
11020  ON KEY 0 GOTO Idle
11030  ON KEY 1 GOTO Idle
11040  ON KEY 2 GOTO Idle
11050  ON KEY 3 GOTO Idle
11060  ON KEY 4 GOTO Idle
11070  ON KEY 5 GOTO Idle
11080  ON KEY 6 GOTO Idle
11090  ON KEY 8 GOTO Idle
11100  ON KEY Disp+ ENTER key
11110  "HELP"
11120  "EXIT"
11130  User:CALL Clear_crt
11140  PRINT " "
11150  PRINT " USER DEFINED SCALE"
11170 PRINT " "
11180 PRINT " "

11190 PRINT " "
11200 PRINT " "
11210 INPUT "Enter the maximum value of RCS scale desired., ymax"
11220 INPUT "Enter the minimum value of RCS scale desired., ymin"
11230 Range=fmax-fmin
11240 IF Range>0 THEN GOTO Good_rge
11250 GSEEK
11260 IF Range=0 THEN PRINT " You have entered the same value for your fmax."
11270 IF Range<0 THEN PRINT " Try again!"
11280 PRINT " "
11290 PRINT " "
11300 GOTO 1120
11310 Good_rge:CALL Clear_crt
11320 OFF KEY
11330 SUBEXIT
11340 Auto: CALL Clear_crt
11350 fmax=fmax*10
11360 Ymax=ROUND(fmax,1)
11370 Ymin=fmin-10
11380 Ymin=ROUND(Ymin,1)
11390 OFF KEY
11400 SUBEND
11410 !
11420 !
11430 SUB Heading
11440 CALL Clear_crt
11450 PRINT " "
11460 PRINT " "
11470 PRINT " "
11480 PRINT " "
11490 PRINT " "
11500 SUBEND
11510 !
11520 !
11530 SUB Draw_r,(fmax,fmin,ymax,Num_traces)
11540 "Written by Lina u. Berger, May 1989"
11550 Num_traces=Num_traces+1
11560 GOTO Clear_crt
11570 Num_d = Num_d + 1
11580 IF Num_d <= Num_max THEN Num_d = Num_d + 1
11590 IF Num_d > Num_max THEN Num_d = 1
11600 " if time."
11610 " time."
11620 " when = 0."
11630 " Press ":CHR$(129):"CONTINUE":CHR$(129)."
1670: \texttt{Clear}_{\textit{crt}}
1680: \texttt{PRINT "Please "$CHRS(130);"wait";CHRS(123):" while
1690: \texttt{ne gto: s dotted"}
1700: \texttt{PRINT "PA1.X","0.X1:"
1710: \texttt{NEXT X}
1720: \texttt{PRINT "TL 1.5.0"}
1730: \texttt{FOR X=0 TO 801 STEP 801/Num_div}
1740: \texttt{PRINT "PA1.X","0.X1:"
1750: \texttt{NEXT X}
1760: \texttt{PRINT "TL 0.3:"
1770: \texttt{FOR X=0 TO 801 STEP 801/Num_div}
1780: \texttt{PRINT "PA1.X","0.X1:"
1790: \texttt{NEXT X}
1800: \texttt{PRINT "TL 0.1.5"}
1810: \texttt{FOR X=0 TO 801 STEP 801/Num_div}
1820: \texttt{PRINT "PA1.X","0.X1:"
1830: \texttt{NEXT X}
1840: \texttt{FOR X=0 TO 1 STEP 1/Num_div}
1850: \texttt{P=801*X}
1860: \texttt{PRINT "PA1.P","0"
1870: \texttt{V=Xmin*(Xmax-Xmin)+X}
1880: \texttt{PRINT "CP -1.5.1:LB";V:ES}
1890: \texttt{NEXT X}
1900: \texttt{IF Dm=1 THEN PRINT "PA1.801/2.0;CP -3.2.5: LBFREQUENCY (GHz)";ES}
1910: \texttt{IF Dm=-1 THEN PRINT "PA1.801/2.0;CP -5.1.2.5: LBTIME (ns)";ES}
1920: \texttt{PRINT "SCD:";min.Thmax:";TL 3.0"
1930: \texttt{Range=max fron
1940: \texttt{FOR Y=Ymin+10 TO Ymax-10 STEP 10
1950: \texttt{PRINT "PA0",Y,"YT"}
1960: \texttt{NEXT Y}
1970: \texttt{PRINT "TL 1.5.0"
1980: \texttt{IF Range>49 THEN Little_tick=2.5
1990: \texttt{IF Range<51 THEN Little_tick=2
2000: \texttt{IF Range=51 THEN Little_tick=1
2010: \texttt{FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
2020: \texttt{PRINT "PA0",Y,"YT"}
2030: \texttt{NEXT Y}
2040: \texttt{PRINT "TL 1.5.0"
2050: \texttt{IF Range>49 THEN Little_tick=2.5
2060: \texttt{IF Range<51 THEN Little_tick=2
2070: \texttt{IF Range=51 THEN Little_tick=1
2080: \texttt{FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
2090: \texttt{PRINT "PA0",Y,"YT"}
2100: \texttt{NEXT Y}
2110: \texttt{PRINT "TL 0.1.5"
2120: \texttt{FOR Y=Ymin+10 TO Ymax-10 STEP 10
2130: \texttt{PRINT "PA1",Y,"YT"
2140: \texttt{NEXT Y}
2150: \texttt{PRINT "TL 0.1.5"}
2160: \texttt{FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
2170: \texttt{PRINT "PA1",Y,"YT"
2180: \texttt{NEXT Y}
2190: \texttt{PRINT "TL 0.1.5"}
2200: \texttt{FOR Y=Ymin+10 TO Ymax-10 STEP 10
2210: \texttt{PRINT "PA1",Y,"YT"
2220: \texttt{NEXT Y}
2230: \texttt{numf
2240: \texttt{numf=Round(V-2)
2250: \texttt{FOR Y=Ymax-Ymin+10 TO Ymax-10 STEP 10
2260: \texttt{PRINT "PA0",Y,"YT"

