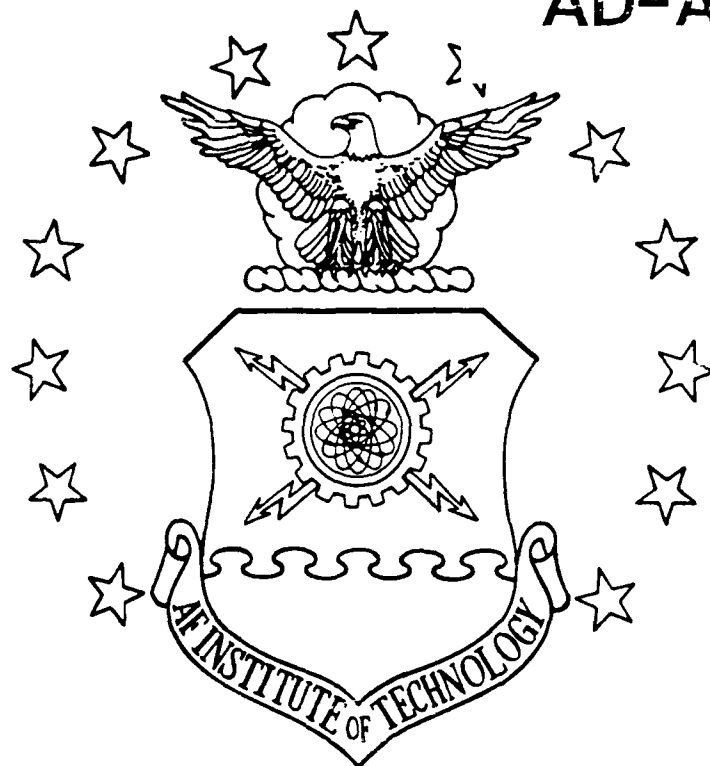




AUTOMATION OF AN RCS MEASUREMENT SYSTEM
AND ITS APPLICATION TO INVESTIGATE
THE ELECTROMAGNETIC SCATTERING FROM
SCALE MODEL AIRCRAFT CANOPIES

Scott A. Owens
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AFIT/GE/ENG/89D-38

DEPARTMENT OF THE AIR FORCE
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AND ITS APPLICATION TO INVESTIGATE
THE ELECTROMAGNETIC SCATTERING FROM
SCALE MODEL AIRCRAFT CANOPIES

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Electrical Engineering

Scott A. Owens, B.S.
Captain, USAF

December 1989

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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

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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
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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

$$R \geq 5D^2/\lambda$$

where D is the crossrange extent of the target and λ 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, σ , is given by

$$\sigma = \lim_{R \rightarrow \infty} 4\pi R^2 \frac{|E^s|^2}{|E^i|^2}$$

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° 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

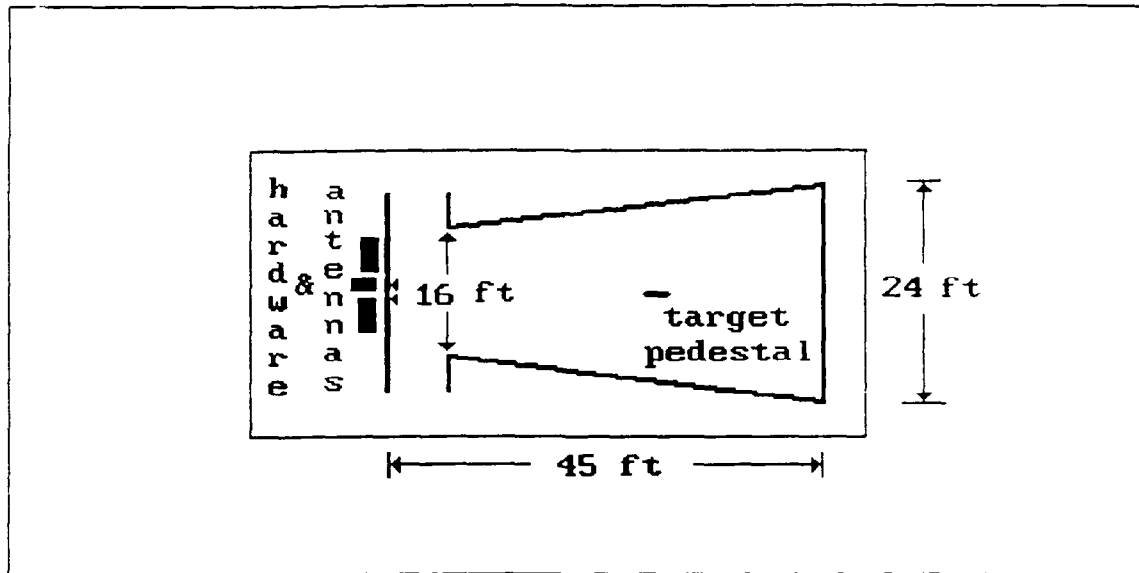
This chapter describes the hardware and physical layout of the AFIT far-field RCS measurement range. Also discussed are the approximations of the conditions assumed in the definition of RCS. These conditions are that of an incident plane wave and of a target in free space. These conditions will be quantified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

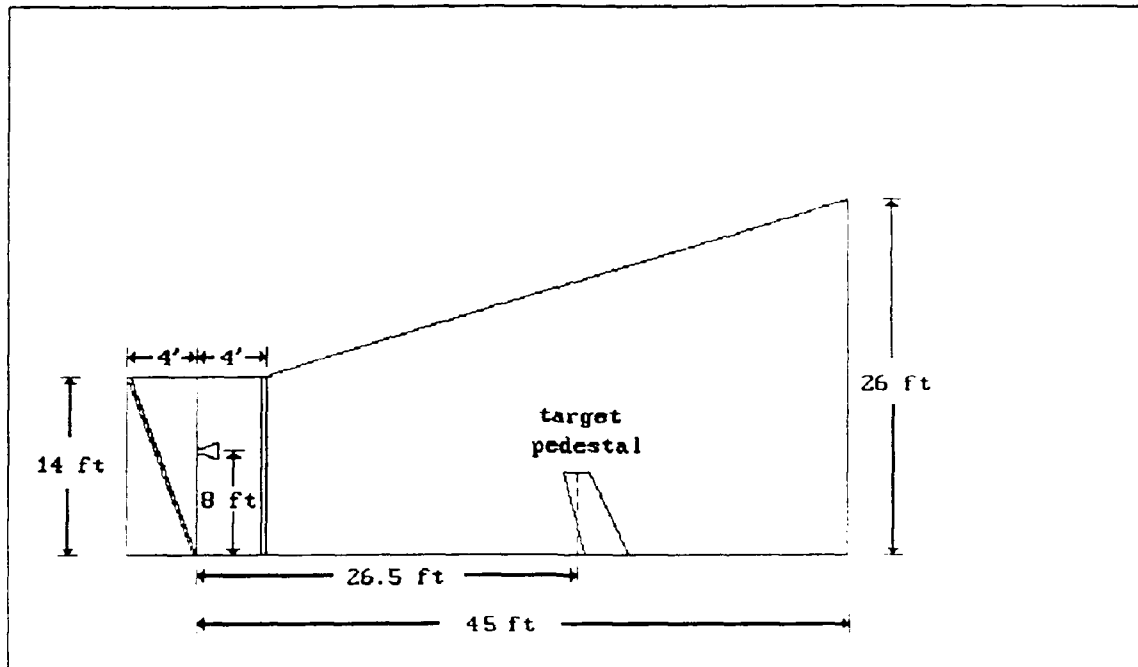


AFIT range floor plan
Figure 2-1

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



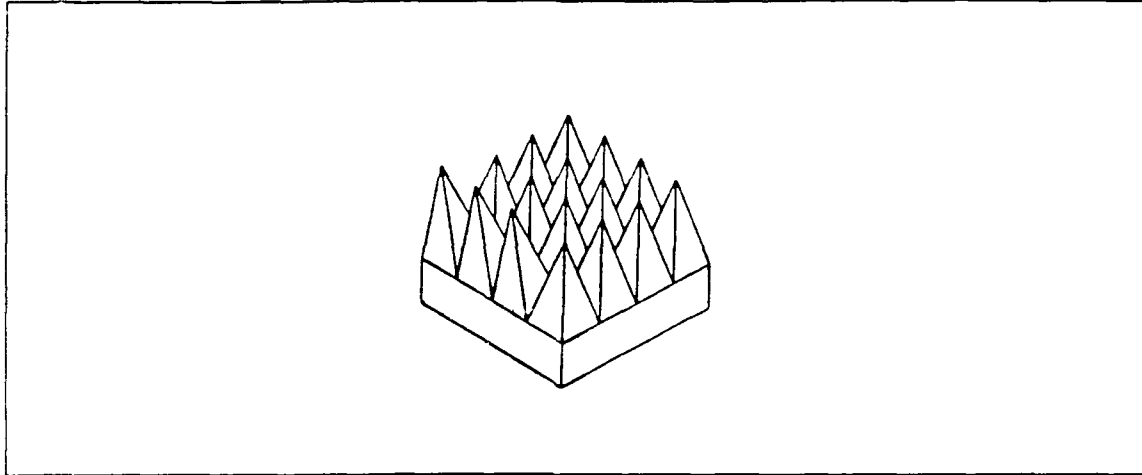
Cross-section of chamber showing target pedestal
and antennas
Figure 2-2

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.

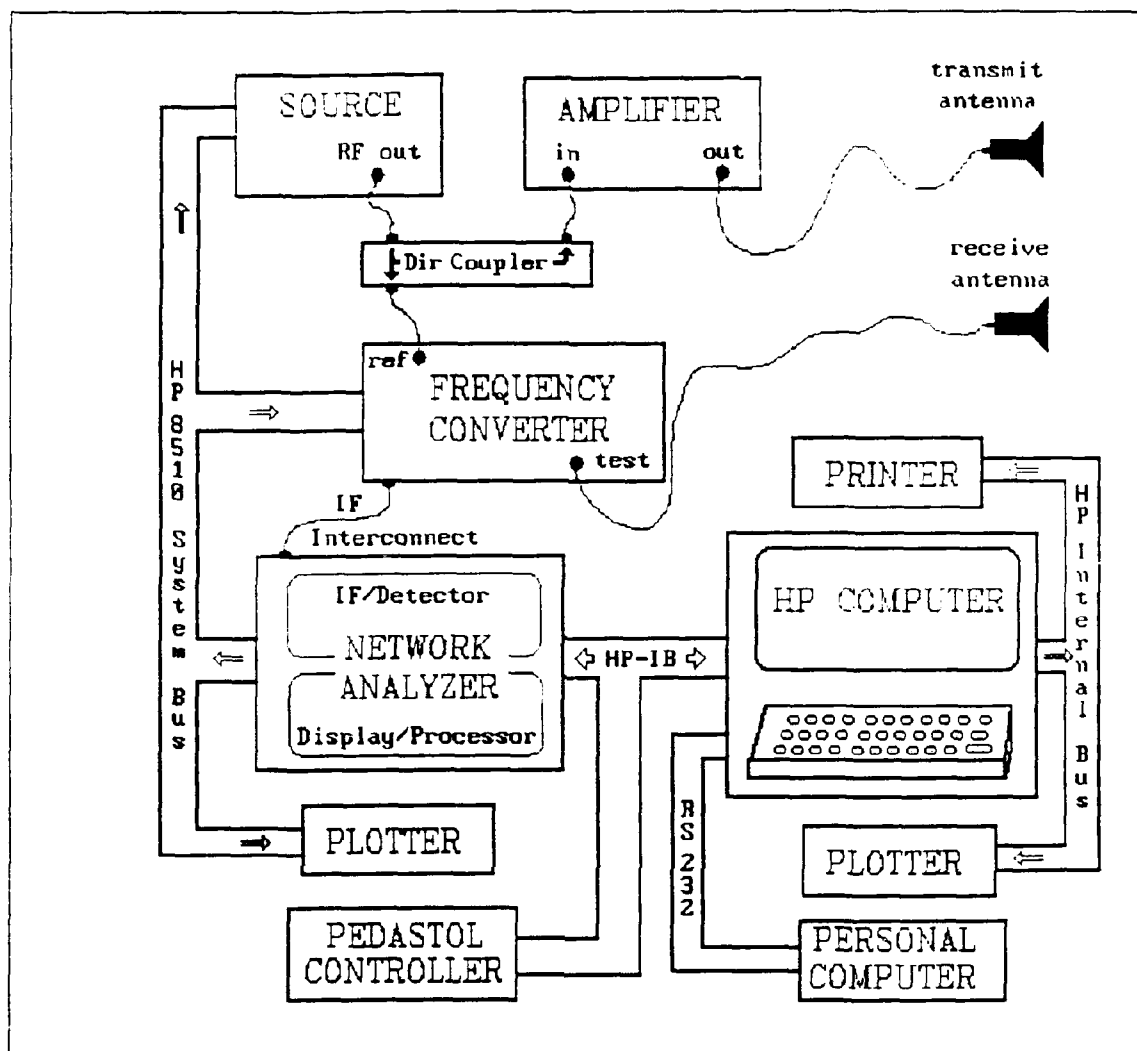
Source/Amplifier. The transmitted signal for the RCS measurement is a continuous wave (CW) microwave radio frequency signal generated by the HP 8340B Synthesized Sweeper. The sweeper output is fixed at 0.0 dBm. The accuracy of the source at this output level is ± 1.5 dB. The signal is passed through 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



Hardware configuration
Figure 2-4

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, σ , 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

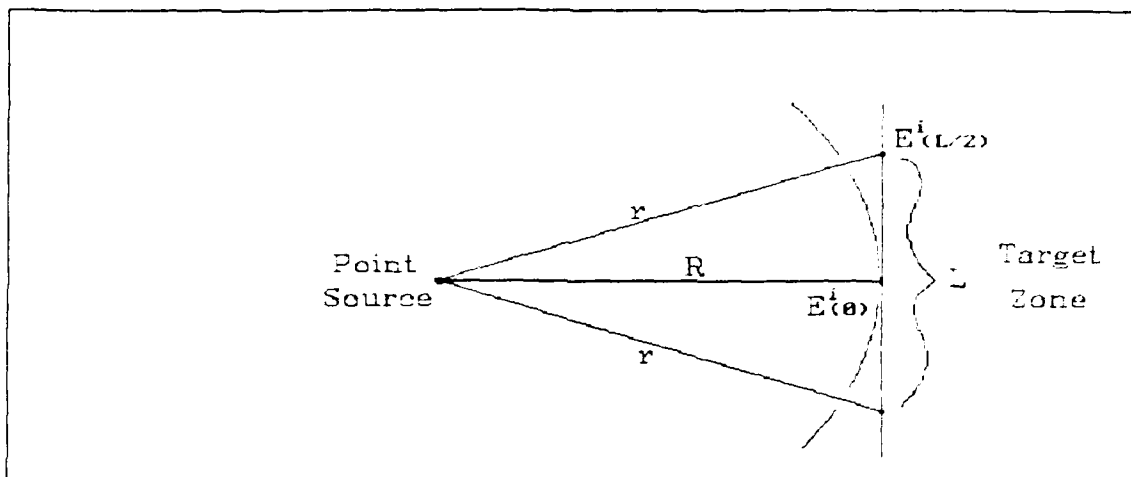
$$D=R/8.2 \qquad 2-1$$

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 $E^i(L/2)/E^i(0)=Ae^{-j\phi}$, so that A and ϕ 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,

$$L \leq \frac{1}{2} (\lambda R)^{1/2} \qquad 2-2$$

where L is the crossrange extent of the target zone and λ is the operating wavelength. By the same argument, the

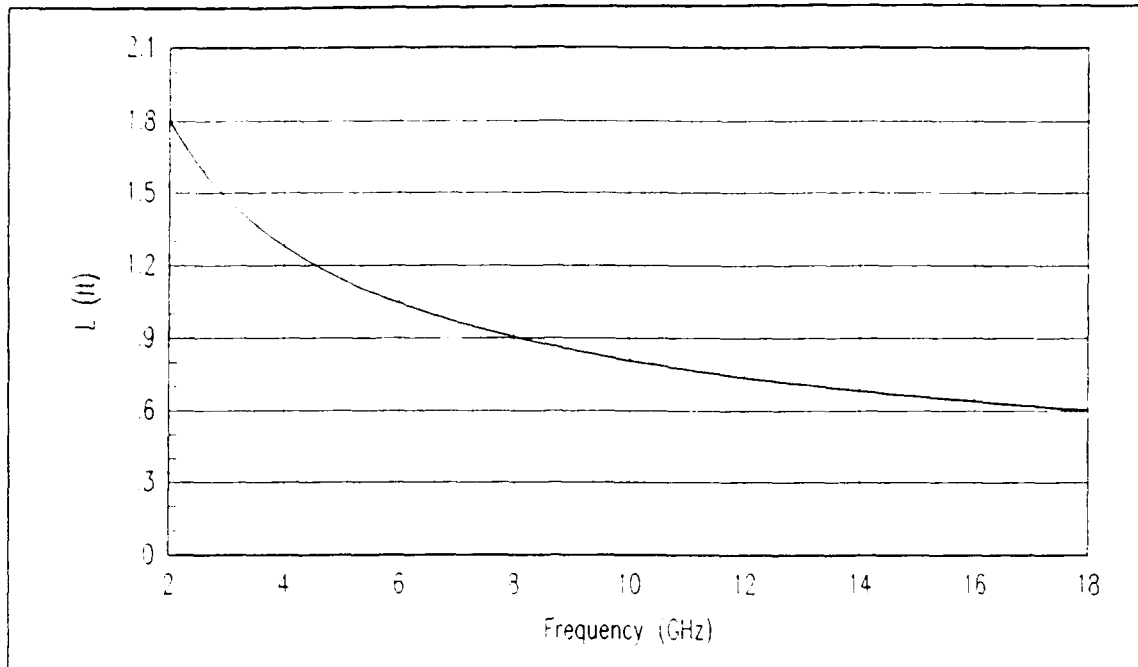


Point source model for phase variation
Figure 2-5

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).

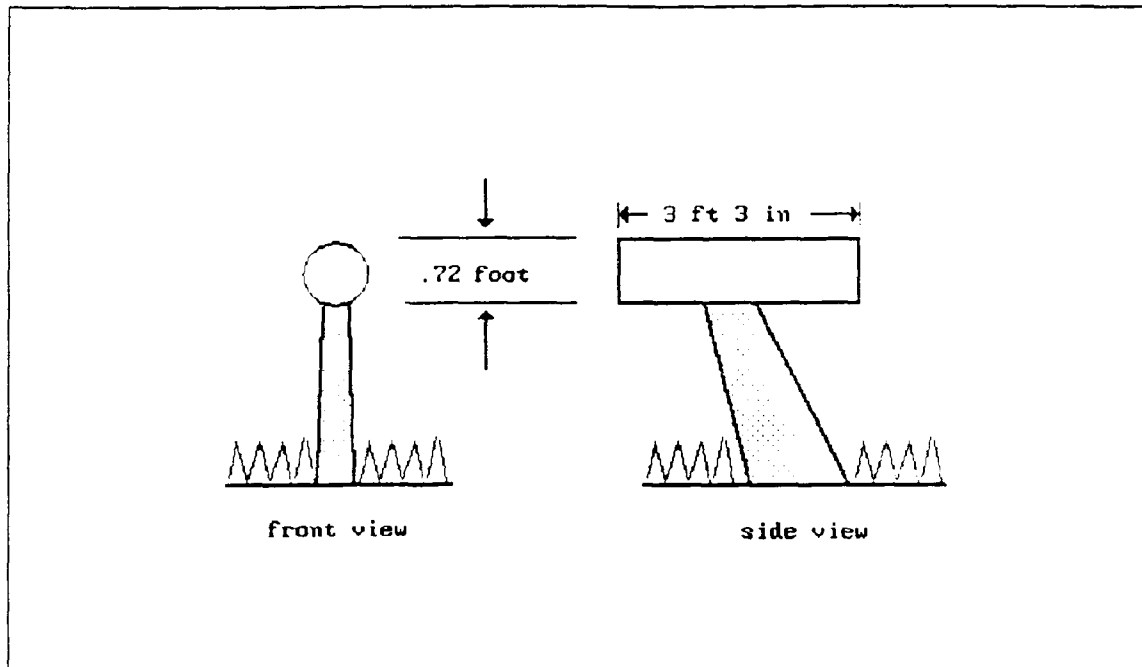
Recalling the fixed range separation in AFIT's chamber of 26.5 feet, equation 2-1 yields a value of 3.2 feet for the downrange extent of the target zone. Figure 2-6 displays L versus frequency for a range of 26.5 feet.



Crossrange extent of target zone versus frequency
Figure 2-6

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 9236 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.