131
1227)  IF Ynum>=1 AND Ynum<10 THEN Offset=3
1228)  IF Ynum>3.99 AND Ynum<20 THEN Offset=2
1229)  IF Ynum<2.99 AND Ynum<10 THEN Offset=1
1230)  IF Ynum>=99.99 THEN Offset=5
1231)  PRINT "CP.,(-2.5)-Offset."-.25:LB",Ynum:.2
1232)  NEXT
1233)  IF Dn+1 THEN
1234)  PRINT "PA0",Ymin+Range/2:"D10.1;CP-5.5"
1235)  PRINT "L",L:
1236)  PRINT "DI",L:
1237)  END IF
1238)  PRINT "PA0",Ymin:"SI.15..225;CP-5.5;"
1239)  PRINT "L",L:
1240)  PRINT "B",Gate Width 
1241)  PRINT "Gate Width Gate":ES
1242)  PRINT "C",Gate Width Gate":ES
1243) SUBEND
1244) SUB
1245) SUB Draw_data(Plot_dt(1),Ymin,File_name,Bandwitht.Polarity.Prep_gate 
1246) SUB Draw data(Plot_dt(1),Ymin,File_name,Bandwitht.Polarity.Prep_gate 
1247) WRITTEN BY Dana J. Bergev, Mky 1989
1248) PRINT "SEC.801",Ymin,Ymax
1249) PRINT 
1250) IF Plot dt(1)<Ymin THEN Plot dt(1)=Ymin
1251) IF Plot dt(1)>Ymax THEN Plot dt(1)=Ymax
1252) PRINT "DP",Plot dt(1)
1253) PRINT "LT",Lin typ:
1254) IF Lin typ=0 THEN PRINT "LT;"
1255) FOR I=1 TO 801
1256) IF Plot dt(I)<Ymin THEN Plot dt(I)=Ymin
1257) IF Plot dt(I)>Ymax THEN Plot dt(I)=Ymax
1258) PRINT "DP",Plot dt(I)
1259) NEXT
1260) IF Polarity=I THEN
1261) PRINT "SP",Plot dt(I)
1262) PRINT "P",";SP2:
1263) PRINT "SP",Plot dt(I)
1264) IF Plot dt(I)<Ymin THEN Plot dt(I)=Ymin
1265) IF Plot dt(I)>Ymax THEN Plot dt(I)=Ymax
1266) END IF
1267) IF Polarity="VERTICAL"
1268) NEXT
1269) IF Polarity="HORIZONTAL"
1270) NEXT
1271) IF Polarity="HORIZONTAL"
1272) NEXT
1273) NEXT
1274) NEXT
1275) END SUB
1276) PRINT "SP",Gate_cent:Gate_span:Date":ES
1277) PRINT "SP",Gate_cent:Gate_span:Date":ES
1278) PRINT "SP",Gate_cent:Gate_span:Date":ES
1279) PRINT "SP",Gate_cent:Gate_span:Date":ES
1280) PRINT "SP",Gate_cent:Gate_span:Date":ES
1281) END SUB
1282) END
```
PRINT "LB":Gate_cent:ES
PRINT "CP:CP67:;"
PRINT "LB":Gate_span:ES
PRINT "CP:CP78:;"
PRINT "LB":Date:ES
PRINT "SL:J..;PUO":Ymin:"SP ;"
PRINT 15 CAT
SUBEND
1290 1
1290 1
1290 SUB Clr_scr
1290 OUTPUT KBD:"v":
1290 SUBEND
1294 1
1295 SUB Pat_procplot
1297 ; Written by Dana J. Bergey, May 1989
1299 OPTION BASE 1
1300 DIM Ptrace_data(360),View(365)
1300 Input:CALL Pat_input(Ptrace_data(*),Fr.Date$,File_name2$,Pol,Pre_gate$)
1300 View:CALL View_crt(Ptrace_data(1:File_name2$.Retn.Coorc)
1302 IF Retrn=2 THEN SUBEXIT
1303 IF Retrn=1 THEN GOTO input
1304 IF Retrn=0 THEN GOTO Idle
1305 ON KEY 0 GOTO Idl
1306 ON KEY 1 LABEL "LINE TYPE" GOTO Lin_typ
1307 ON KEY 2 GOTO Idle
1308 ON KEY 3 GOTO Idle
1309 ON KEY 4 GOTO Idle
1310 ON KEY 5 LABEL "PLOT GRID" GOTO Pgrid
1311 ON KEY 6 GOTO Idle
1312 ON KEY 7 LABEL "PLOT DATA" GOTO Pdata
1313 ON KEY 8 GOTO Idle
1314 ON KEY 9 LABEL "EXIT" GOTO Pexit
1315 ON KEY 0 LABEL "C" GOTO Zero
1316 ON KEY 1 LABEL "O" GOTO One
1317 ON KEY 2 LABEL "N" GOTO Two
1318 ON KEY 3 LABEL "T" GOTO Three
1319 ON KEY 4 LABEL "W" GOTO Four
1320 ON KEY 5 LABEL "F" GOTO Five
1321 ON KEY 6 LABEL "S" GOTO Six
1322 ON KEY 7 GOTO Idl
1323 ON KEY 8 GOTO Idle
1324 ON KEY 9 GOTO Idle
1325 ON KEY 10 GOTO Idle
1326 ON KEY 11 LABEL "ELEC" GOTO Line
1327 ON KEY 12 LABEL "LINE TYPE"
1328 GOTO Idle
1329 GOTO Pat_menu
1330 GOTO Ptrace_menu
1331 GOTO Pdata_menu
1332 GOTO Pgrid_menu
1333 GOTO Pexit_menu
1334 Ptrace menu
1335 Pgrid menu
1336 Pdata menu
1337 Pexit menu
1338 
```

13430 "Menu"
13440 CALL Cir_scr
13450 CALL Pscale_en(Ymax, Ymin, *trace_data*)
13460 IF Coord=0 THEN CALL Pdrow_l(Ymax, Ymin, Num_traces)
13470 IF Coord=1 THEN CALL Pdrow_p(Ymax, Ymin, Num_traces)
13480 GOTO Menu
13490 Pscale_en(Cir_scr
13500 IF Coord=0 THEN CALL Pdrow_data(*trace_data*), Ymax, Ymin, File_name2S, Fr, Fo
13510 IF Coord=1 THEN CALL Pdrow_data(*trace_data*), Ymax, Ymin, File_name2S, Fr.
13520 GOTO Menu
13530 Exit: CALL Cir_scr
13540 GRAPHICS OFF
13550 GOTO View
13560 SUBEND
13570
13580 !
13590 SUB Pat_input(*trace_data*, Fr, Date$, File_name2S, Pol, Pre_gates)
13600 ! Written by Dana J. Bergey, May 1989
13610 OPTION BASE
13620 DIM View(365)
13630 CALL Cir_scr
13640 Start:PRINT ""
13650 PRINT "" Inset: disc containing data file into right hand disk drive..."
13660 PRINT "" when ready..."
13670 PRINT "" Press "",CHR$(13), ""CONTINUE"",CHR$(128):
13680 PRINT "" ""
13690 PAUSE
13700 ON ERROR GOTO Err2
13710 CALL Cir_scr
13720 INPUT "Do you wish to see listing of disk (Y or N)? Default is N.";List$=Y
13730 IF List$="Y" THEN
13740 CAT
13750 ON KBD GOTO Again
13760 DISP CHR$(131);"Press space bar when ready.";CHR$(128)
13770 Loop:GOTO Loop
13780 ELSE
13790 END IF
13800 Again:CALL Cir_scr
13810 IF Pol=Fr THEN "Error"
13820 NAME:INPUT "Enter the file name of the stored file.";File_name2S
13830 ON ERROR GOTO Err2
13840 GOTO Input
13850 Err:PRINT ERRMS
13860 NAME: INPUT "Enter the file name of the stored file.";File_name2S
13870 ON ERROR GOTO Err2
13880 NAME: INPUT "Enter the file name of the stored file.";File_name2S
13890 WRITE * , File_name2S
13900 WRITE * , File_name2S
13910 WRITE * , File_name2S
13920 WRITE * , File_name2S
13930 WRITE * , File_name2S
13940 WRITE * , File_name2S
13950 WRITE * , File_name2S
13960 WRITE * , File_name2S
13970 WRITE * , File_name2S