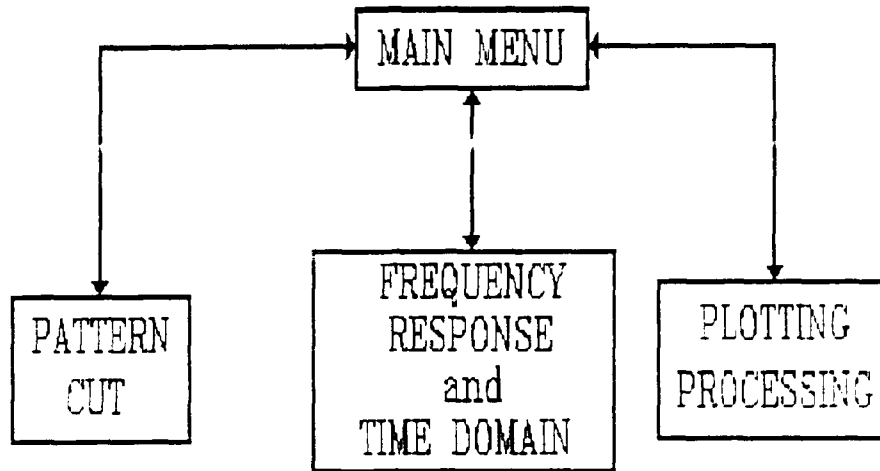
The overall organization of ARMS is shown in Figure 3-1. The motivation behind this structure is to separate the measurement activity from the plotting and processing activity. This organization was selected in part because of the ability and preference to transfer the calibrated data files from the 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 4π constant.

ARMS PROGRAM



ARMS organization
Figure 3-1

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/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.

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

where E^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

$$\sigma = 4\pi \left| F \frac{E^s}{E_{SM}^s} \right|^2 \quad 3-2$$

which, ideally is equivalent to

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

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

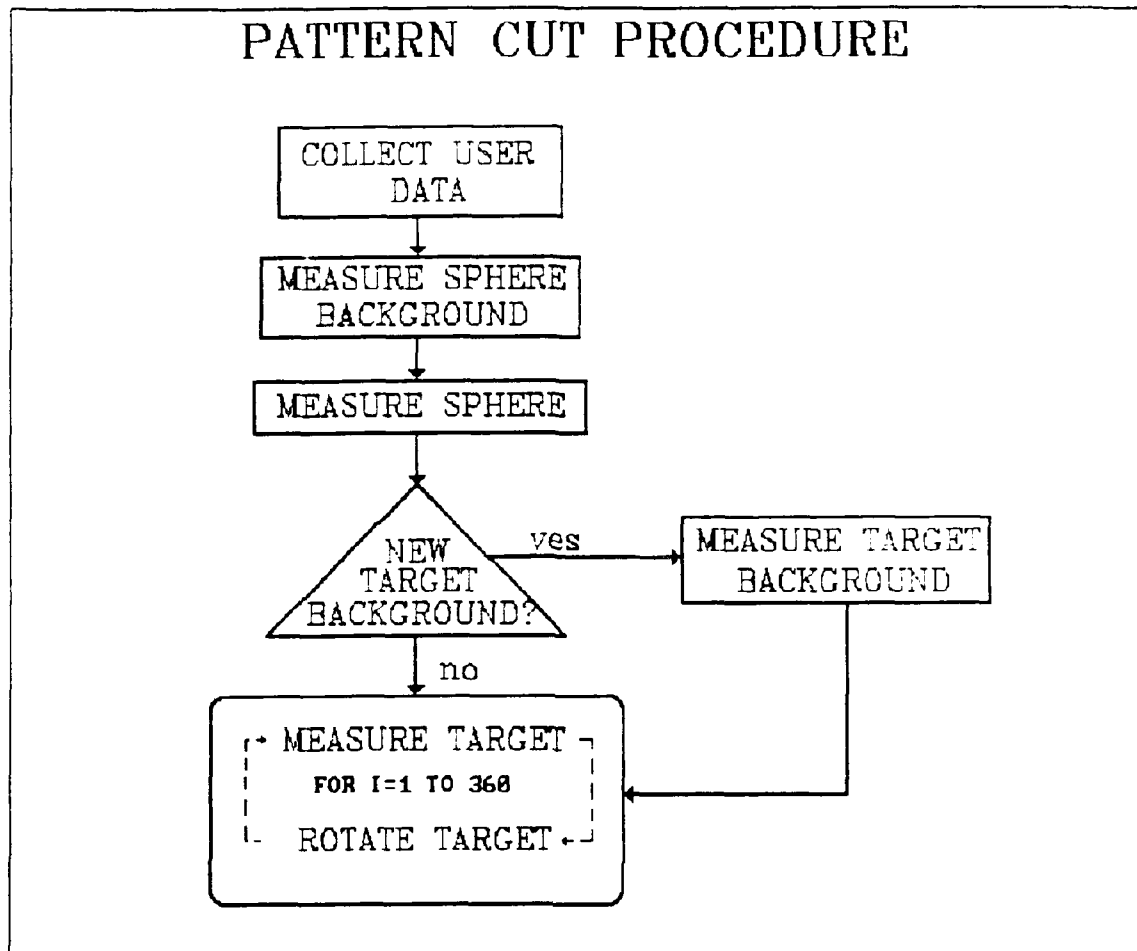
data is collected. The pattern cut is the first measurement option to be discussed.

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



Measurement procedure for a pattern cut
Figure 3-2

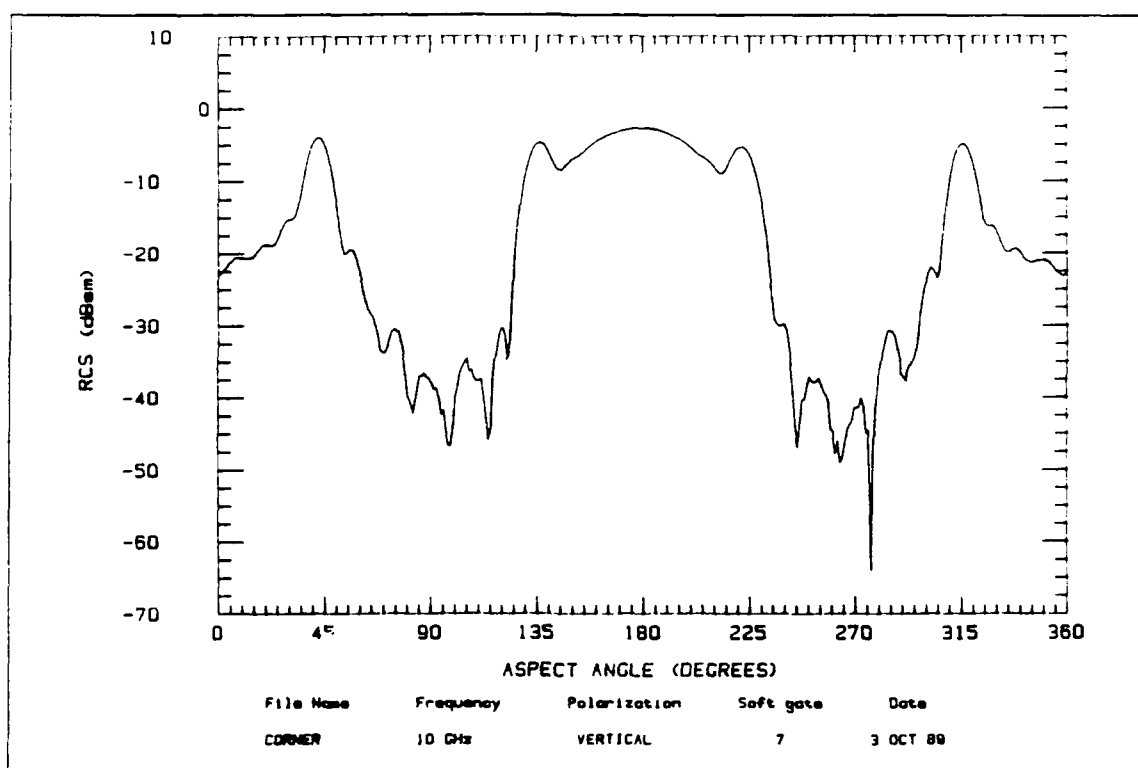
substitute the sphere background return for the target background return upon subtraction. If the target background is different, care should be taken that the target background, or mount, is symmetrical in the azimuthal plane since the mount will be rotated in a pattern cut. As before, the target background 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 last 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, πa^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.

$$\sigma_{\text{pattern cut}} = 10 \log(\pi a^2) + [\text{Target-Target_background}] \\ - [\text{Sphere - Sphere_background}] \text{ (dBsm)} \quad 3-3$$

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



Example plot of a pattern cut
Figure 3-3

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

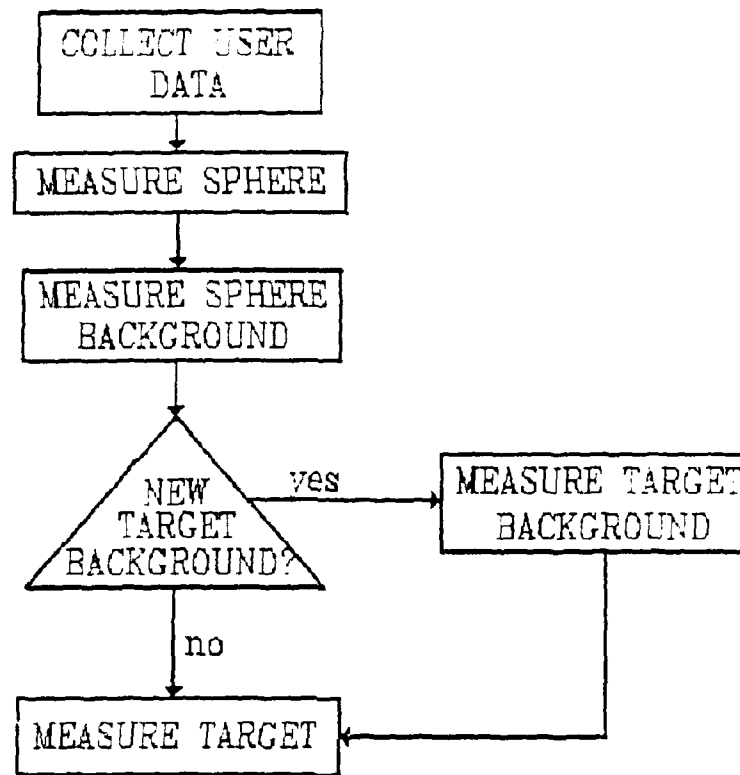
width of the software gate selected at the beginning of the measurement.

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

FREQUENCY RESPONSE PROCEDURE

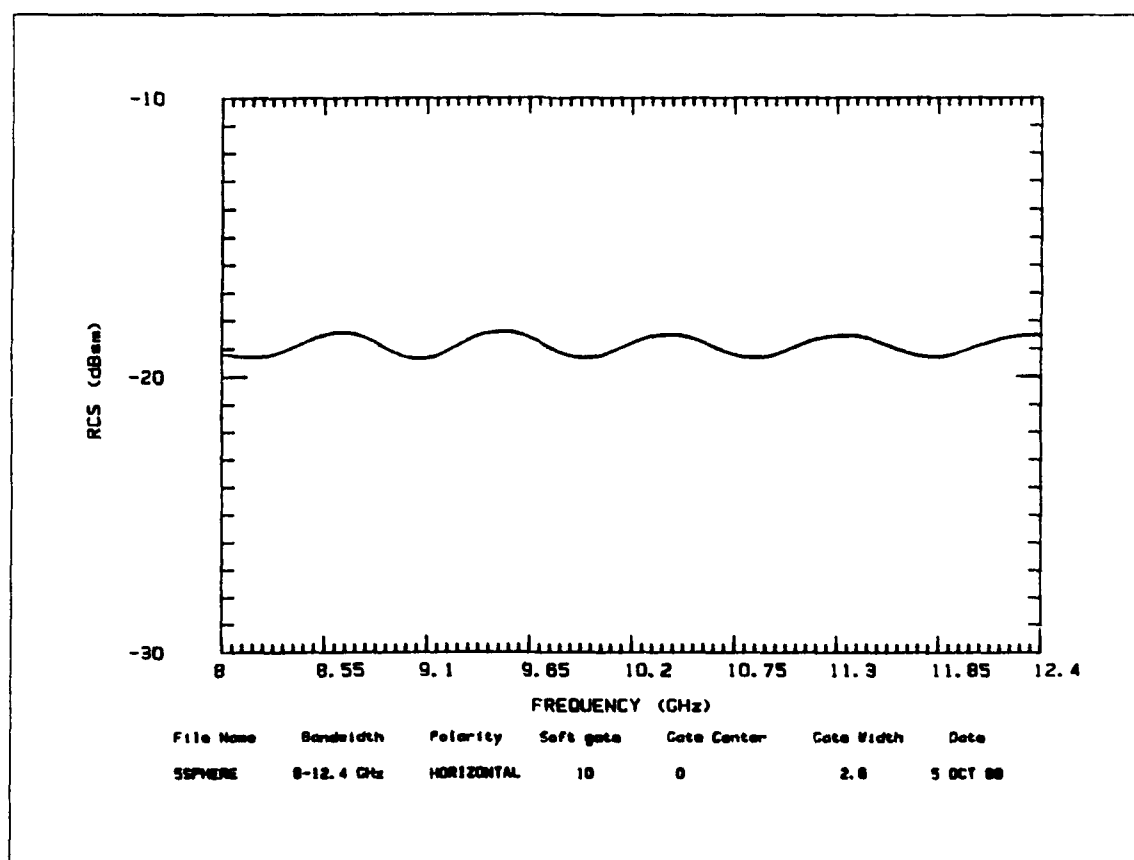


Measurement procedure for a frequency response
Figure 3-4

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
Figure 3-5

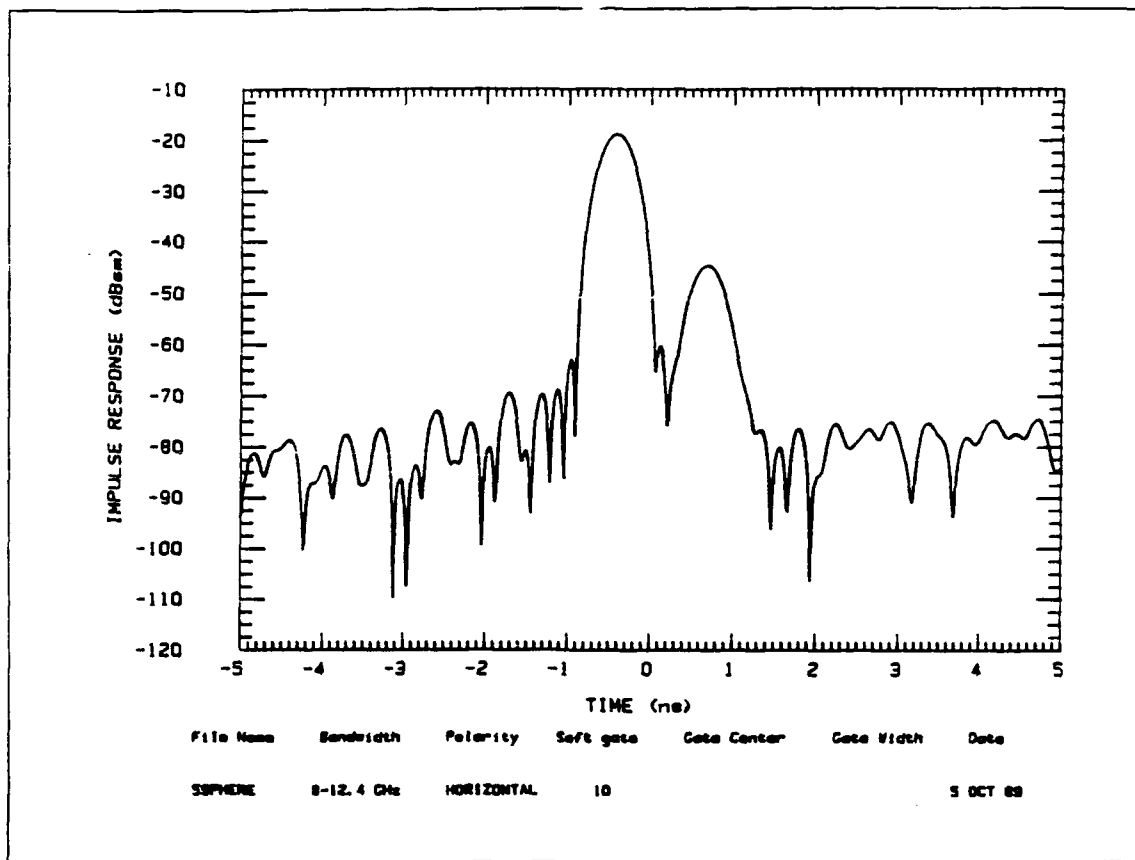
The target in the example frequency response in Figure 3-5 is a five inch sphere. The dominant contributor to the

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



Example plot of RCS vs time
Figure 3-6

illustration of aliasing is provided in Figure 3-7.

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 Δf 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

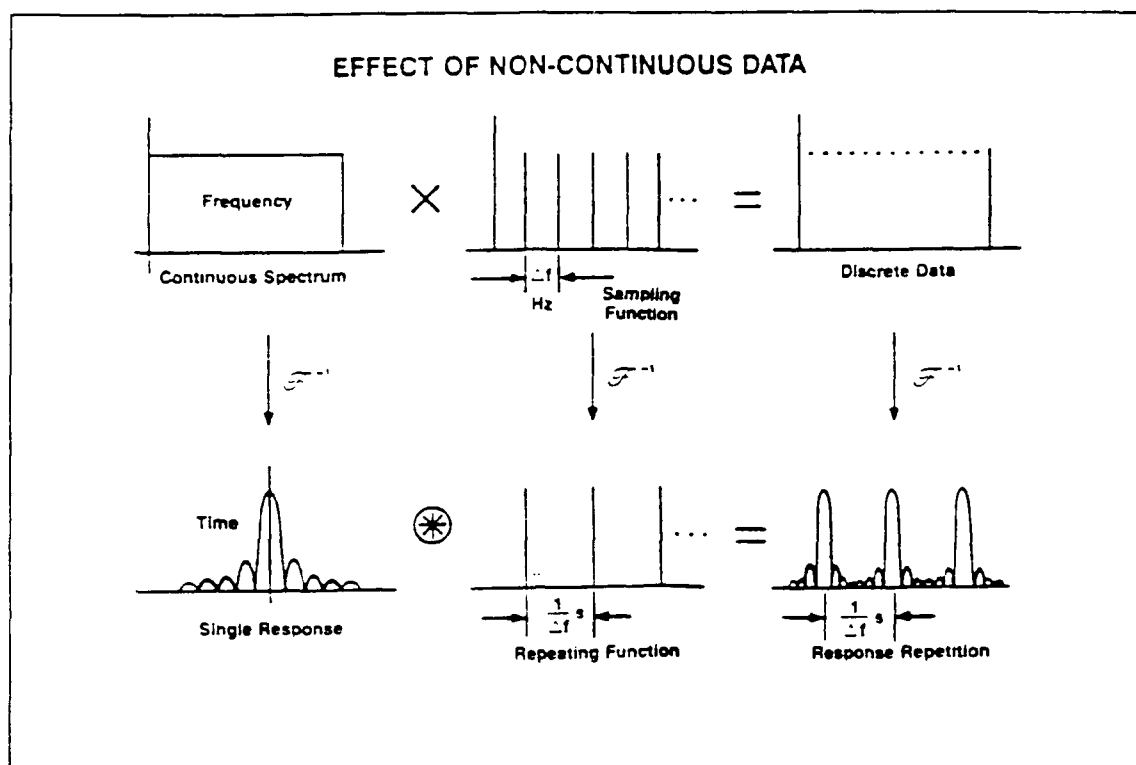


Illustration of aliasing
Figure 3-7 (1:Sec 3.5-11)

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

$$\text{Impulse Width} = 0.96/f_{\text{range}}(\text{Hz})$$

where f_{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,

$$\text{Display Resolution} = t_{\text{span}} / (\text{no. of points} - 1)$$

where t_{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.