134
SUB Pscale_cn(Ymax, min, Ptrace_data(j))

! Written by Dana J. Bergey, May 1989

GRAPHICS OFF

Ymin=Ptrace_data(j) ! INITIALIZE

FOR J=1 TO 360

IF Ptrace_data(j)<min THEN Ymin=Ptrace_data(j)

IF Ptrace_data(j)>Ymax THEN Ymax=Ptrace_data(j)

NEXT J

CALL Cir-scr

PRINT " SCALING CHOICES"

PRINT ":CHR$(129):"AUTO SCALE":CHR$(128):" AUTO SCALE 

PRINT "USER":CHR$(129):USER"

PRINT "USER DEFINED SCALE"

PRINT ". User defines scale."

PRINT ". User defines scale."

ON KEY 5 LABEL " AUTO SCALE" GOTO Auto

ON KEY 7 LABEL " USER" GOTO User

ON KEY 9 GOTO Idle

ON KEY 0 GOTO Idle

ON KEY 1 GOTO idle

ON KEY 2 GOTO idle

ON KEY 3 GOTO idle

ON KEY 4 GOTO Idle

ON KEY 6 GOTO Idle

ON KEY 8 GOTO Idle

:DISP "Enter appropriate soft key."

ON KEY 5 LABEL " CLEAR CUR" 

PRINT " CLEAR CUR"

PRINT " USER DEFINED SCALE"
********
14500 PRINT ****
14510 PRINT:YMin
14520 INPUT "Enter the maximum value of RCS scale desired. ":ymax
14530 INPUT "Enter the minimum value of RCS scale desired. ":ymin
14540 RANGE=ymax-ymin
14550 IF Range >= THEN GOTO Good_rge
14560 SEED
14570 IF Range > THEN PRINT "You have entered the same value for Ymin and Range."
14580 IF Range >= THEN PRINT "Your Ymin is greater than Ymax."
14590 PRINT ****
14600 PRINT ****
14610 GOTO 14500
14620 Good_rge:CALL Clear_crt:
14630 EXIT
14640 SUBEXIT
14650 AUTO:CALL Clear_crt:
14660 ymax=MAX(ymax,l)
14670 ymin=ROUND(ymin.
14680 ymin=ROUND(ymin.
14700 EXIT
14710 SUBEND
14720 !
14730 !
14740 SUB P:draw_plot(ymax,0,0,0,Num_traces)
14750 ! Written by Dana J. Bergey, May 1989
14760 Num_traces=
14770 CALL Clear_crt
14780 PRINT ****
14790 PRINT ****
14800 PRINT ****
14810 PRINT "Ensure that paper and two pens are in the plotter at this time.
14820 PRINT ****
14830 PRINT ****
14840 PRINT ****
14850 PRINT ****
14860 PRINT ****
14870 PRINT ****
14880 PRINT ****
14890 PRINT "xav=500 STEP 5**:PRINT "x=500 STEP 5:PRINT "xav=500 STEP 5:
14900 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14910 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14920 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14930 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14940 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14950 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14960 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14970 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14980 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
14990 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
15000 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
15010 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
15020 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
15030 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
15040 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:
15050 PRINT "xav=500 STEP 5:PRINT "xav=500 STEP 5:

136
PRINT "PA",X,"100.X"  NEXT X
FOR X=0 TO 360 STEP 45
PRINT "PA",X,":"
IF X=10 THEN PRINT "PA",11.5,":":LB":X:ES
IF X=9 AND X<100 THEN PRINT "CP",X-.5,":":LB":X:ES
IF X=99 THEN PRINT "CP",10.5,":":LB":X:ES
NEXT X
PRINT "PA 160.0,CP -11.2.5; L3ASPECT ANGLE (DEGREES)":ES
PRINT "SC0.360",Ymin,Ymax,"L3.0"  NEXT Y
PRINT "PA 360",Y":":Y"  NEXT Y
IF Range<5 THEN Little_tick=2.5
IF Range=5 THEN Little_tick=2
IF Range>5 THEN Little_tick=1
FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
PRINT "PA 0",Y":":Y"  NEXT Y
PRINT "PA 0.3":Y":":Y"  NEXT Y
PRINT "PA 0.1.5":Y":":Y"  NEXT Y
PRINT "PA 360",Y":":Y"  NEXT Y
PRINT "PA 360",Y":":Y"  NEXT Y
PRINT "PA 0",Y":":Y"  NEXT Y
Ynum=Y
Ynum=ROUND(Ynum,0)
IF Ynum<99.99 THEN Offset=6
IF Ynum>10 AND Ynum<9.99 THEN Offset=5
IF Ynum=10 AND Ynum<.99 THEN Offset=4
IF Ynum=1 AND Ynum<.9 THEN Offset=3
IF Ynum=0 THEN Offset=2
IF Ynum=.9 AND Ynum<.1 THEN Offset=1
IF Ynum=.999999 THEN Offset=0
PRINT "CP",Ynum-Offset,".25":LB":Ynum:ES
NEXT Y
NEXT X
PRINT Ymax,range2,"210.1;CP -5.5"  NEXT X
PRINT Ymin,range2,"210.1;CP -5.5"  NEXT Y
PRINT Ymin,range2,"210.1;CP -5.5"  NEXT Y
PRINT Ymax,range2,"210.1;CP -5.5"  NEXT Y
PRINT Ymax,range2,"210.1;CP -5.5"  NEXT Y
PRINT "File Name Frequency Polarization Soft gate"
PRINT name2S.Fr.Pol.Pre_gates.Date.
draw_catal.trace_catal.*Ymax,Ymin.File_name2S.Fr.Pol.Pre_gates.Date.
"San Francisco, CA, USA, May 1989
SFO  "3.360",Ymin,Ymax
137
15650 PRINT "CP2;"
15660 PRINT "P0:Trace_data(1):
15670 PRINT "LT:lin_type;"
15680 IF lin_type=0 THEN PRINT "LT;"
15690 FOR I=1 TO 360
15700 IF Trace_data(I)<Ymin THEN Trace_data(I)=Ymin
15710 IF Trace_data(I)>Ymax THEN Trace_data(I)=Ymax
15720 PRINT "PD":I:Trace_data(I)
15730 NEXT I
15740 Num_traces=Num_traces+1
15750 PRINT "PU:PA0",Ymin:,SI:15:.225:CPS.-5;"
15760 ES=CHR$(3)
15770 IF Pol=1 THEN
15780 Pol="VERTICAL"
15790 ELSE
15800 Pol="HORIZONTAL"
15810 END IF
15820 FOR I=0 TO Num_traces
15830 PRINT "CP0.-;"
15840 NEXT I
15850 PRINT "LB":File_name2S:ES
15860 PRINT "CP:CP20,1;"
15870 PRINT "LB":Fer:"CH":ES
15880 PRINT "CP:CP38,1;"
15890 PRINT "LB":PolS:ES
15900 PRINT "CP:CP59,1;"
15910 PRINT "LB":Pre_date$:ES
15920 PRINT "CP:CP59,1;"
15930 PRINT "LB":Date$:ES
15940 Bottom:PRINT "SI:2..3:PU0",Ymin."SP;"
15950 PRINTER IS CRT
15960 SUBEND
15970 !
15980 !
15990 SUB ViewCRT(View(*),File_name2S,ReturnCoord)
16000 ! Written by Dana J. Bergey. May 1989
16010 Start: CALL Cir_scr
16020 OPTIONS
16030 "JOTTER IS 3."'INTERNAL"
16040 "View(*),File_name2S,ReturnCoord"
16050 max=Ymin
16060 OR I=1 TO 359
16070 IF View(I)<Ymin THEN Ymin=View(I)
16080 IF View(I)>Ymax THEN Ymax=View(I)
16090 NEXT I
16100 max=MAX
16110 max=ROUND(max,.1)
16120 min=Ymin-10
16130 min=ROUND(min,.1)
16140 range=max-min
16150 GRAPHICS ON
16160 MOVE 0,0
16170 "FILE_IMAGE"File_name2S
16180 "FILE_IMAGE"
16190 "FILE_IMAGE"
16200 "FILE_IMAGE"
16210 "FILE_IMAGE"
16220 "MOVE 0.3,0.3 SetP:"
16230 "MOVE 0.3,0.3 SetP:"
16240 "FILE_IMAGE"
16250 "FILE_IMAGE"
DIM View2(361)  
INPUT "How many degrees should the data be shifted ? (- for shift left)"