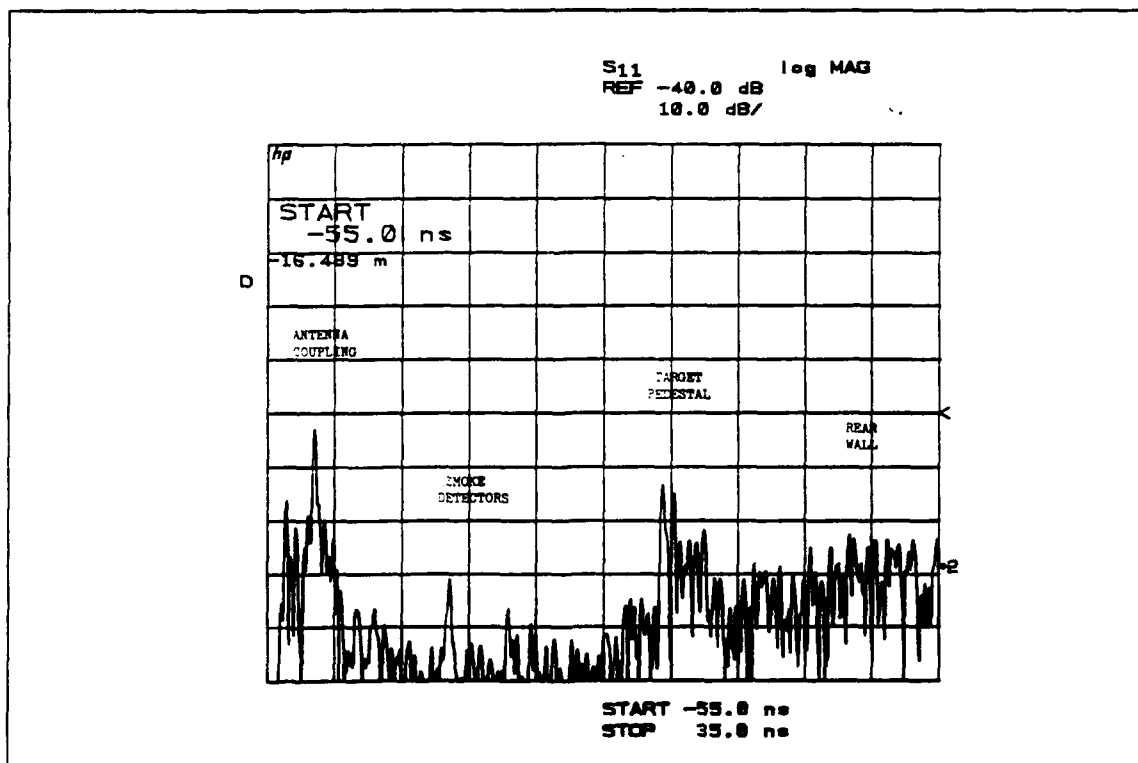
Noise Floor

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.

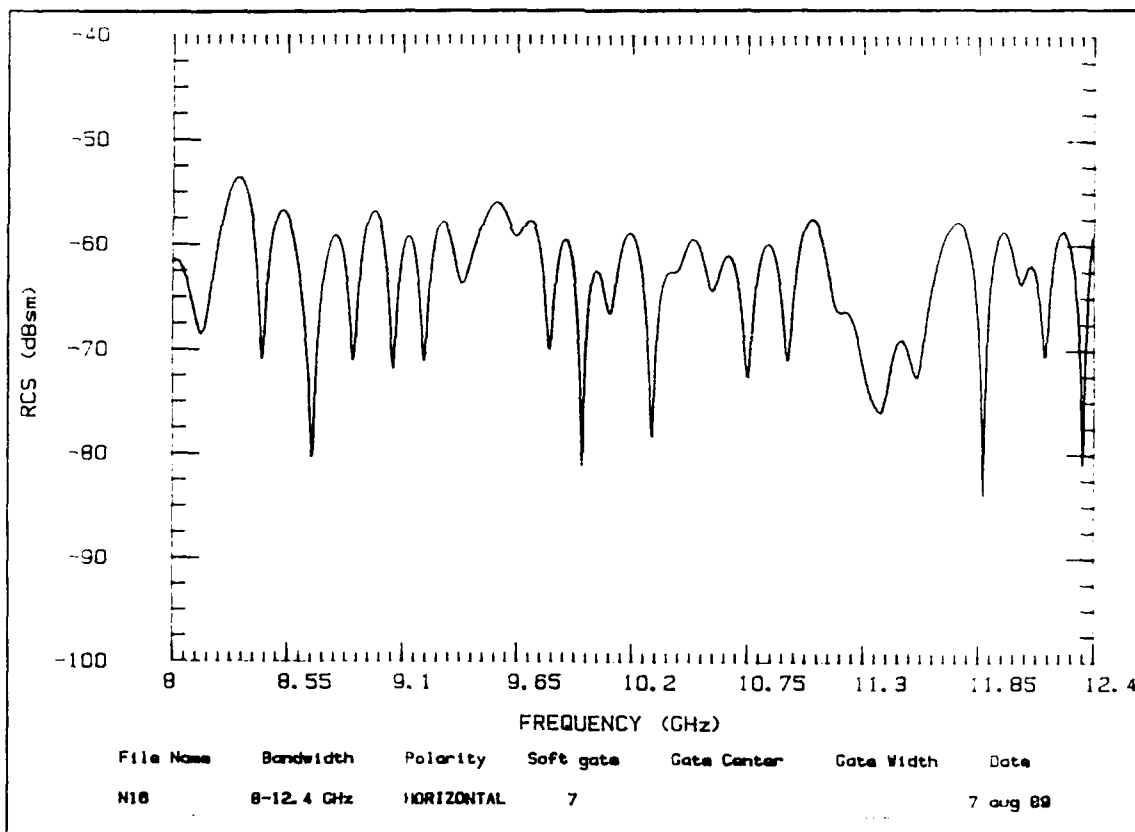
The unwanted signals can be partially removed by attenuation, vector subtraction, and hardware/software range gating. The chamber is lined with RAM which attenuates the energy as discussed in Chapter II. ARMS also utilizes vector subtraction and software range gating to reduce all unwanted signals. The 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



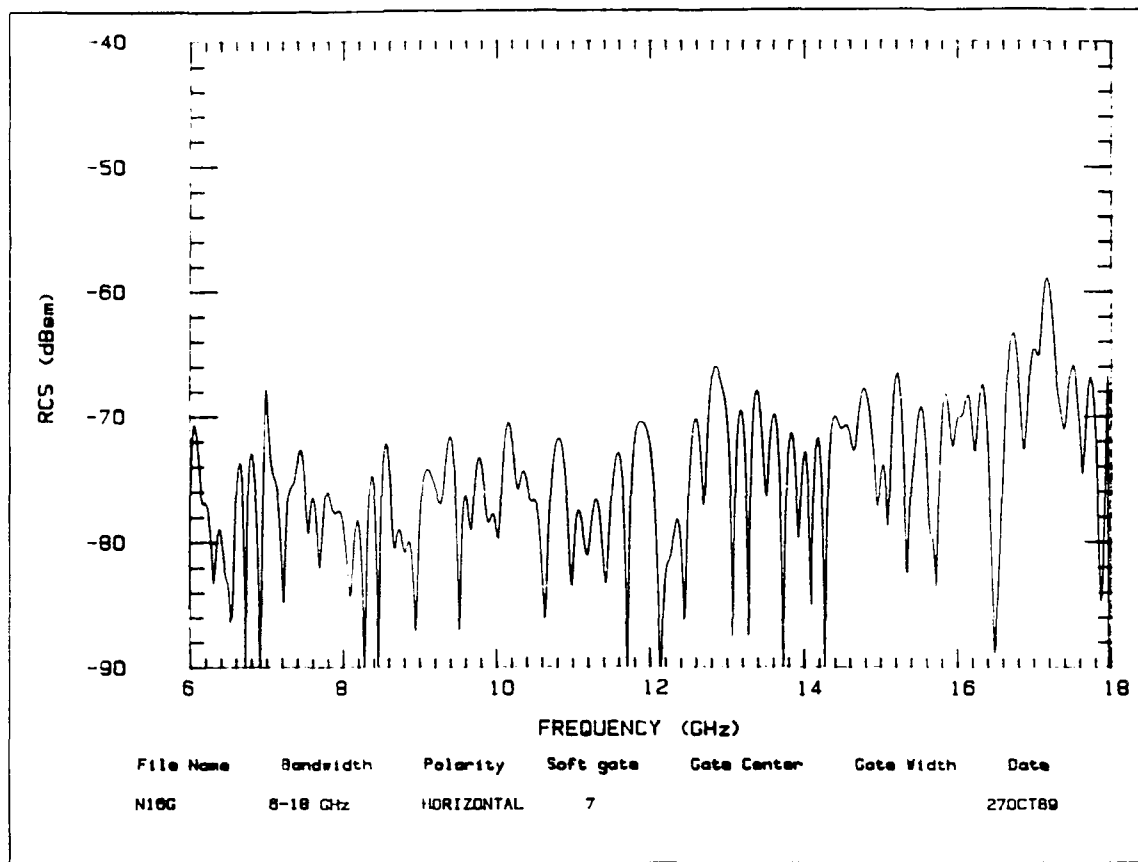
Noise floor of AFIT range using 8-12.4 GHz antennas; soft gate of 7 nsec, averaging factor of 16, and horizontal polarization
Figure 4-2

figure shows the RCS of the empty chamber between 8 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
Figure 4-3

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.

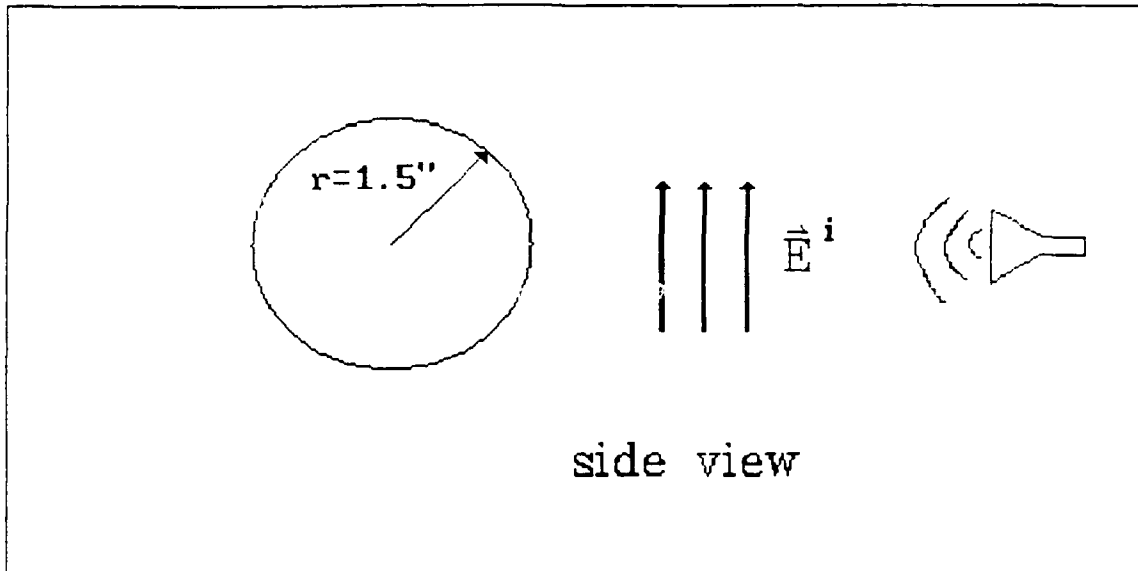
The Barn's range is built around a Lintek system instead of the Hewlett Packard Network Analyzer used at AFIT's range. The sources used in each chamber are identical, however the Barn has the capability to simulate a pulsed

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.



Orientation of cylinder for validation measurements
Figure 4-4

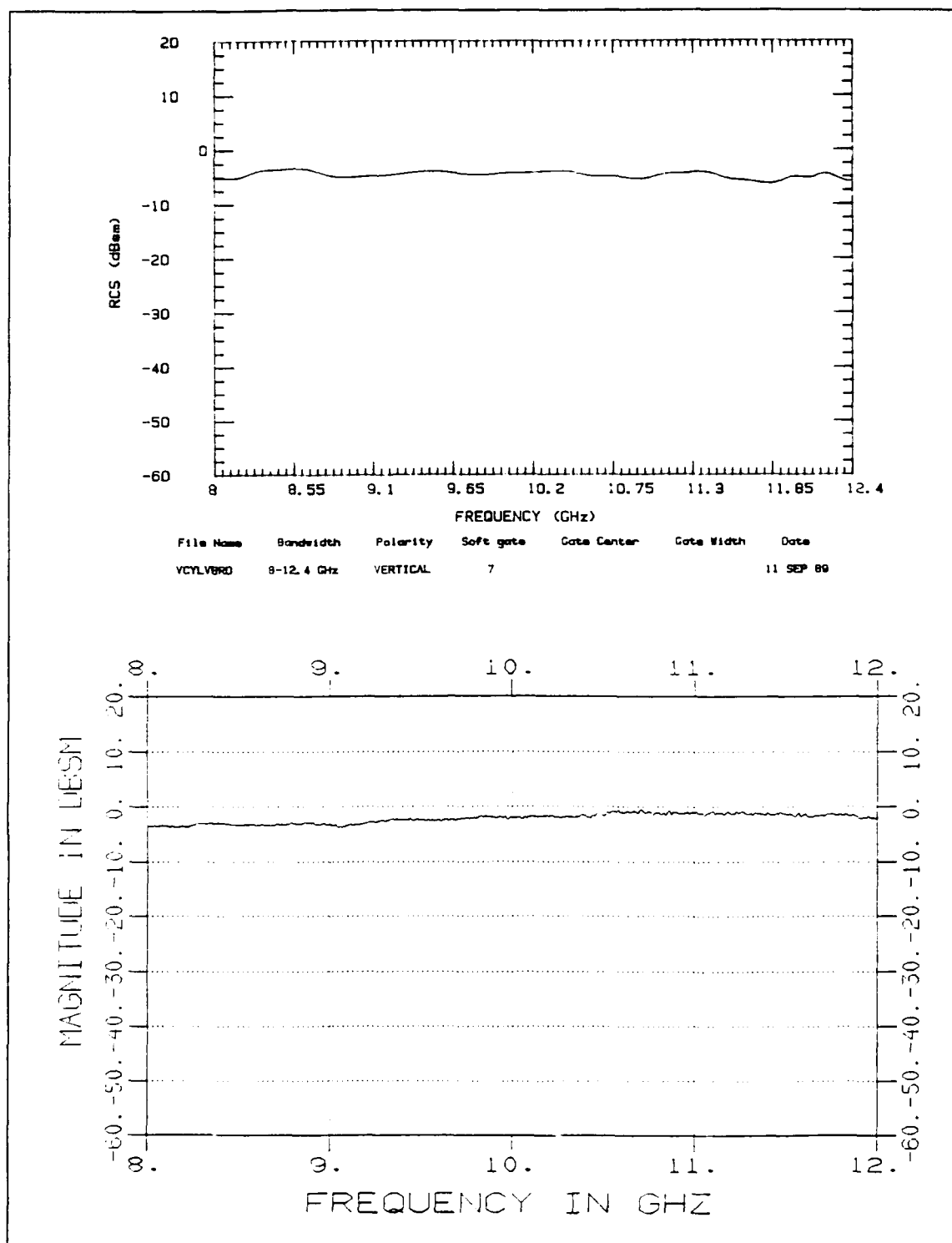
The high frequency approximation for the RCS of a cylinder at broadside is given as,

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

where a = radius of the cylinder
 l = length of the cylinder
 λ = 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

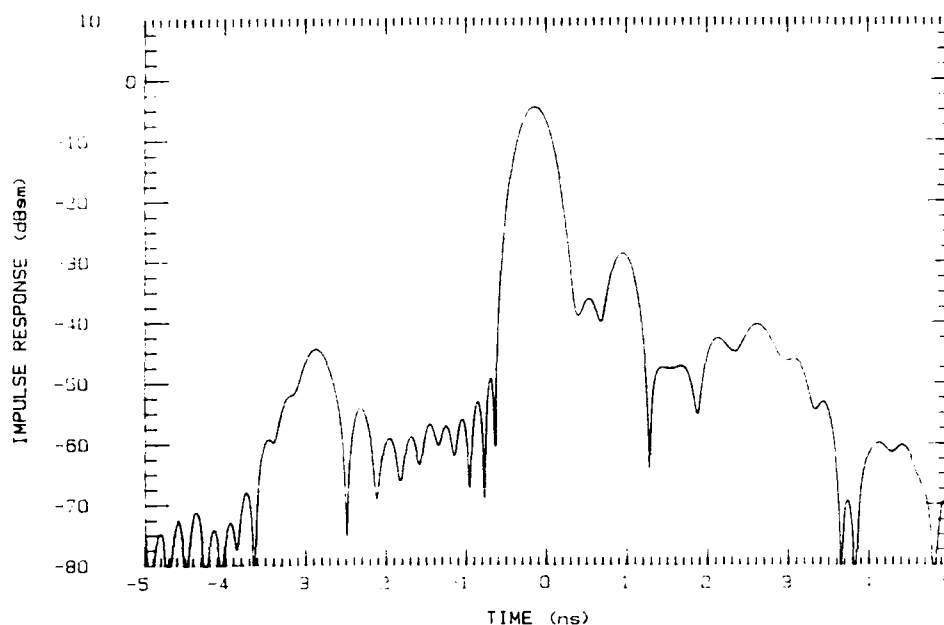


Frequency response from 8 to 12.4 GHz of a cylinder of length 12.25 inches and radius 1.5 inches at broadside and vertical polarization at a) AFIT and b) the Barn
Figure 4-5

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.

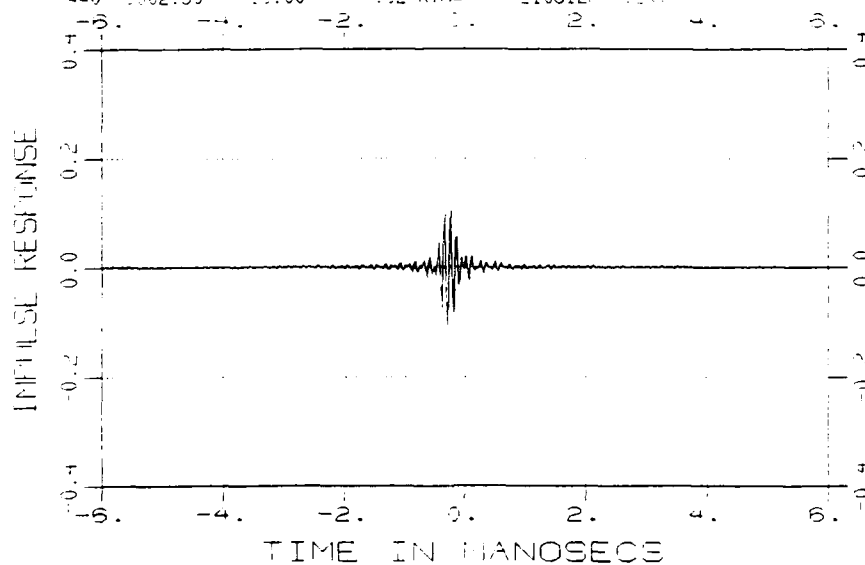
Analysis Technique

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.