IF Dshift<360 OR Dshift>360 THEN GOTO 16710  
IF Dshift<0 THEN  
Dshift=360-Dshift  
ELSE  
Dshift=-1-Dshift  
END IF  
FOR I=1 TO 360-Dshift  
View2(I)=View(I-Dshift)  
NEXT I  
FOR I2=1 TO Dshift  
View2(360-Dshift+I2)=View(I2)  
NEXT I2  
FOR I3=1 TO 360
16860  raw(13);view(13)
16870  CAT 13
16880  AUTO Start
16890  Plot: CALL Cir_ser
16900  return;
16910  result;
16920  SUBEXIT;
16930  Plot: CALL Cir_ser
16940  return;
16950  Cout <1>
16960  SUBEXIT;
16970  New_data: GRAPHICS OFF
16980  return;
16990  CALL Cir_ser
17000  SUBEXIT;
17010  Exit: GRAPHICS OFF
17020  return;
17030  CALL Cir_ser
17040  SUBEND
17050  !
17070  !
17080  SUB "plot_pltr,max,min,Num_traces)
17090  ! written by Dana J. Bergey, May 1989
17100  num_traces=n)
17110  PRINT "".;
17120  PRINT ""
17130  PRINT ""
17140  PRINT ". Ensure that paper and two pens are in the plotter at this time."
17150  PRINT ""
17160  PRINT ""
17170  PRINT ""
17180  PRINT ""
17190  PRINT ""
17200  PRINT ""
17210  PRINT ""
17220  PRINT ""
17230  PRINT ""
17240  PRINT ""
17250  PRINT ""
17260  PRINT ""
17270  PRINT ""
17280  PRINT ""
17290  PRINT ""
17300  PRINT ""
17310  PRINT ""
17320  PRINT ""
17330  PRINT ""
17340  PRINT ""
17350  PRINT ""
17360  PRINT ""
17370  PRINT ""
17380  PRINT ""
17390  PRINT ""
17400  PRINT ""
17410  PRINT ""
17420  PRINT ""
17430  PRINT ""
17440  PRINT ""