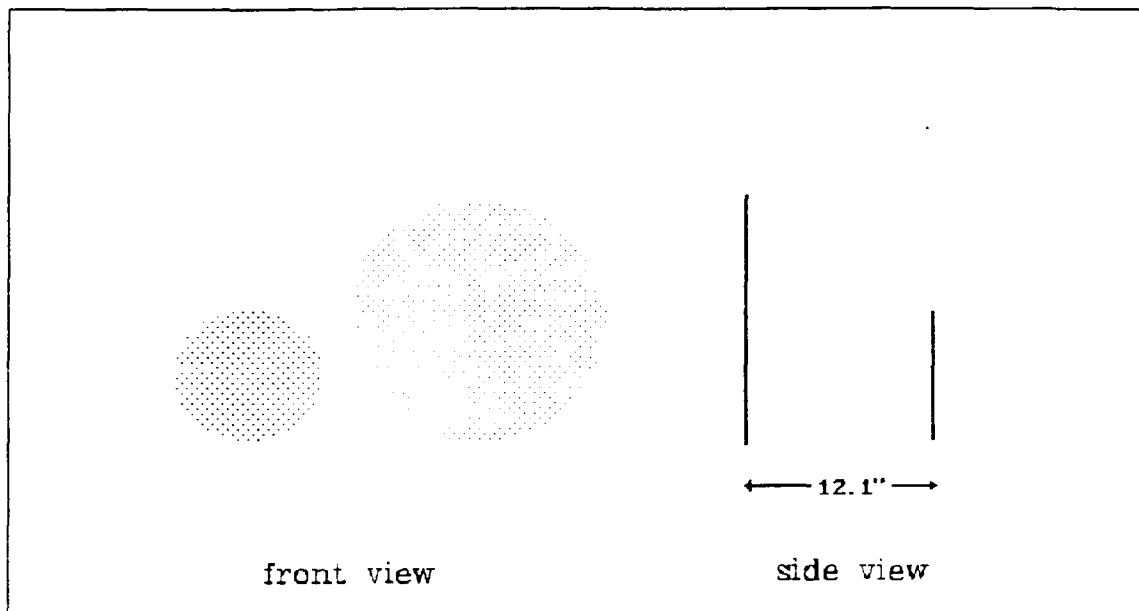


File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
VCYLVRD	8-12.4 GHz	VERTICAL	7			11 SEP 89

09250FA0000-A FREQ: 09-07-89 08:49 09250FA0000-A.STA
 TARGET 12.25" CYLINDER AVE= 84 09250FA0000-A.REF
 DEG=BROSIDE IP REF= 09250FA0000-A.BRE
 440 9002.30 10.00 1.02 ATN= E10812F-A.EXT



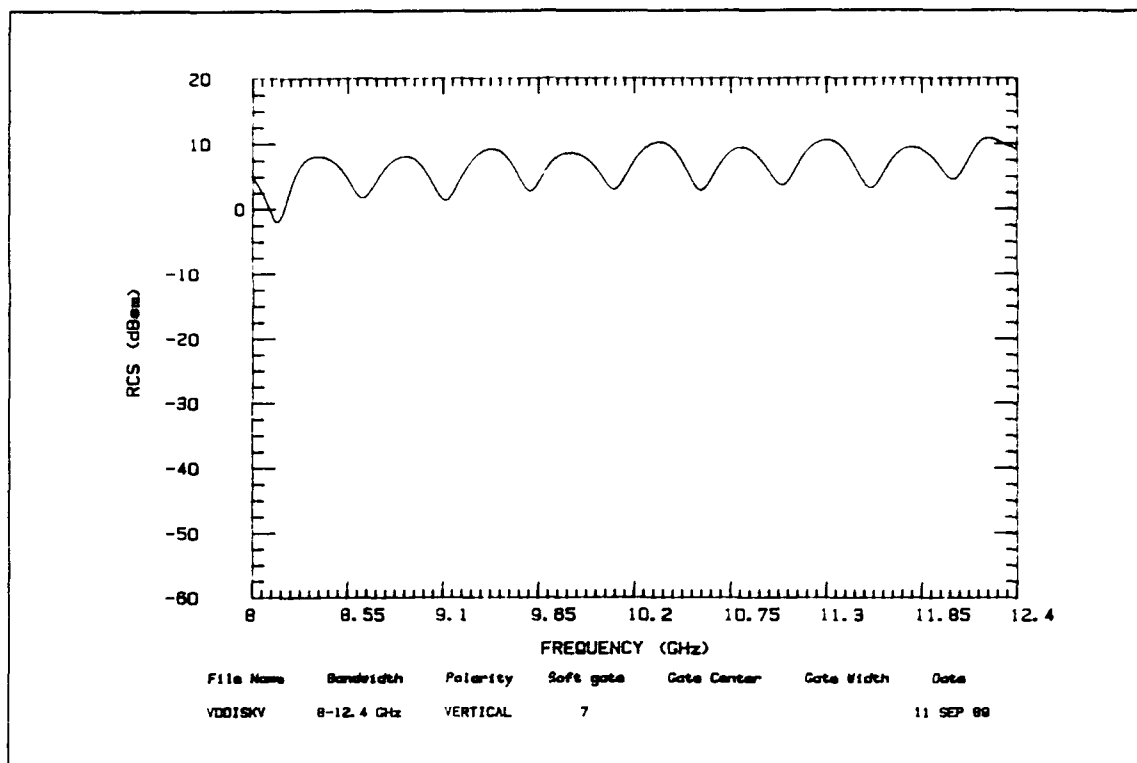
Time domain view of cylinder at a) AFIT and b) the Barn
 Figure 4-6



Orientation of circular flat plates for
validation measurements

Figure 4-7

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

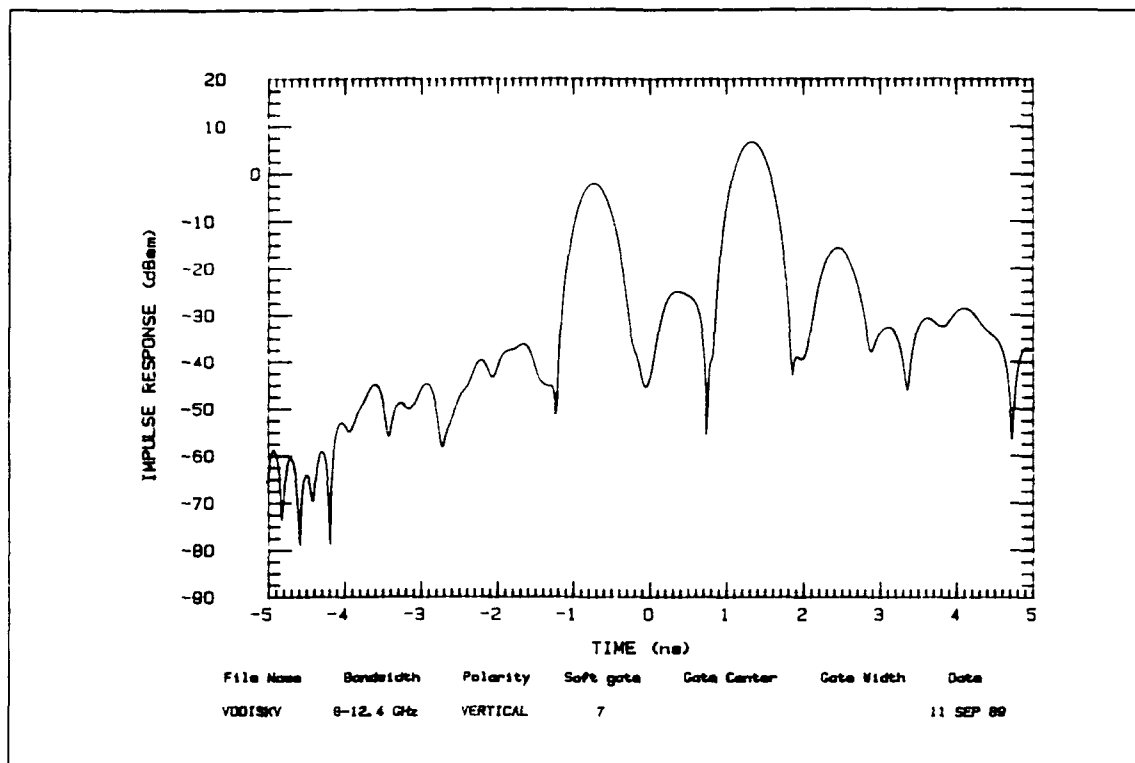


Frequency response of circular flat plates with vertical polarization
Figure 4-8

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.

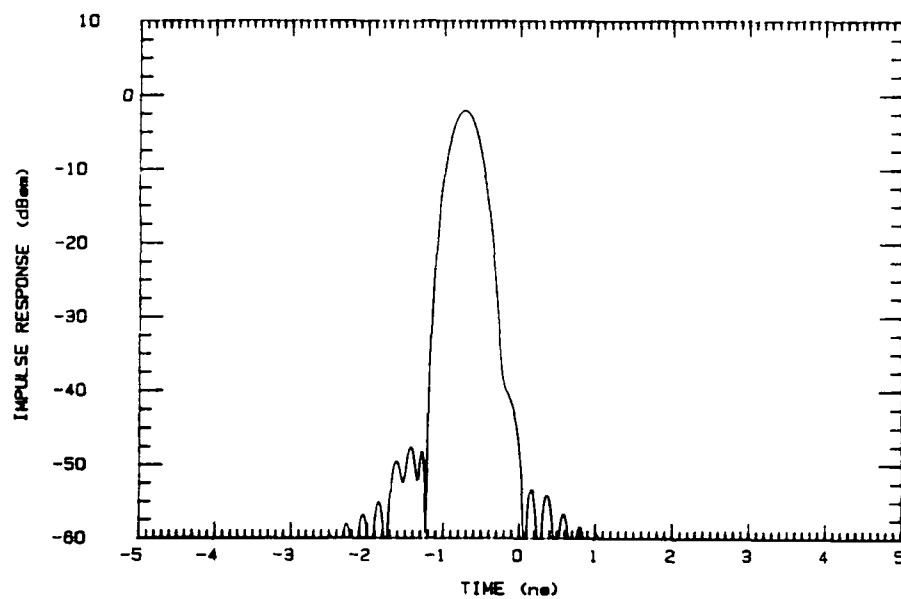
The RCS of a flat plate is dependent on the angle of incidence and wavelength of the incident wave. According to the high frequency prediction formula, $\sigma = 4\pi A^2 / \lambda$, where A is the area of the plate and λ is the wavelength, the RCS of a



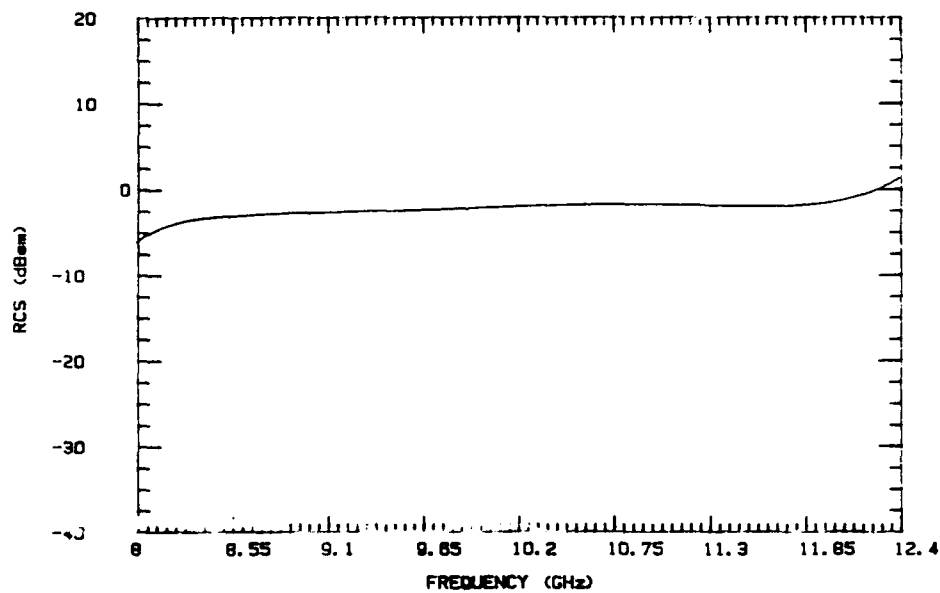
Time domain view of RCS of two plates
Figure 4-9

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.



File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
VDDISRV	8-12.4 GHz	VERTICAL	7	-0.71	1.3	11 SEP 88



File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
VDDISRV	8-12.4 GHz	VERTICAL	7	-0.71	1.3	11 SEP 88

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

available for use at the AFIT chamber for these measurements. The illuminating frequencies for pattern cuts were 8 GHz and 10 GHz.

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

hamber	Type Meas	Pol	Freq (GHz)	F-18			F-15			TEST BODY	
				CAN	SET	COC	CAN	SET	COC	CAN	COC
A F I T	FREQ	VERT	8-12.4	X	X	X	X	X	X		
			6-18							X	X
	RESP	HORIZ	8-12.4	X	X	X	X	X	X		
			6-18							X	X
	PATTERN CUT	VERT	8								
			18	X	X	X	X	X	X		
		HORIZ	8	X	X	X					
			18	X	X	X	X	X	X		
B A R N	FREQ	VERT	8-12.4	X	X	X	X	X	X		
			6-18	X		X	X		X	X	X
			2-18	X	X	X	X	X	X	X	X
	RESP	HORIZ	8-12.4								
			6-18	X		X	X		X	X	X
			2-18	X		X	X		X	X	X
	PATTERN CUT	VERT	8	X		X	X		X		
			18	X		X	X		X		
		HORIZ	8								
			18								

Measurement test matrix
Figure 5-1

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.

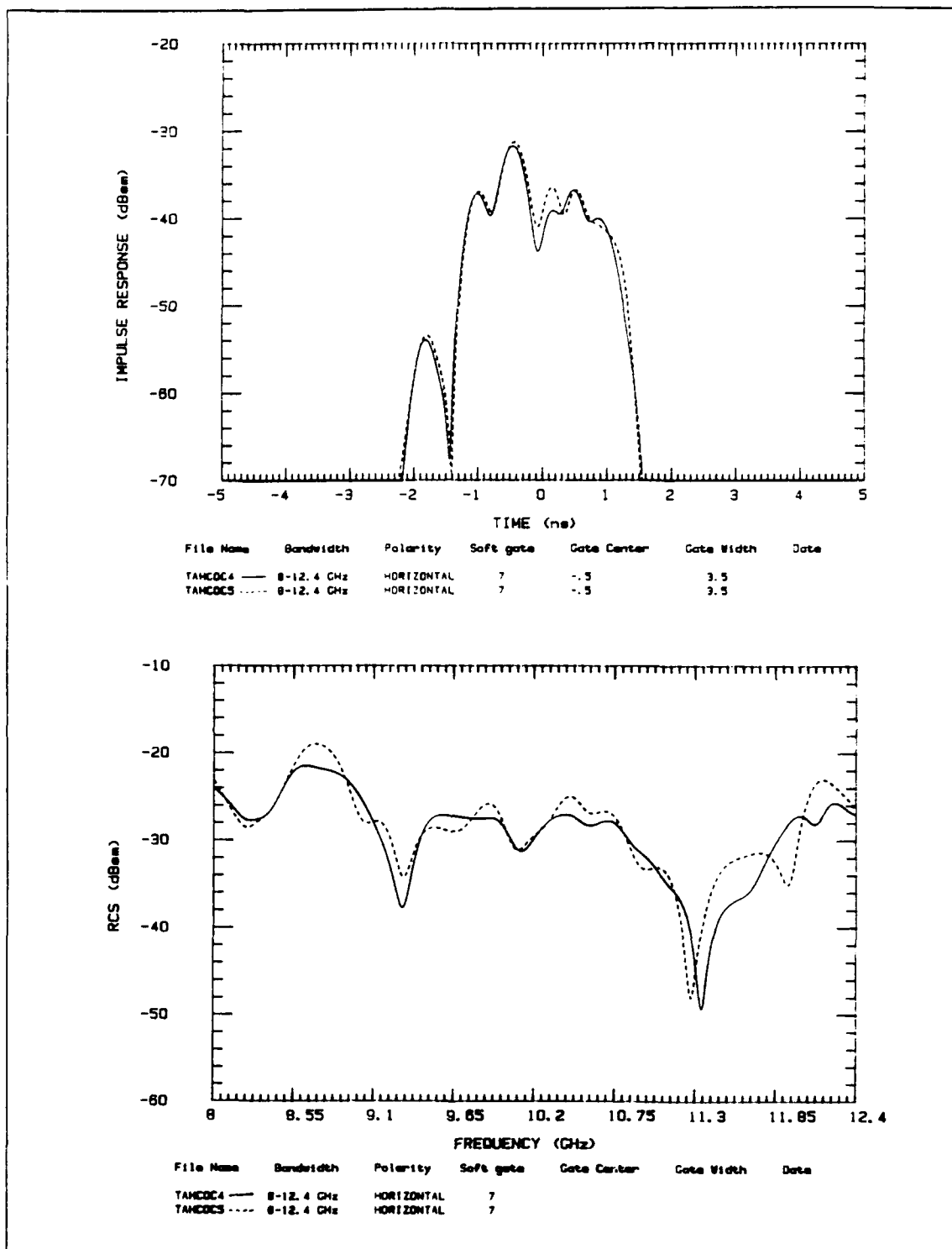
Due to the limited space available for labeling the plots, the filename is encoded. The first two letters designate the target; the third letter designates the polarization of the incident field; the fourth, fifth, and sixth letters represent the target configuration; and the seventh and eighth letters 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.

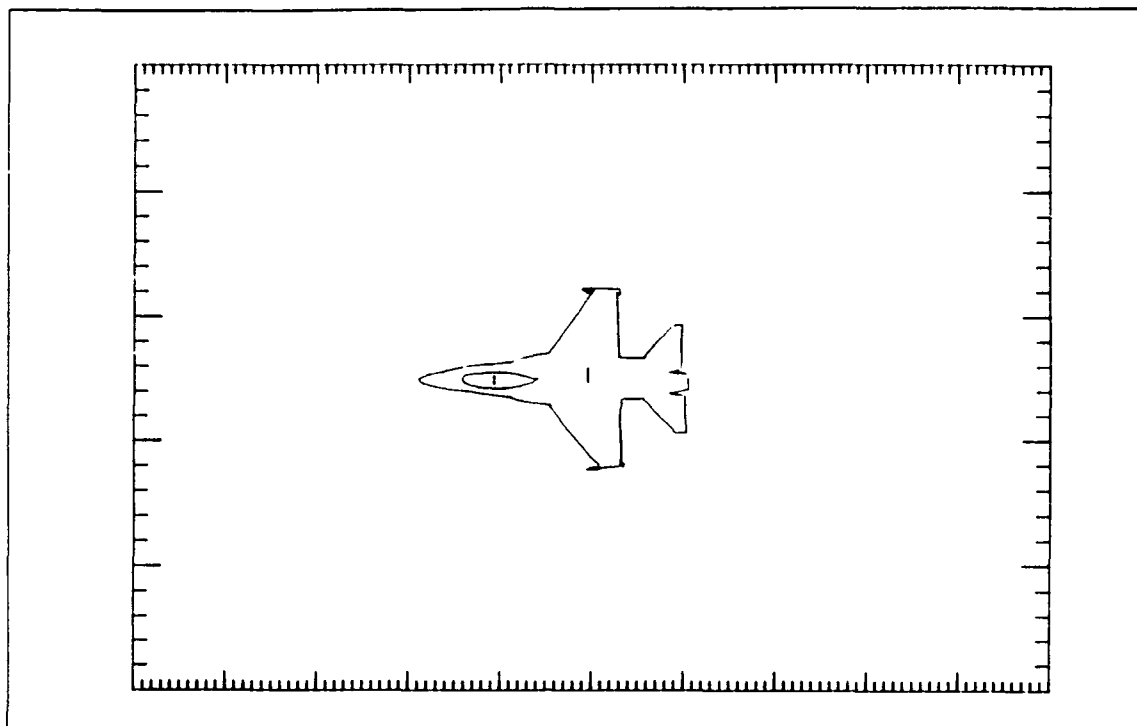
An extensive number of frequency response measurement runs were performed to resolve this concern, and all target configurations produced the same conclusions. Figure 5-2 shows the RCS for two independent measurements of the F-16 without the canopy or seat in the time domain and frequency domain. The 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,



Template for time domain analysis of 1/32 scale F-16
Figure 5-3

scattering from the tail of the F-16 corresponds to 1.05 nsec from the center of the reference target.

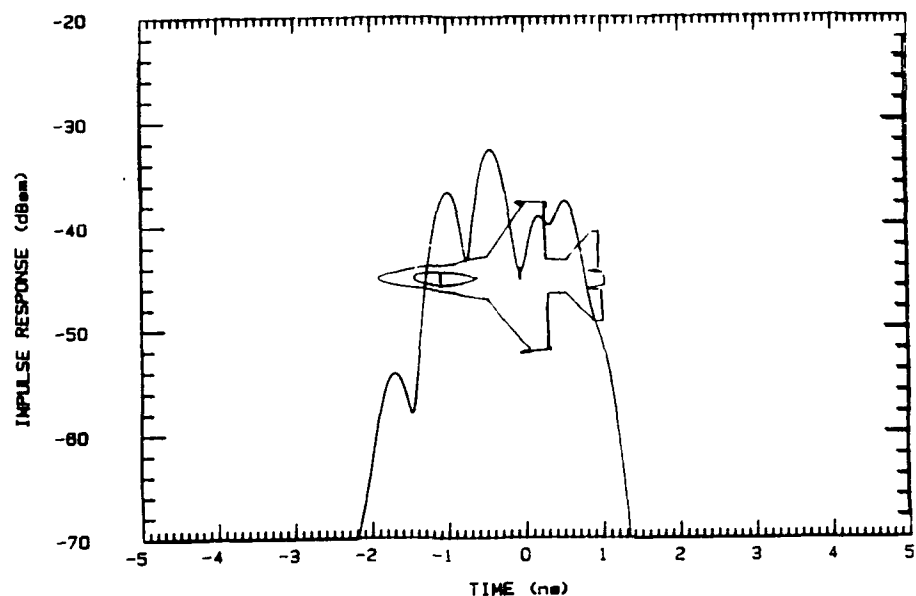
F-16, 8 to 12.4 GHz, horizontal polarization, AFIT. The first target to be analyzed is the 1/32 scale F-16 (TA) with a horizontally polarized incident field. The next three figures (Figures 5-4 through 5-6) show the RCS for each of the three target configurations in the time domain and frequency domain.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

The first scatterer in all three measurements is unmistakably due to the nose of the target. The -55 dBsm level of the return is comparable to the RCS of a similarly

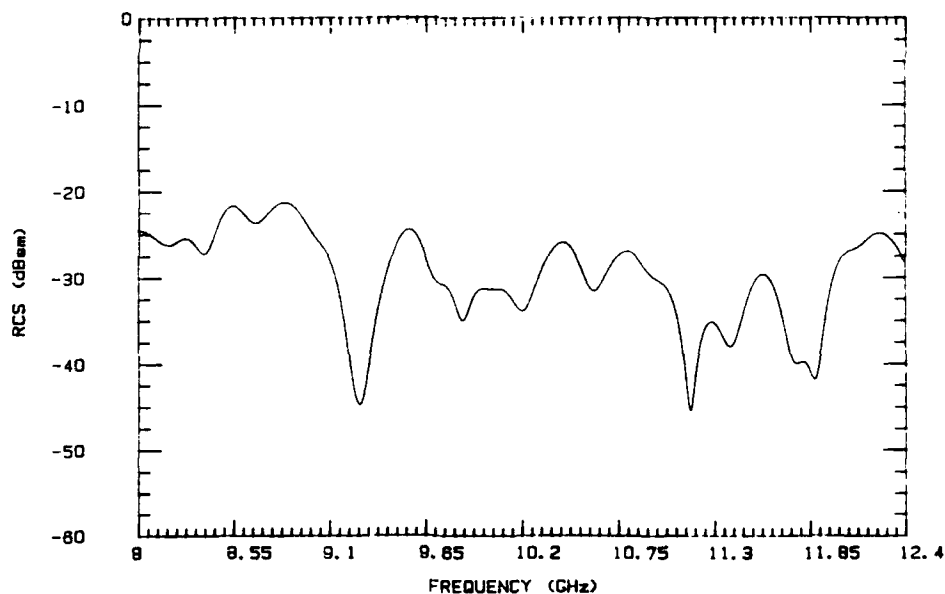
dimensioned cone, and the time of the return, -1.75 nsec, closely corresponds to the downrange location of the nose.