180
SUB Poldraw_data(Ptrace_data(1),Ymin,Ymin,File_name$.Fr.Pol.Pre_gate$.Date
5,Num_traces,Line_type)

17710 "Written by Dana J. Bergey, May 1989"

17720 PRINT "IP 1000,900,9000,8900:SC",Ymin,Ymin,Ymin,Ymax
17730 PRINT "SP":
17740 Num_circ=(Ymax-Ymin)/10
17750 Radmax=(Ymax-Ymin)/2
17760 Extra=Radmax/Num_circ
17770 Cntr+Newmax
17780 Cntr+Max=(Ymax-Ymin)/2
17790 Xp=Cntr+.5*(Ptrace_data(1)-Ymin)-.81
17800 PRINT "PT",Xp,Cntr
17810 IF Line_type=0 THEN PRINT "LT":
17820 IF X=99999 THEN PRINT "E":
17830 FOR I=1 TO 360
17840 Theta=I/180*.3.1415
17850 X=(Ptrace_data(1)-Ymin)+COS(Theta)-.81
17860 Xp=Cntr+X/2
17870 Y=(Ptrace_data(1)-Ymin)+SIN(Theta)
17880 IF X=Cntr+T2
17890 PRINT "PD",Xp,Yp
17900 NEXT I

17910 Num_traces=Num_traces+1
17920 X=Cntr+.5*(Ptrace_data(1)-Ymin)-.81
17930 PRINT "PN",Xp,Cntr
17940 Wrdosx=Cntr+Radmax
17950 Wrdosy=Cntr+Radmax
17960 IF Pol=1 THEN
17970 Pol="HORIZONTAL"
17980 ELSE
17990 Pol="VERTICAL"
18000 FOR I=1 TO Num_traces
18040 PRINT "CP0.-1:";
18050 NEXT [ ]
18060 PRINT "";LB";File_names;ES
18070 PRINT "CP:CP16.1:";
18080 PRINT "";LB";CP33.1;ES
18090 PRINT "CP:CP33.1:";
18100 PRINT "";LB";CP54.1;ES
18110 PRINT "CP:CP52.1:";
18120 PRINT "";LB";Pre.gate$;ES
18130 PRINT "CP:CP54.1:";
18140 PRINT "";LB";Date$;ES
18150 Out=Cntr.Maxmax
18160 PRINT "";PU";Cntr.Out.";SP0;"
18170 PRINTER IS CRT
18180 SUBEND
18190 !
Bibliography


8. Swarner, W.G. *et al.*, Sixth Status Report on Contract #OR-549651-B28, ElectroScience Laboratory, The Ohio State University, Columbus OH.

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Vita

Captain Scott A. Owens four years prior to receiving his Bachelor of Science degree in Electrical Engineering from Clarkson University in May of 1985. Captain Owens received his commission in the USAF as a distinguished graduate from the University's ROTC program and entered active duty in September 1985. His first assignment was to the Avionics Laboratory of the Air Force Wright Aeronautical Laboratories (AFWAL) at Wright Patterson AFB, Ohio. Captain Owens worked in offensive and defensive avionics in the Mission Avionics Division until entering the School of Engineering, Air Force Institute of Technology, in May 1988.
The purpose of this study was twofold. The first objective was to complete the development of AFIT's Far-Field Radar Range with a fully automated measurement process. The second objective was to use the facility to investigate the scattering of metallic versus transparent aircraft canopies relative to the scattering of the total aircraft. The approach for the investigation was: first, to measure scale model aircraft to determine the effect of the RCS of the canopy/cockpit area on the RCS of the total aircraft, and second, to design and measure a test body which would isolate the canopy/cockpit area from the rest of the aircraft.

The result of the work on the first task is a software package called AFIT RCS Measurement Software (ARMS). The successful performance of the far-field range was validated by very favorable comparisons with the Wright Research and Development Center's anechoic chamber. The scale model measurements suggest at most a 5 dB difference between the scattering from the two extreme cases. The test body, however, clearly demonstrated differences up to 20 dB at certain frequencies.

This study documents the upper and lower bounds of the subject measurements in an indoor measurement range. The Air Force has expressed interest in steering the investigation to examine materials and/or canopy construction.
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