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

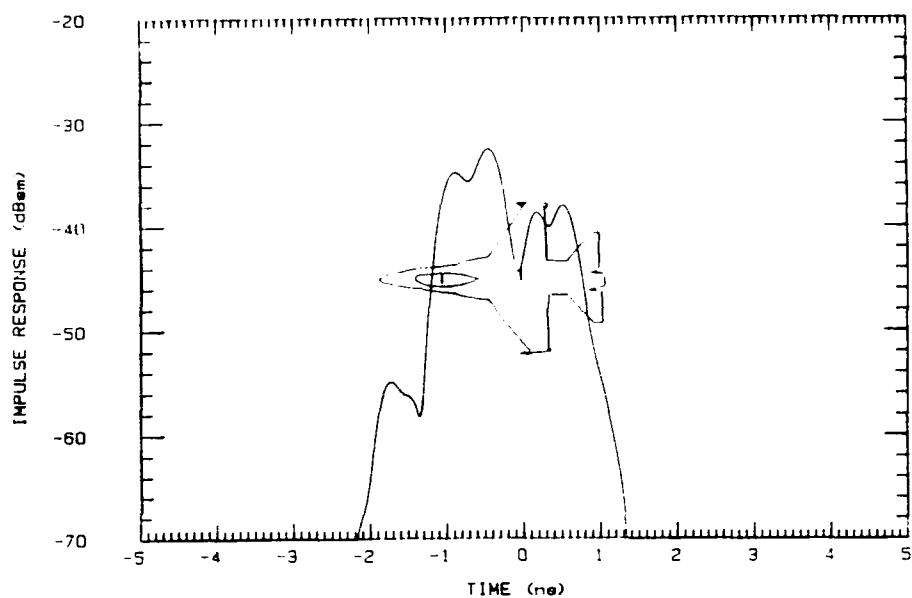


File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
TAHCAN28	8-12.4 GHz	HORIZONTAL	7	-1.5	3.01	3 OCT 88

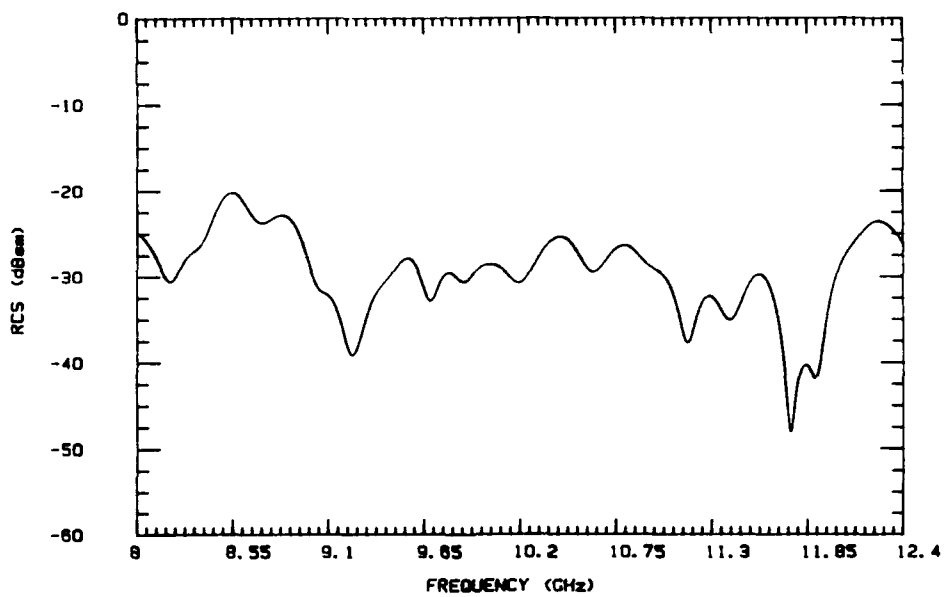


File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
TAHCAN28	8-12.4 GHz	HORIZONTAL	7			3 OCT 88

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

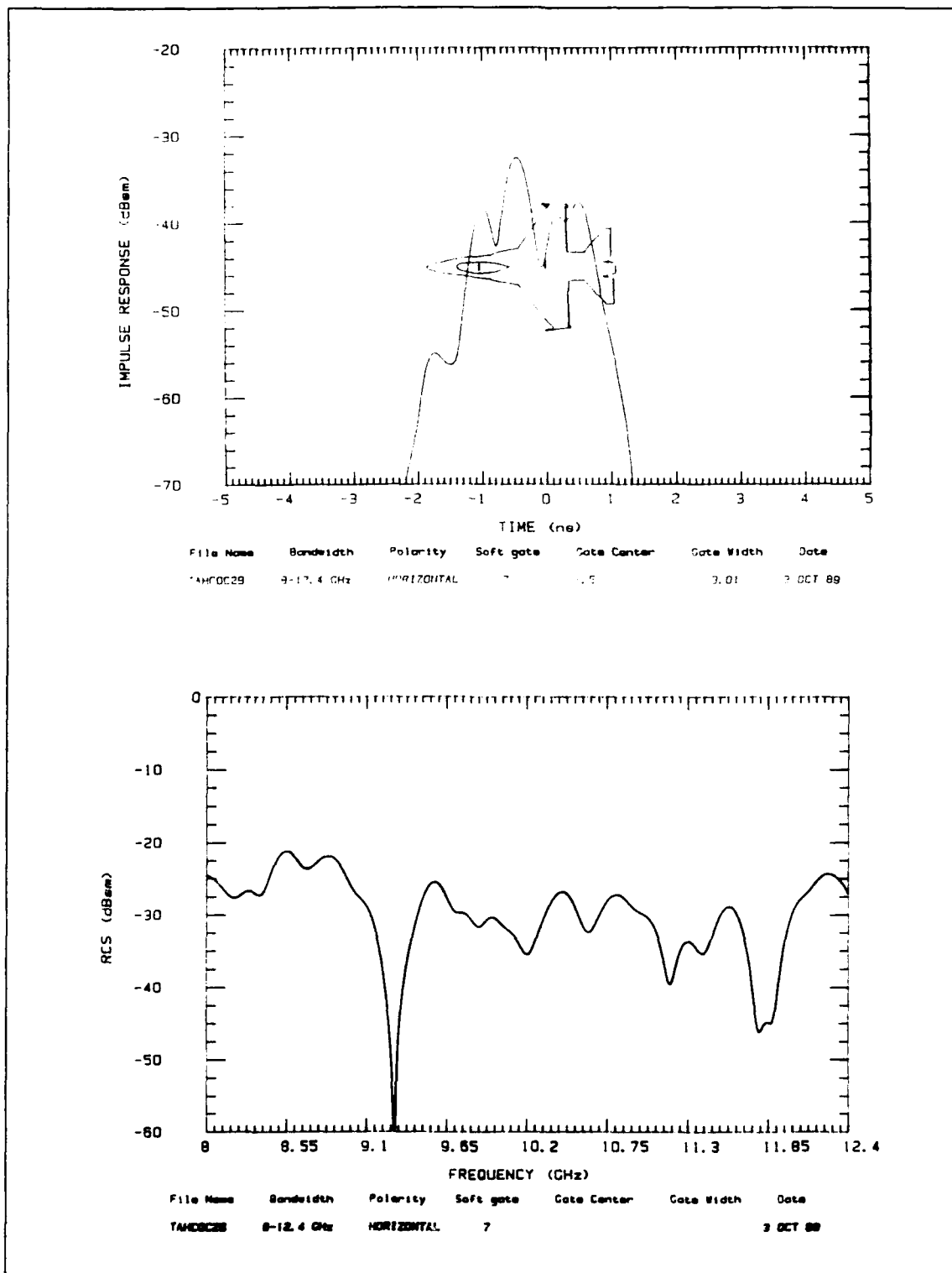


File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
TARGET28	8-12.4 GHz	HORIZONTAL	7	-1.5	3.01	3 OCT 89



File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
TARGET28	8-12.4 GHz	HORIZONTAL	7			3 OCT 89

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 believed to be a result of the scattering from the end of the engine inlet cavity.

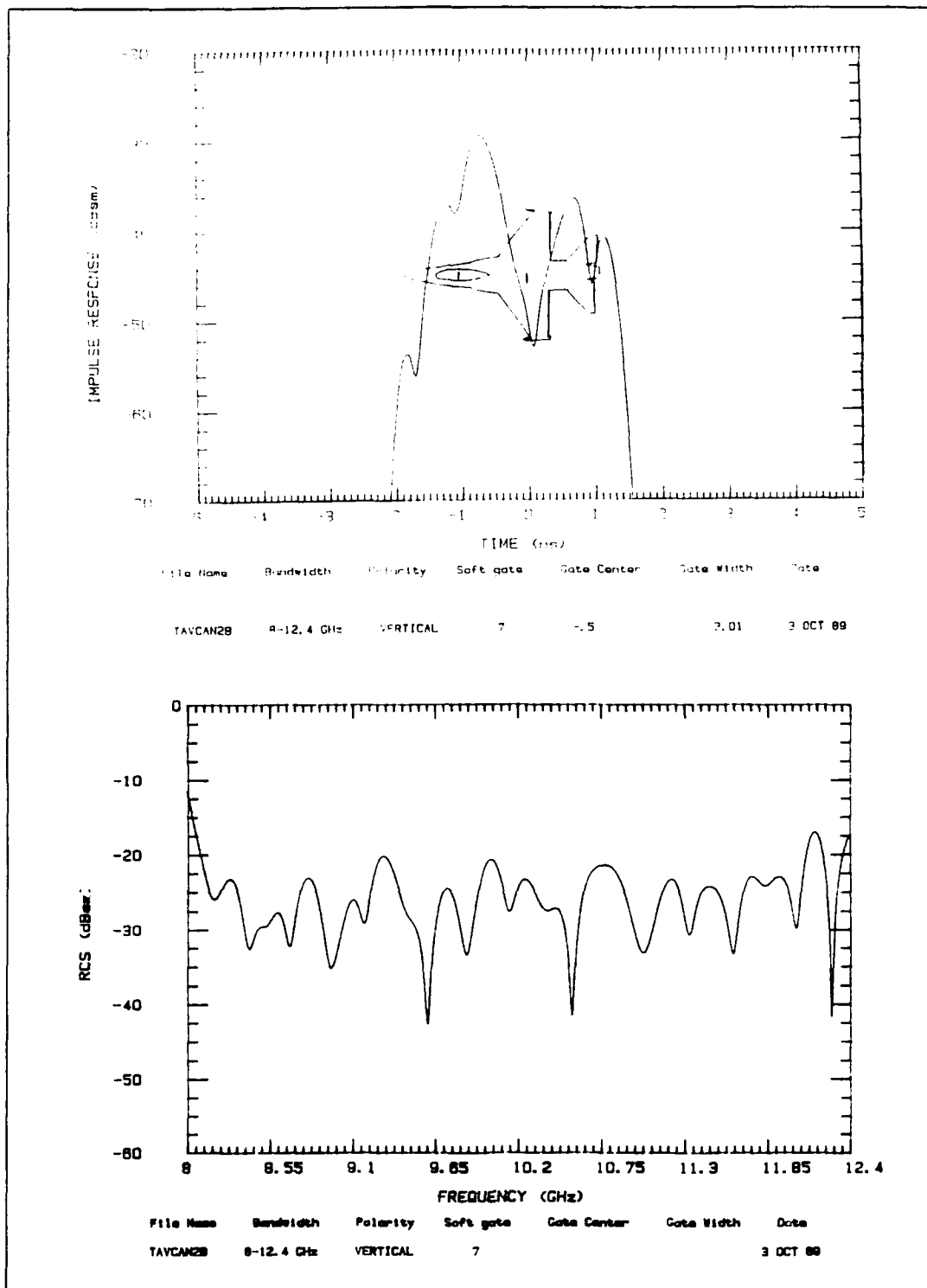
In summary, for a horizontally polarized incident field, little information regarding the scattering from the canopy/cockpit area of the F-16 model was gained. This is primarily because the electric field was aligned with and scattered from the horizontally oriented and oblong-shaped engine inlet, thus 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

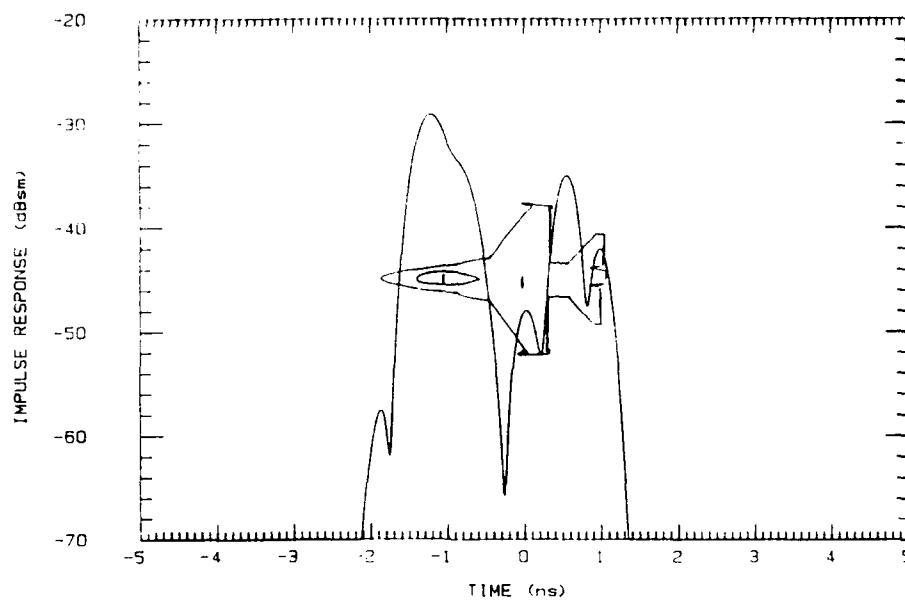
with the preceding horizontally polarized measurements, the data is provided in a series of six plots (Figure 5-7 through 5-9). As before, the nose of the aircraft is the first resolvable scatterer based on the temporal location and magnitude of the response. The level is almost 4 dB lower than the same 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.

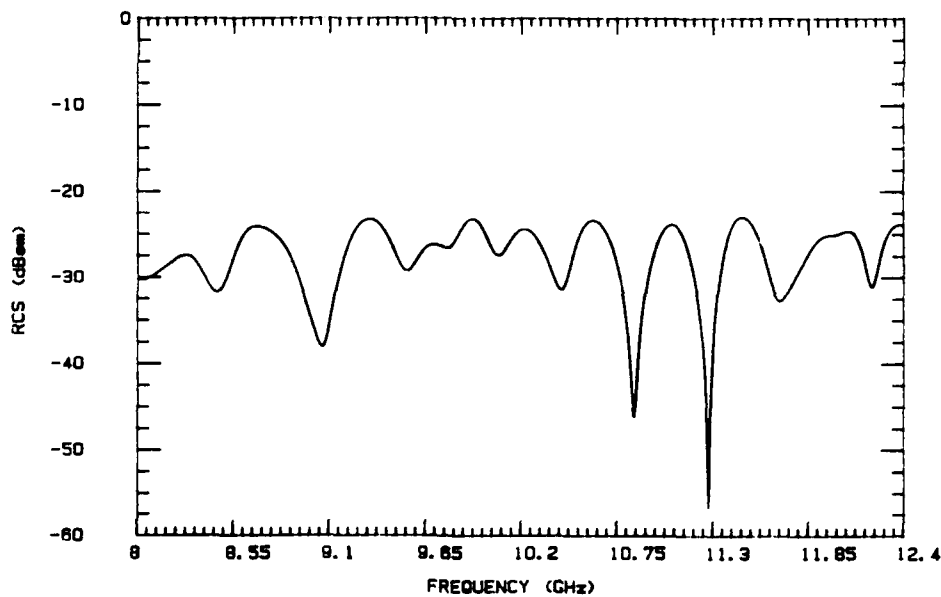
Another unexpected result occurs at -0.7 nsec which corresponds to the discontinuity caused by the intersection between the back of the canopy and the fuselage. Significant scattering occurs with the canopy, possibly via a traveling wave propagating from the front of the canopy to the back. Also, the 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

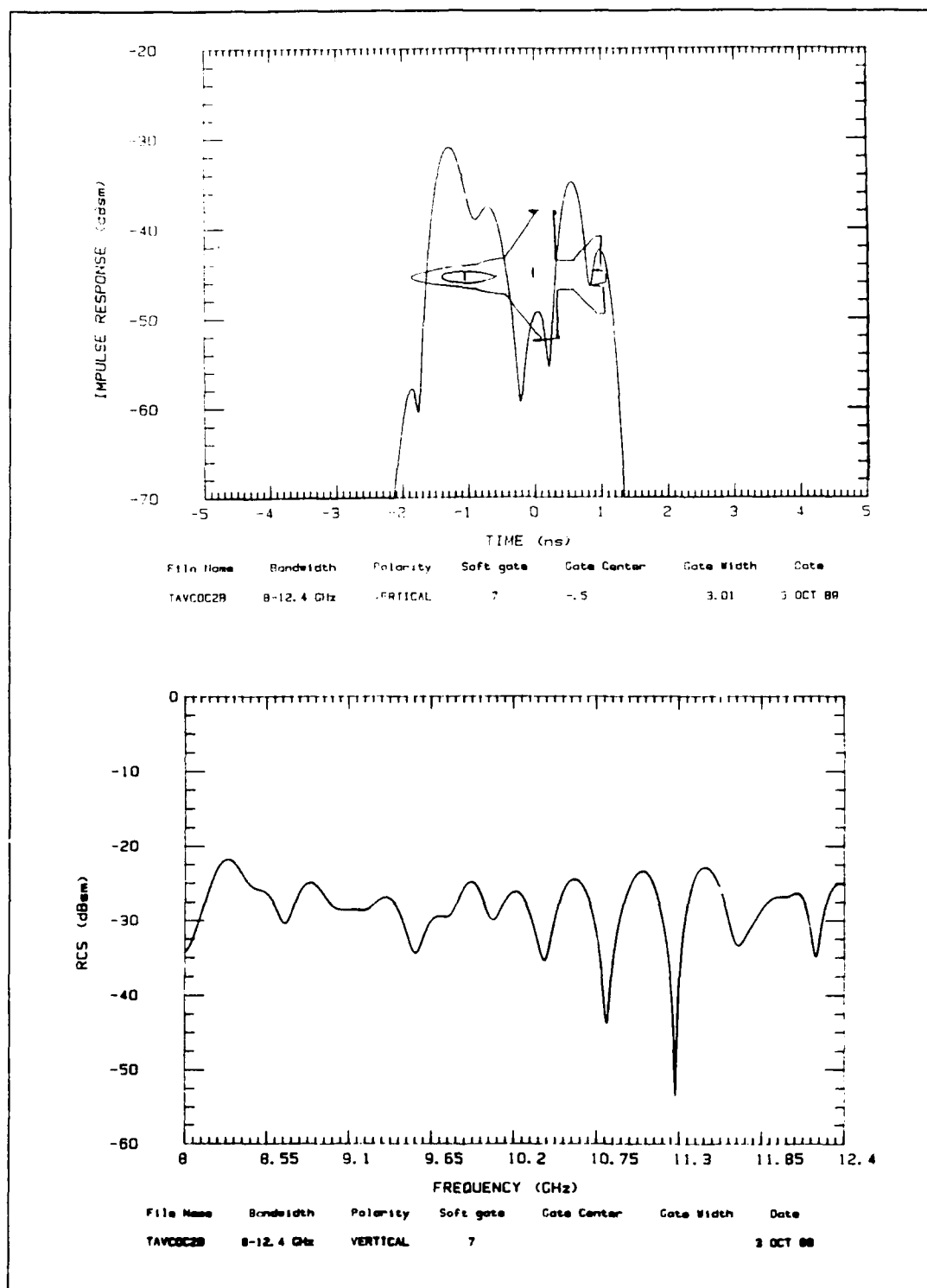


File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
AVSET2B	8-12.4 GHz	VERTICAL	7	-1.5	3.01	3 OCT 89

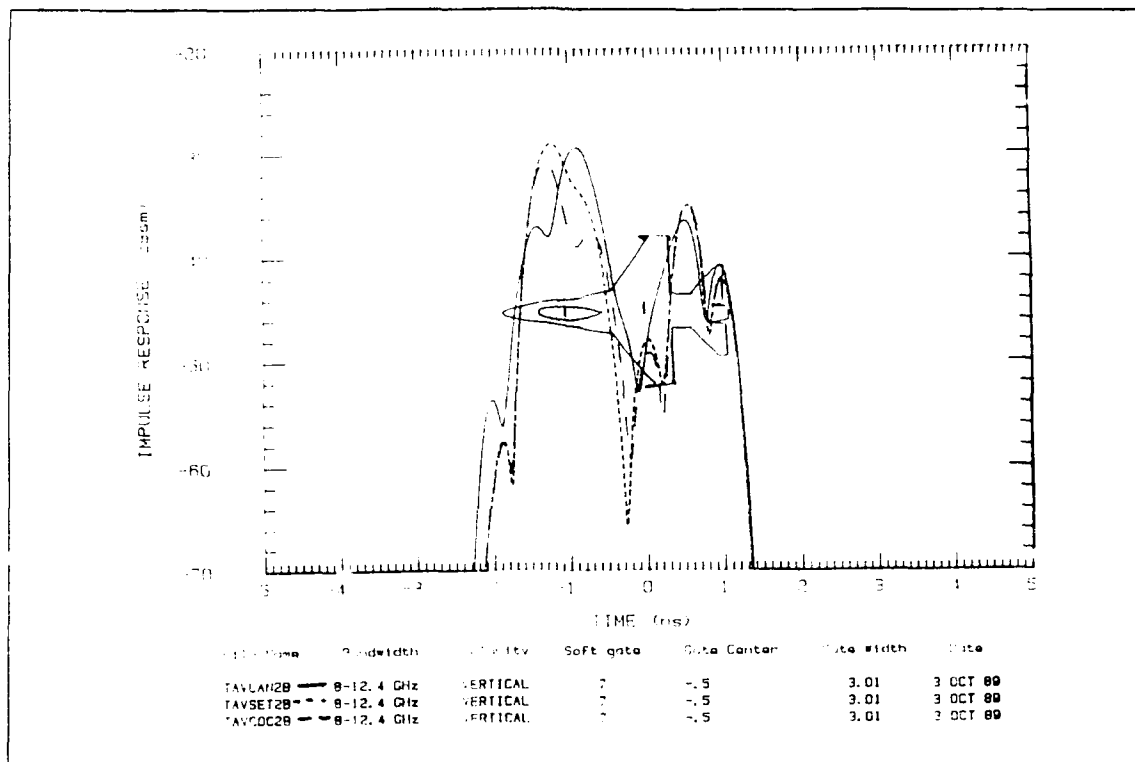


File Name	Bandwidth	Polarity	Soft gate	Gate Center	Gate Width	Date
AVSET2B	8-12.4 GHz	VERTICAL	7			3 OCT 89

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



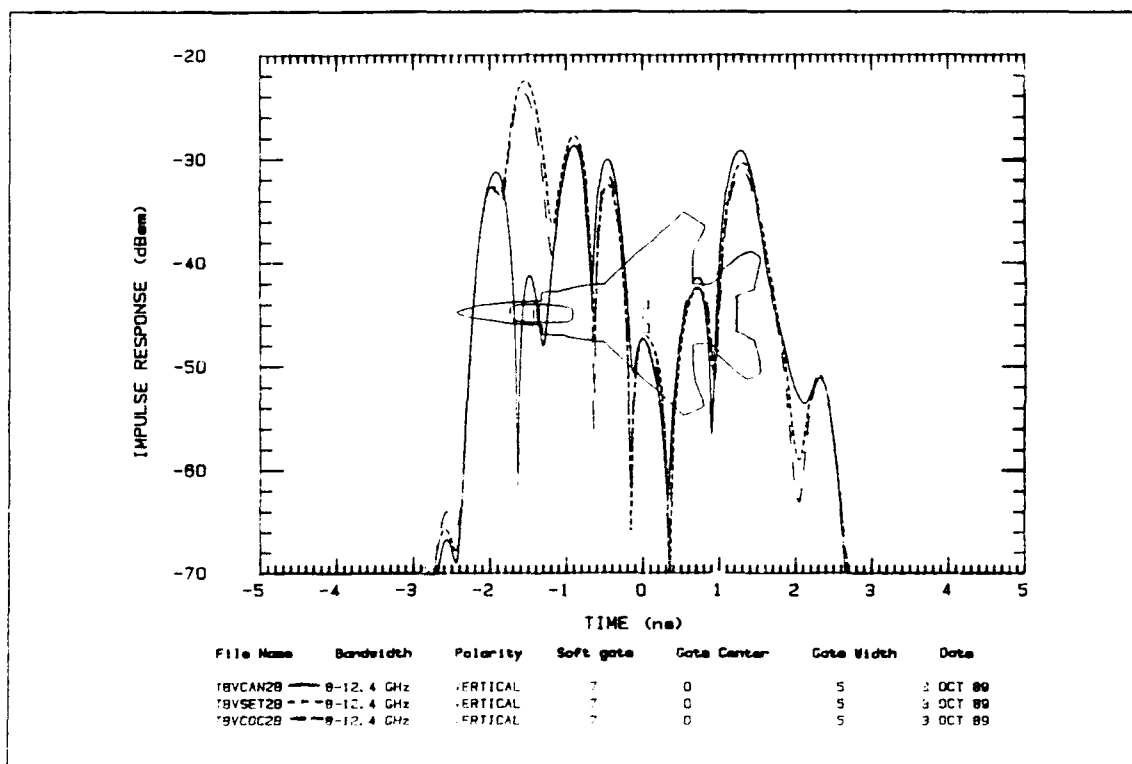
Time domain view of RCS of 1/32 scale F-16, three target configurations, vertical polarization

Figure 5-10

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
Figure 5-11

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).

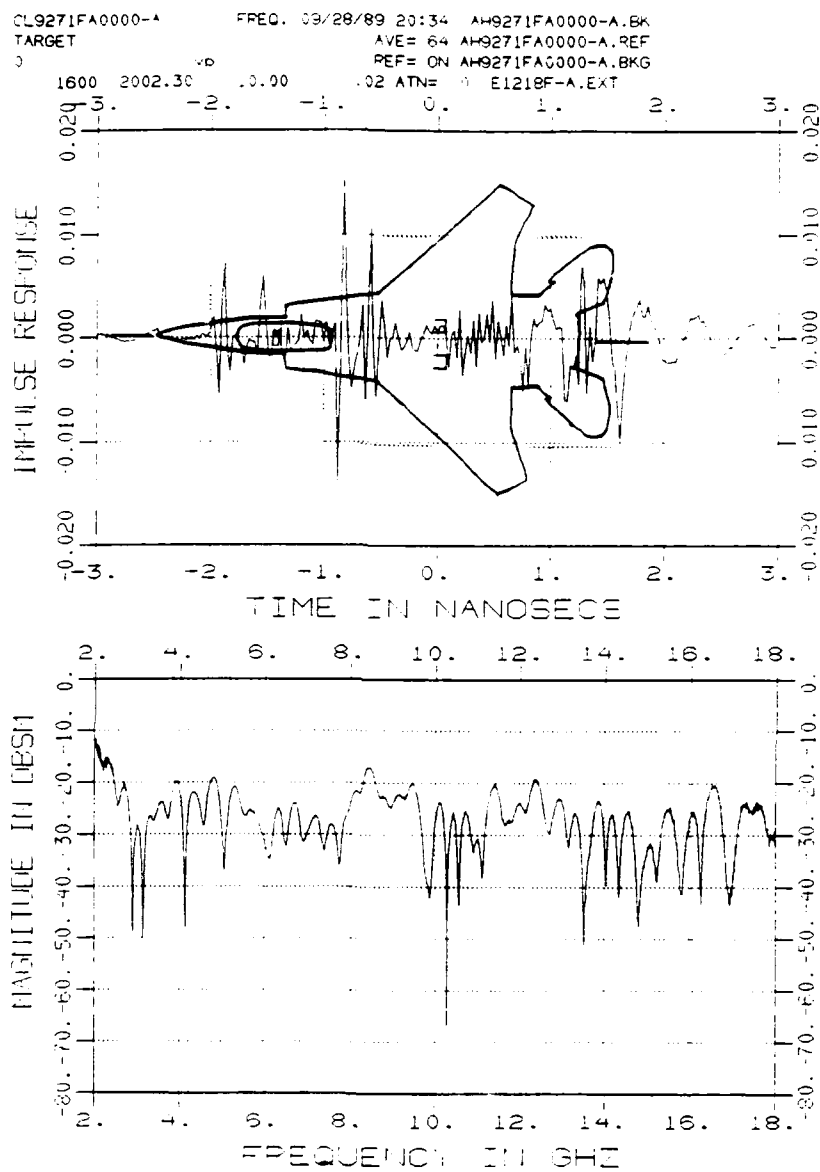
F-15, 2 to 18 GHz, vertical polarization, the Barn. As before, the three target configurations were measured, and the time domain and frequency response plots for each configuration are provided in Figure 5-12 through Figure 5-14. A template of the model is overlayed on selected plots to aid in viewing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

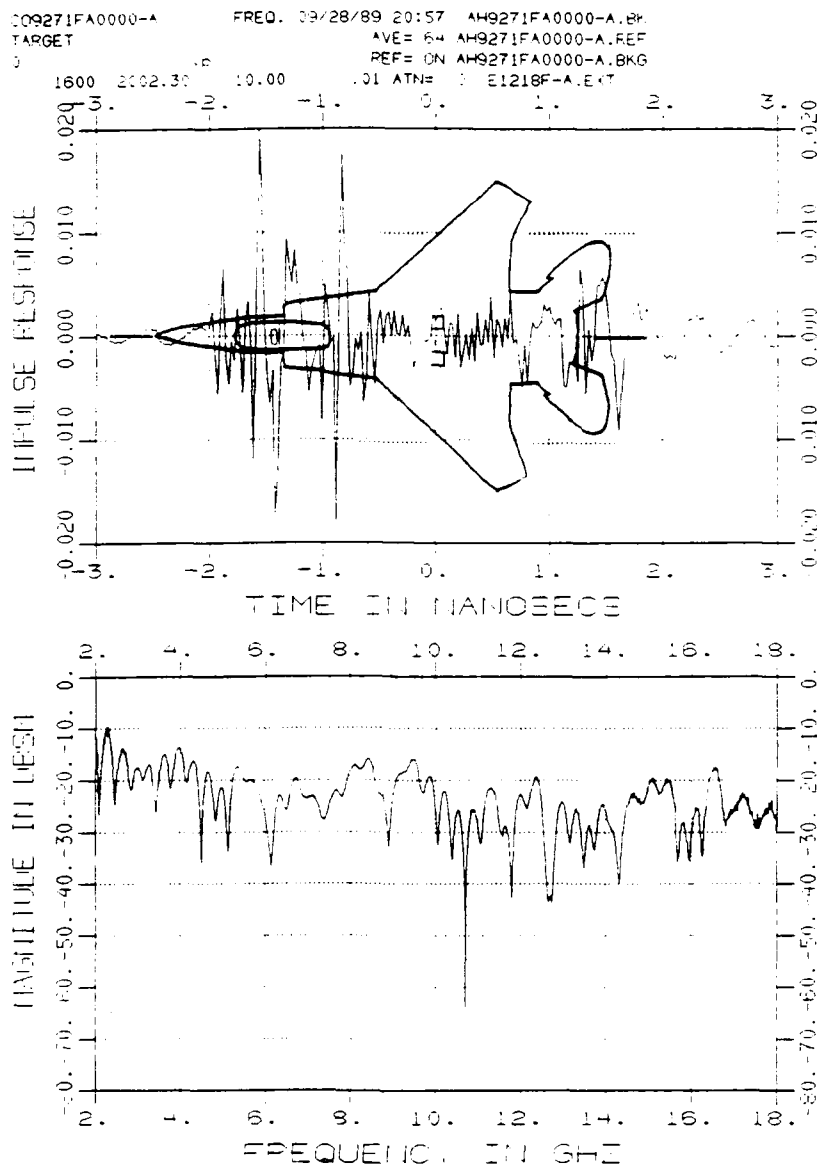
The first task is to identify the causes of the major peaks which occur in the region of interest. The front and back of the cockpit define this region, which extends from -1.8 nsec to -0.9 nsec, respectively. By observing the effect that changing the target configuration has on the amplitude of a peak, 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

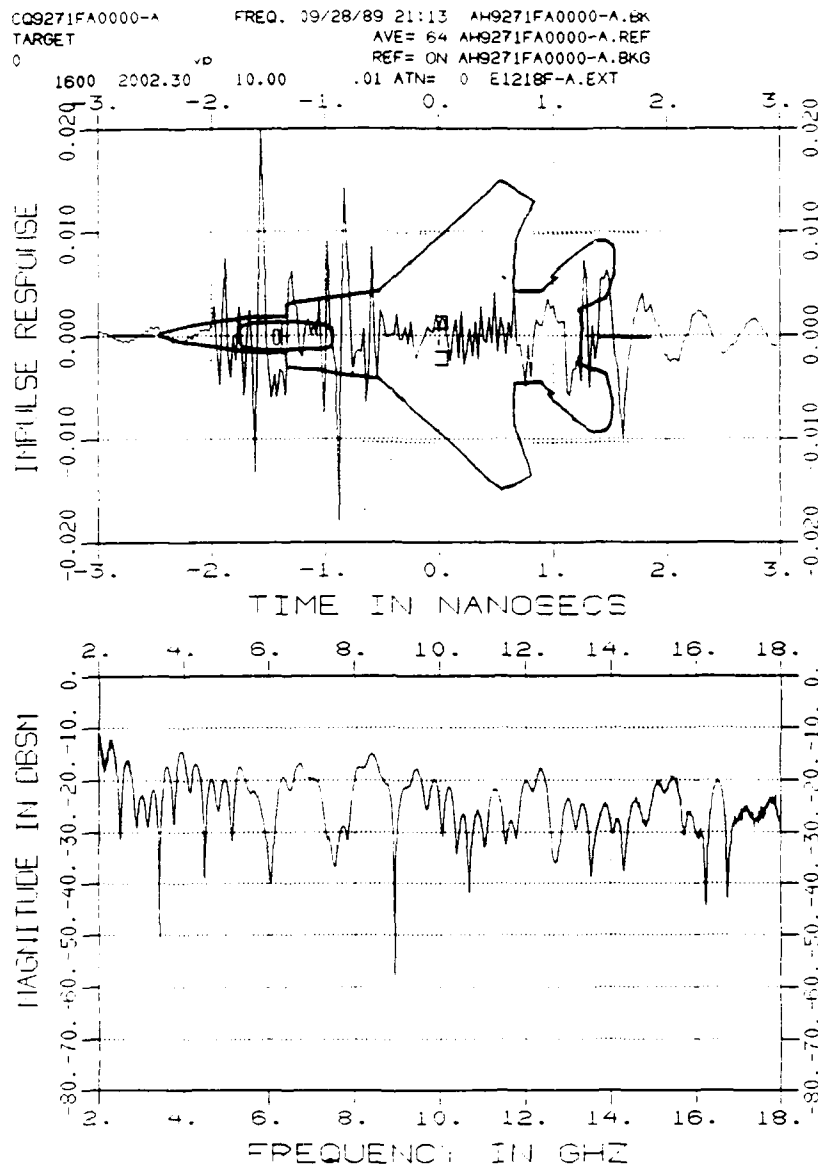


Barn measurement of RCS of 1/32 scale F-15, with canopy, vertical polarization; a) time domain and b) frequency response

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

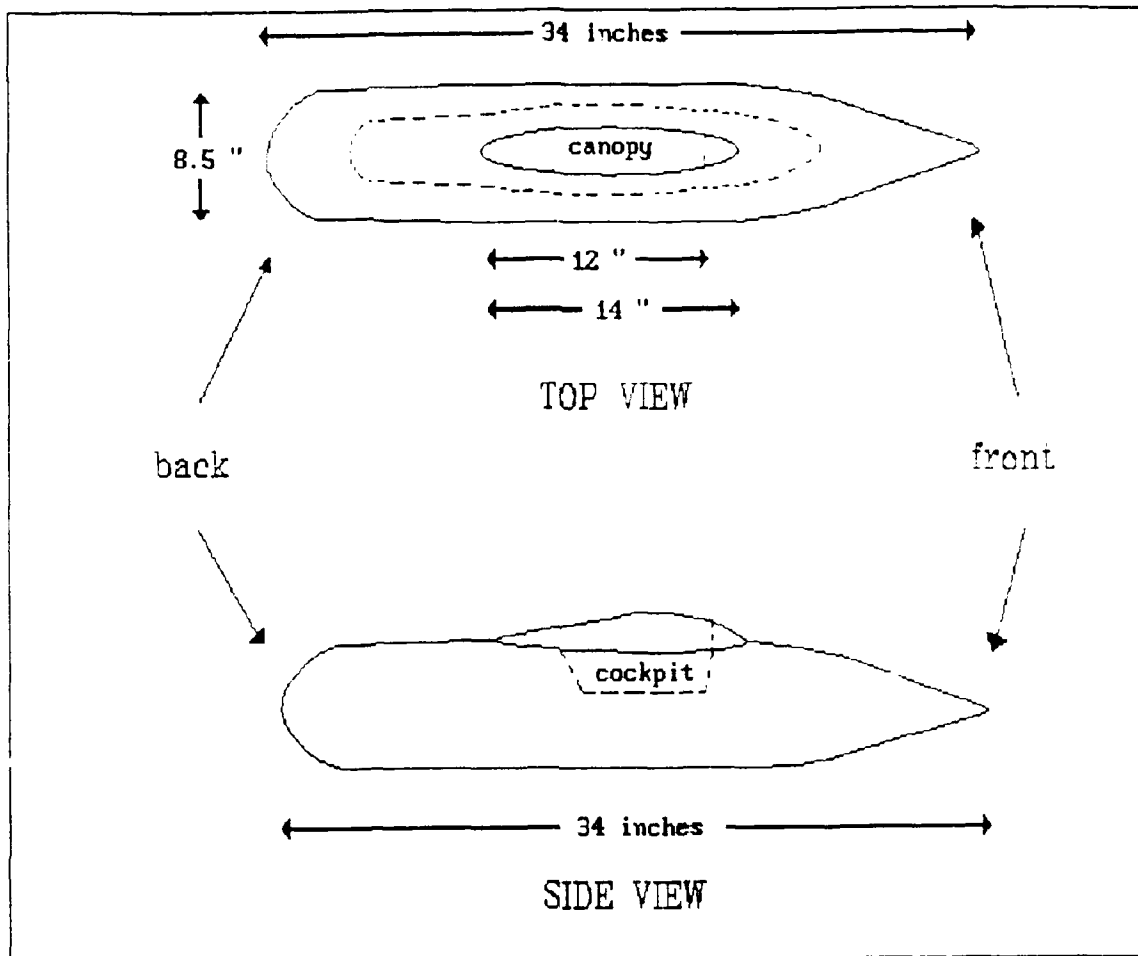
the canopy was also restricted by this dimension. The actual dimensions of an F-16 canopy were obtained and it was determined that a 1/5 scale canopy would just fit. A canopy of this scale was not readily available; however, a spare canopy from a 1/10 scale model F-16 was obtained from the Air Force 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



Test body
Figure 5-15

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

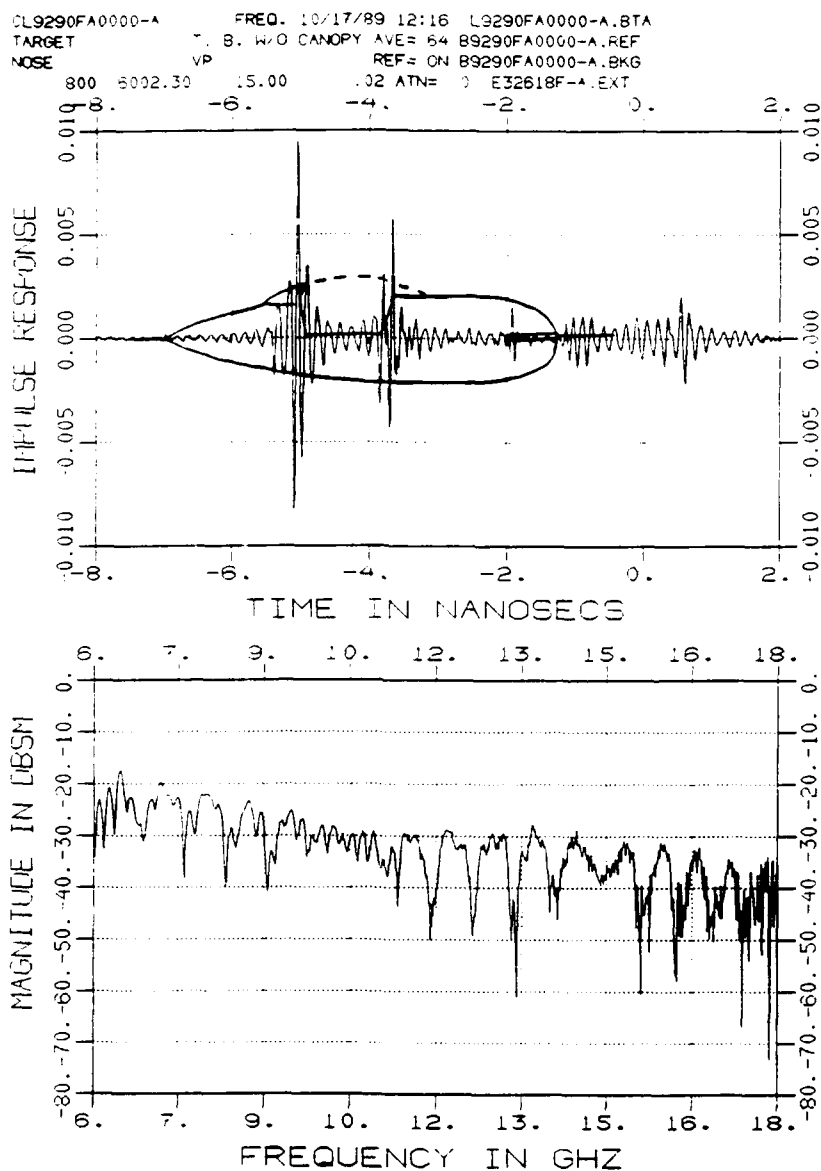
For the test body measurements, there are two target configurations. These simulate the extreme cases of a metallic and transparent canopy. The SET configuration is not considered. All measurements presented in this section use a vertically polarized incident field (for the same reasons cited for the 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

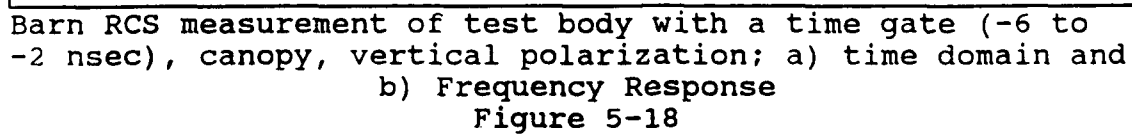
sparse returns attest to the success of isolating the canopy/cockpit. The spikes in Figure 5-16a correspond to the discontinuities shown by the template. The peak at -4.0 nsec, however, is not associated with any discontinuity. It is due possibly to a flaw, or non-uniformity in the paint job. Another 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.

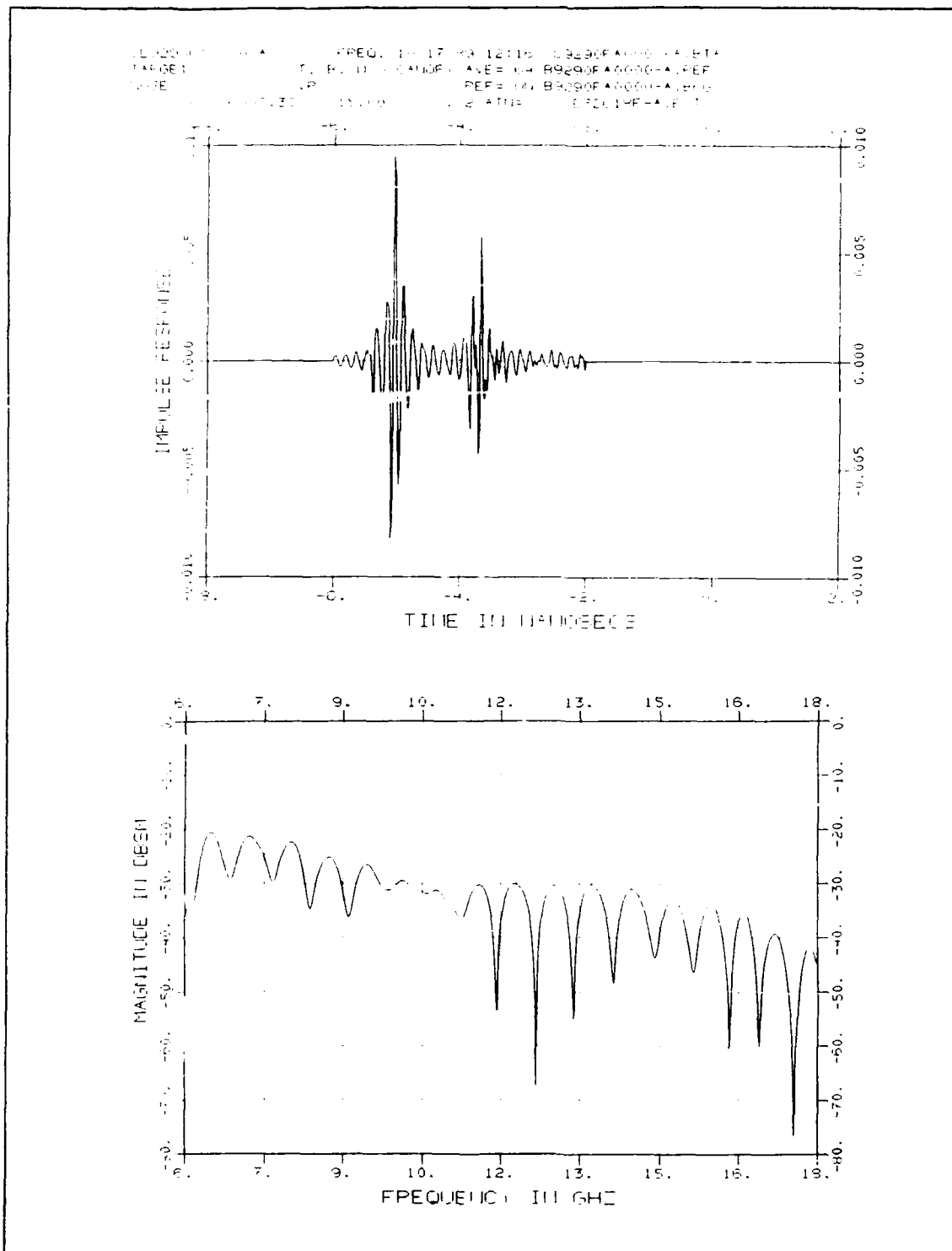
At the lower frequencies, the COC configuration is scattering up to 20 dB more than the CAN configuration. The disparity lessens as the frequency is increased, but is at least 10 dB until about 14 GHz, or approximately two thirds of the plot.

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; cockpit, vertical polarization; a) time domain and b) frequency response
 Figure 5-17

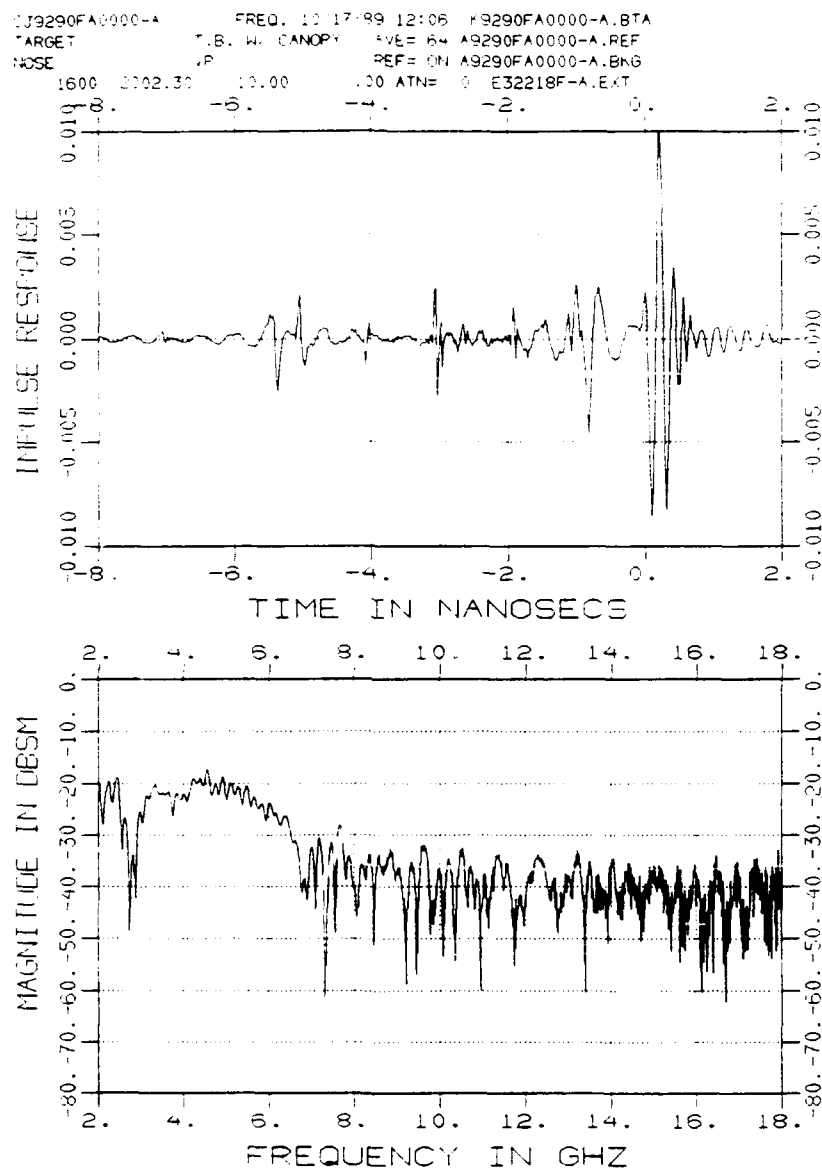




Barn RCS measurement of test body with a time gate (-6 to -2 nsec); cockpit, vertical polarization, a) time domain and b) frequency domain
 Figure 5-19

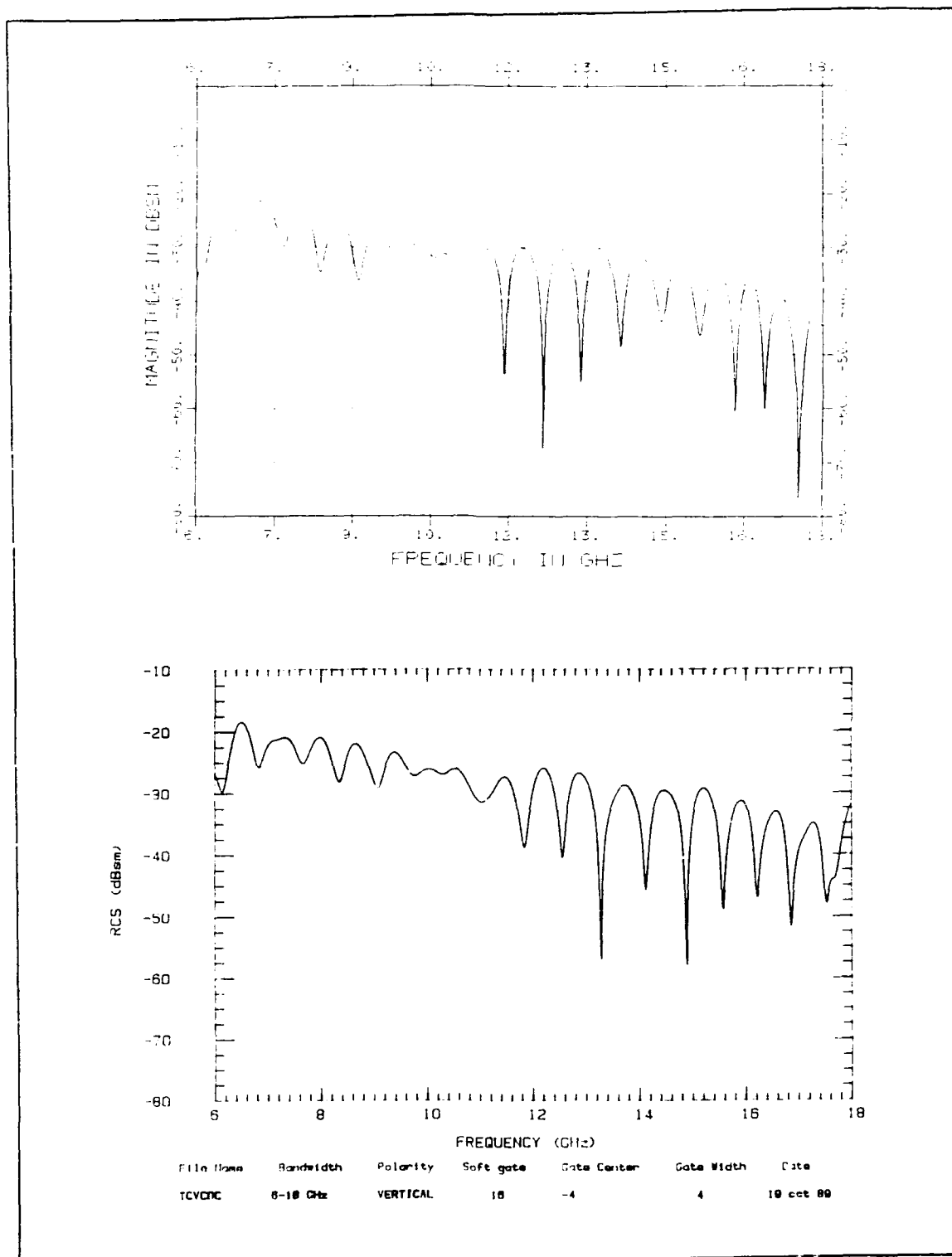
frequency response of this measurement are shown in Figure 5-20. Notice the significant amount of energy between 2 GHz and 6.5 GHz. The cause of the low frequency energy appears to be the large spike which occurs at approximately 0.25 nsec in the time domain plot. (In comparing the same measurement from 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, 6 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 $-20 \cdot \log(\text{scale factor})$ 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 recalled 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.

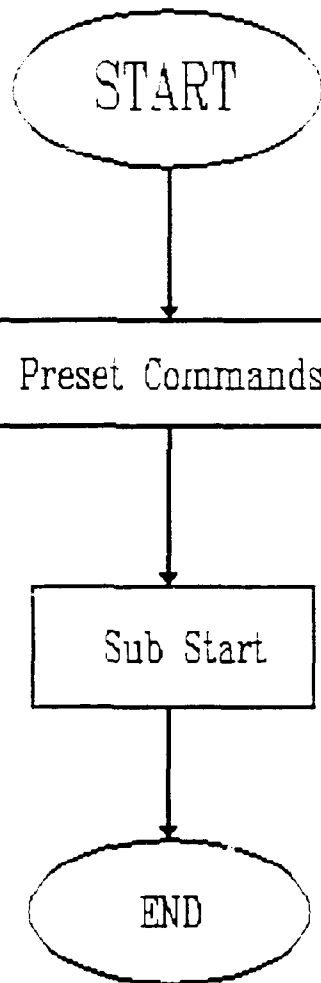
The scale model measurements revealed a small but measurable difference in the RCS of the two configurations. The metallic canopy scattered less than a transparent canopy, which was simulated by an exposed cockpit. In the context of the entire aircraft, the frequency responses of the aircraft models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

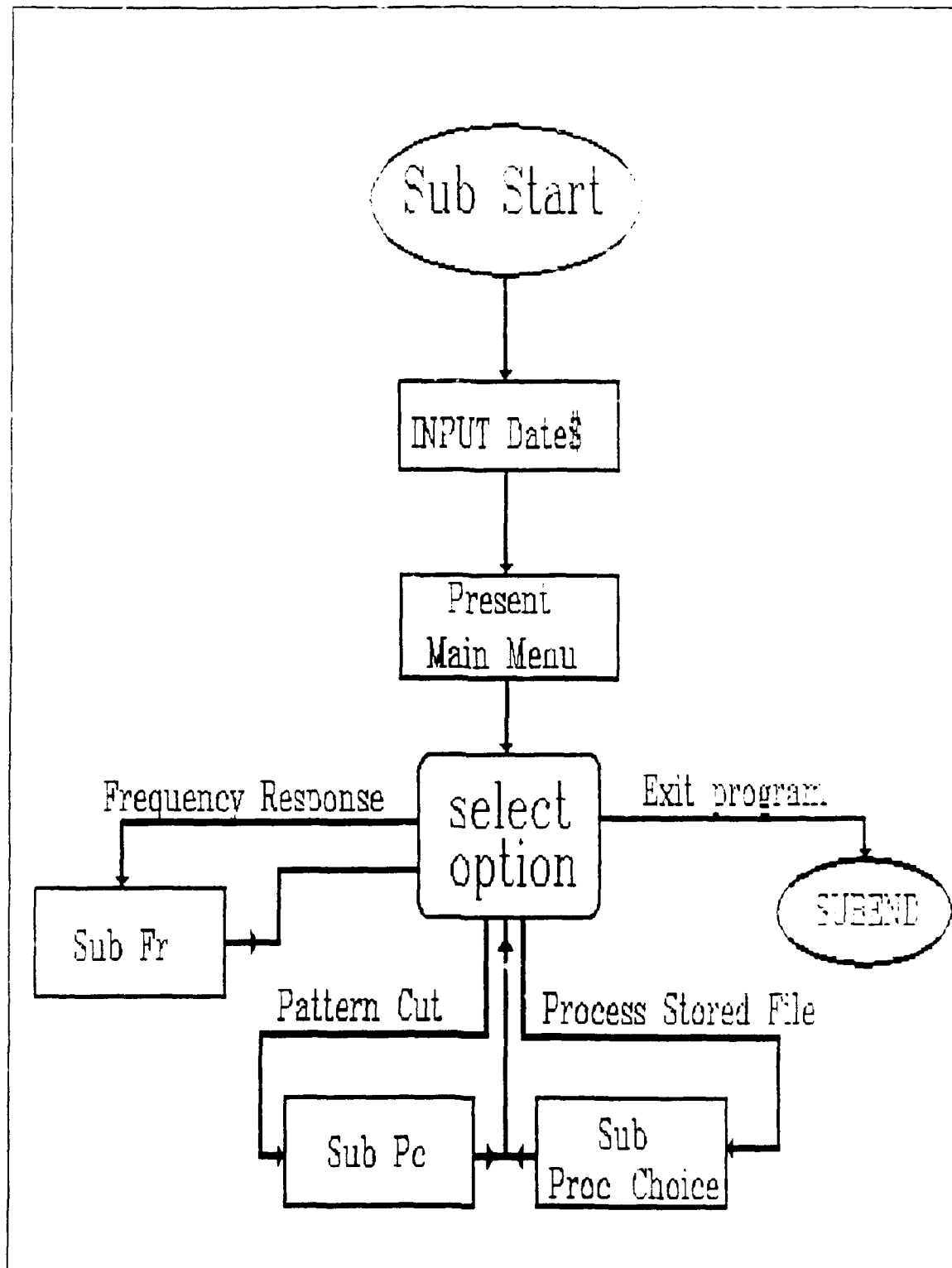
The secondary objective was to investigate the scattering from just the canopy/cockpit, without the complications of the scattering from the rest of the aircraft. As expected, the difference in the RCS between the two configurations was demonstrated more clearly. There was a 10 to 20 dB change between 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.

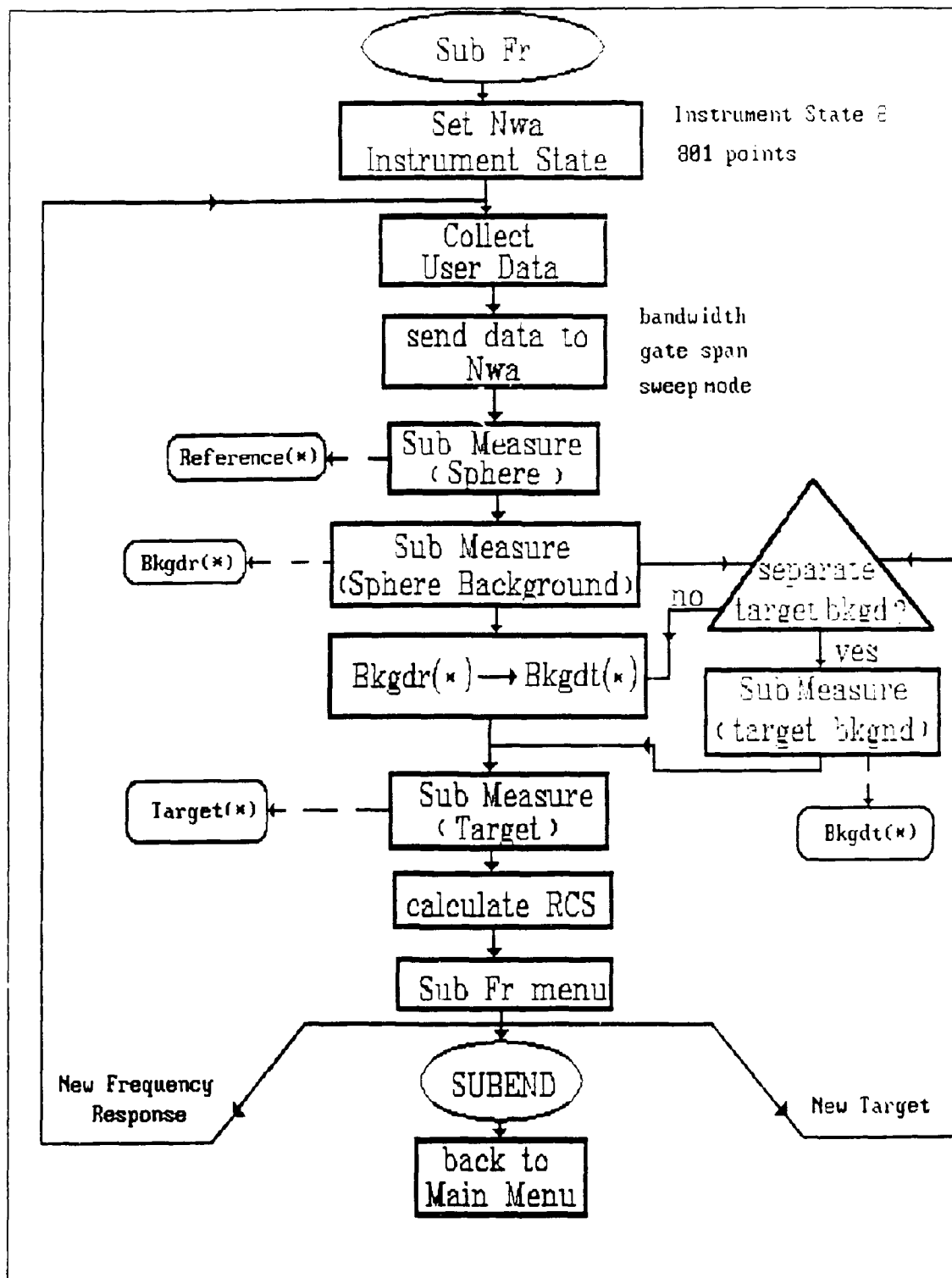
There is interest and value in learning more about this subject. While the results of the measurement portion of the thesis effort may or may not be surprising, they do define the upper and lower bounds on the scattering, and present the limitations and benefits of the various approaches. Further work 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.

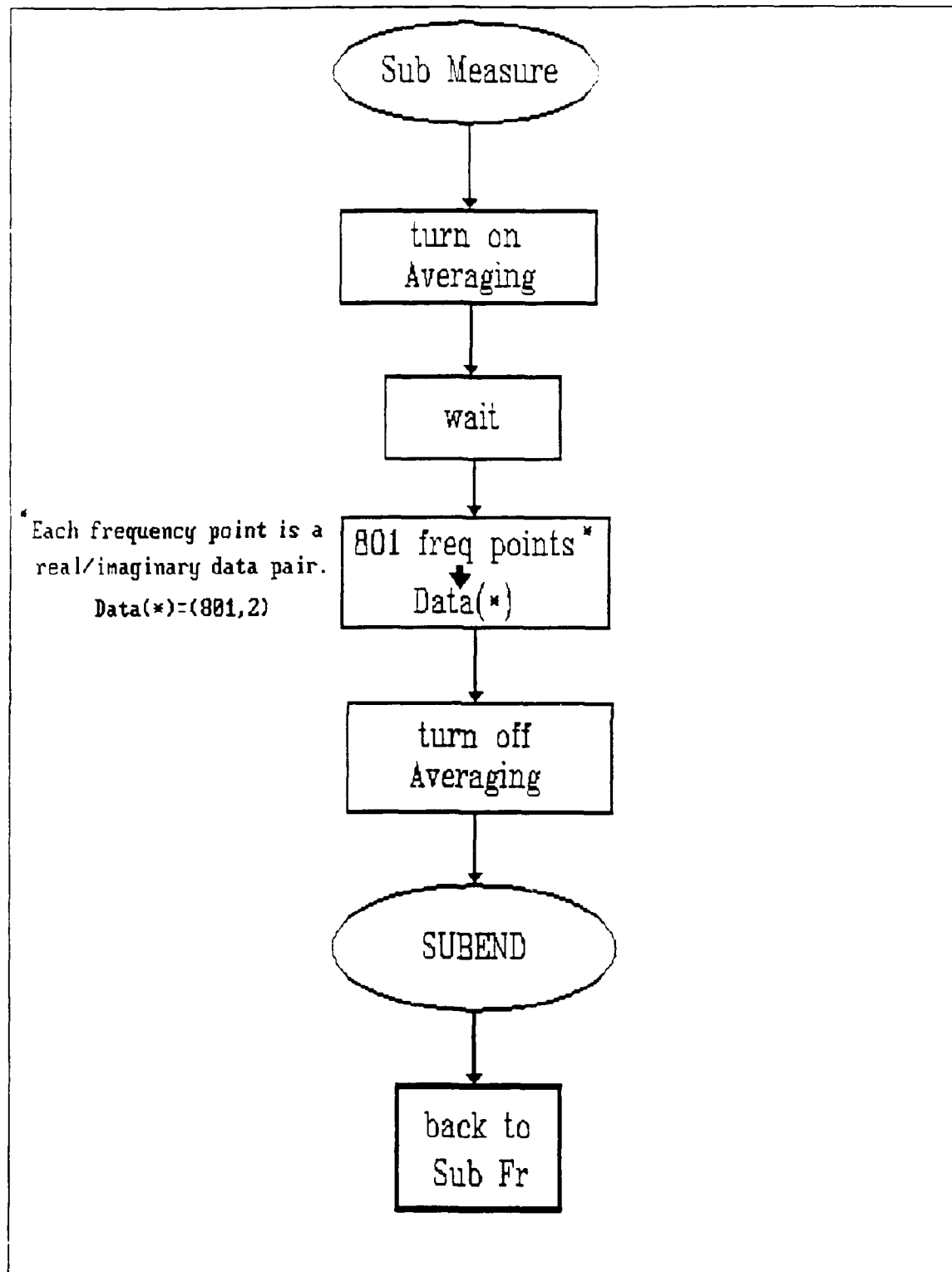
Appendix A: Flow Charts of Subroutines
in ARMS Code

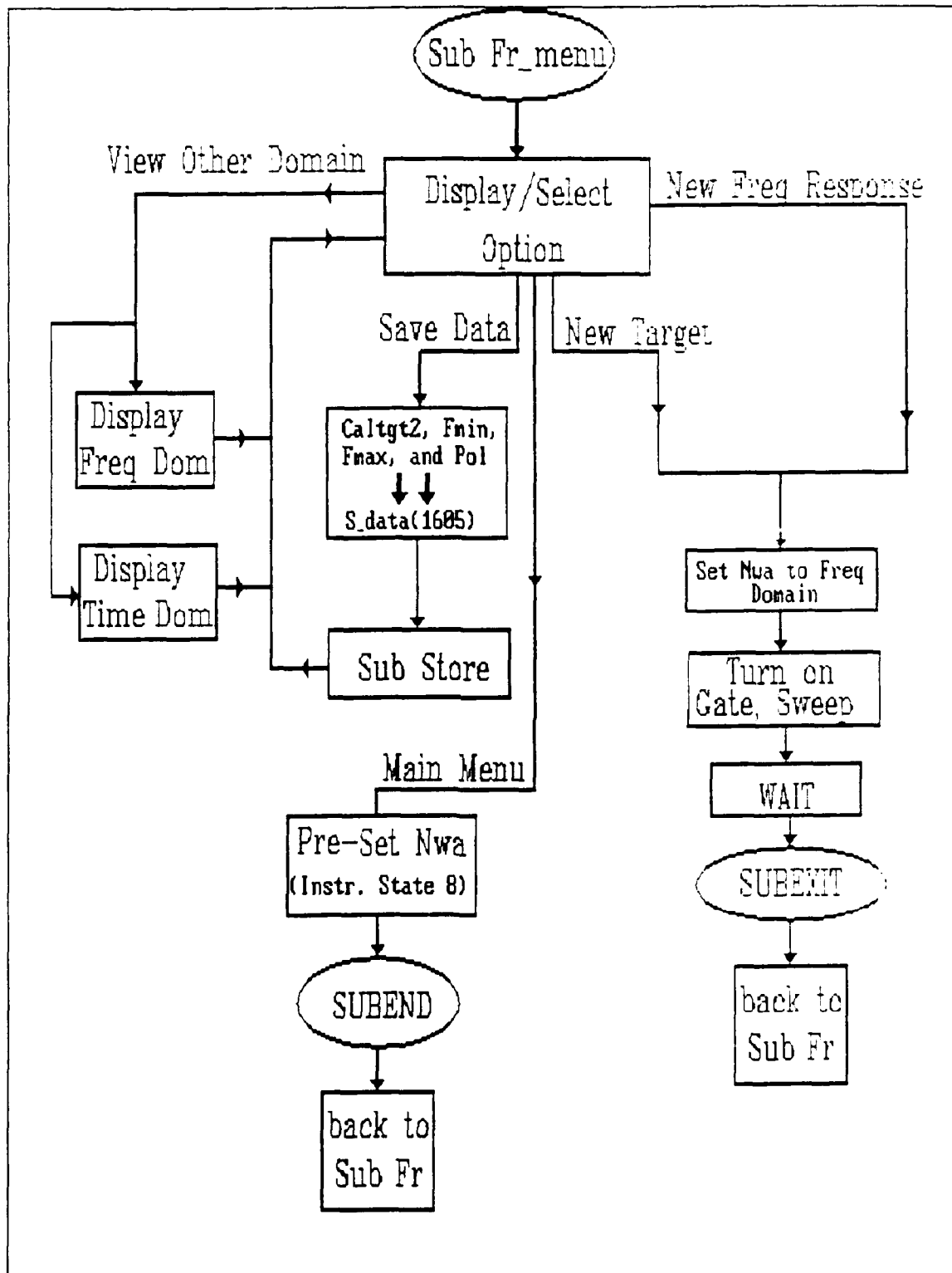
ARMS MAIN PROGRAM

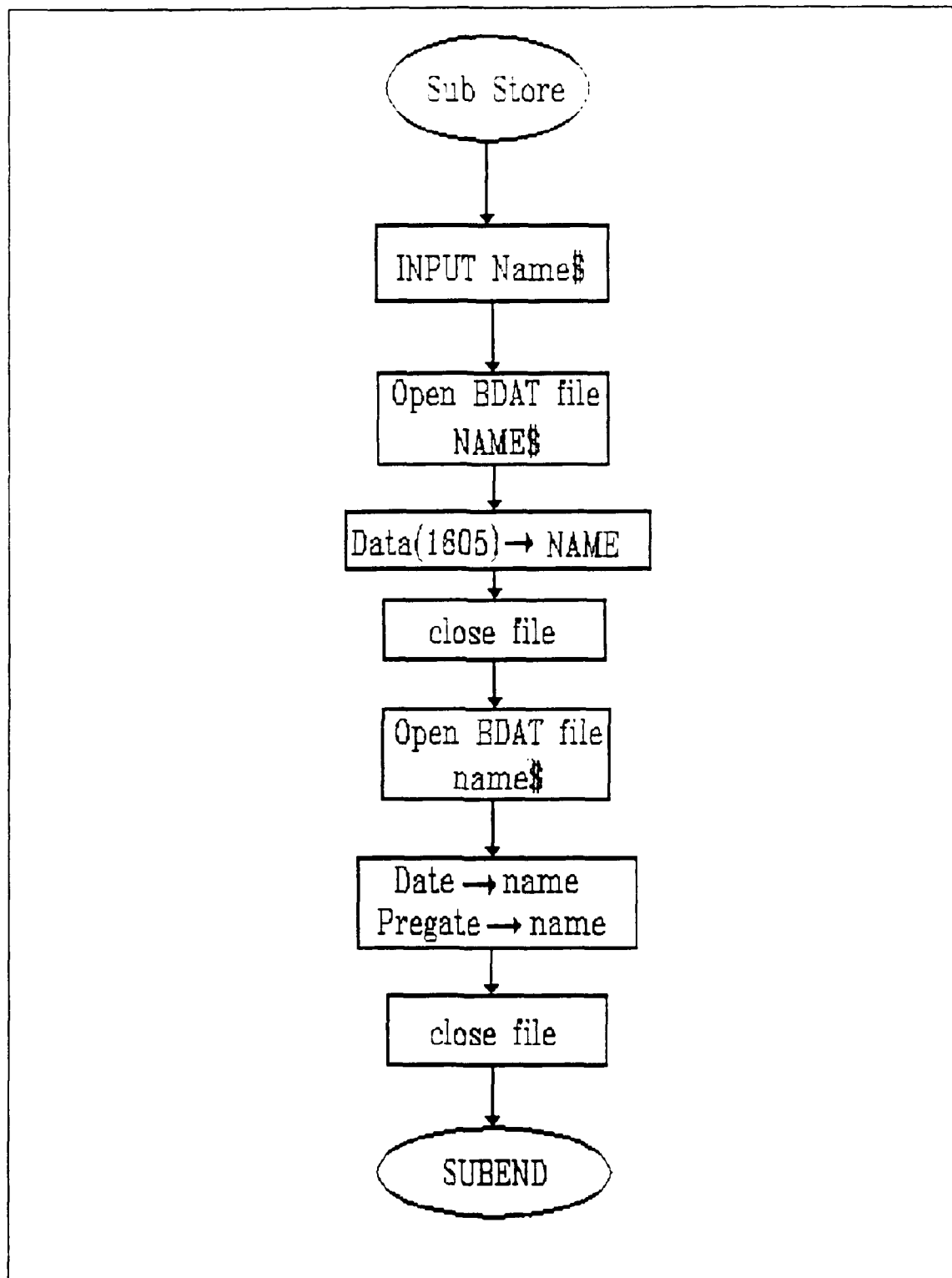


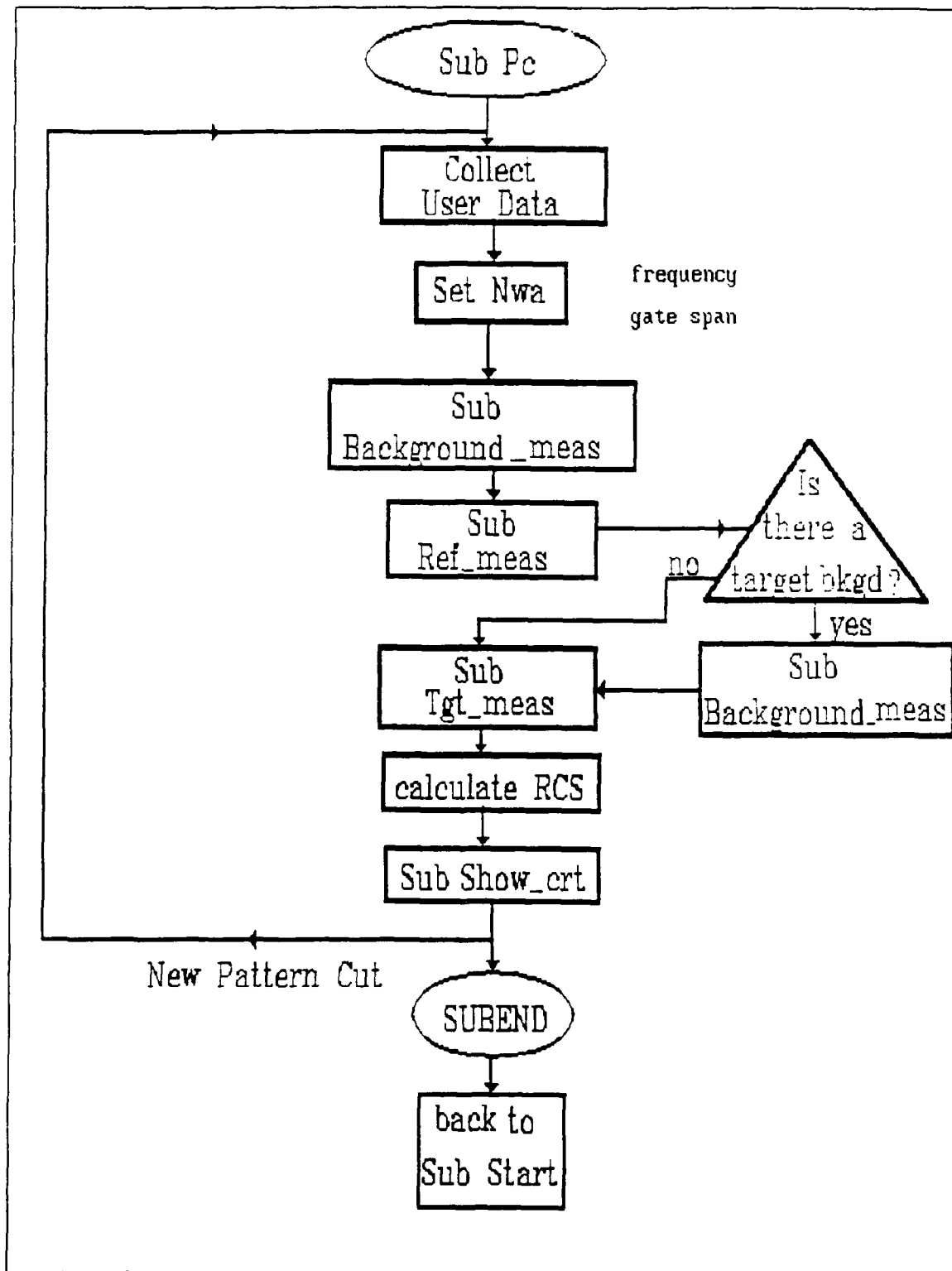


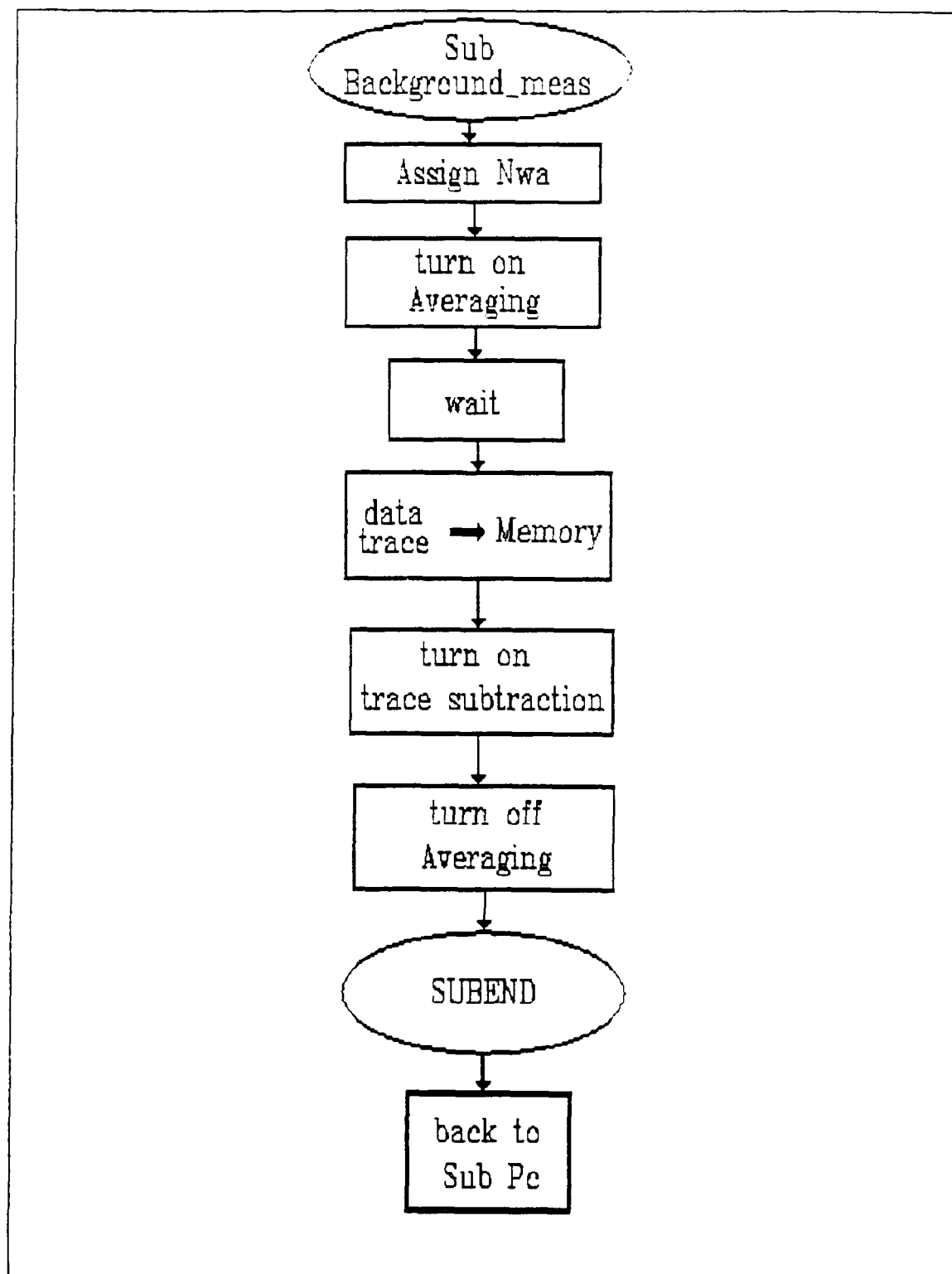


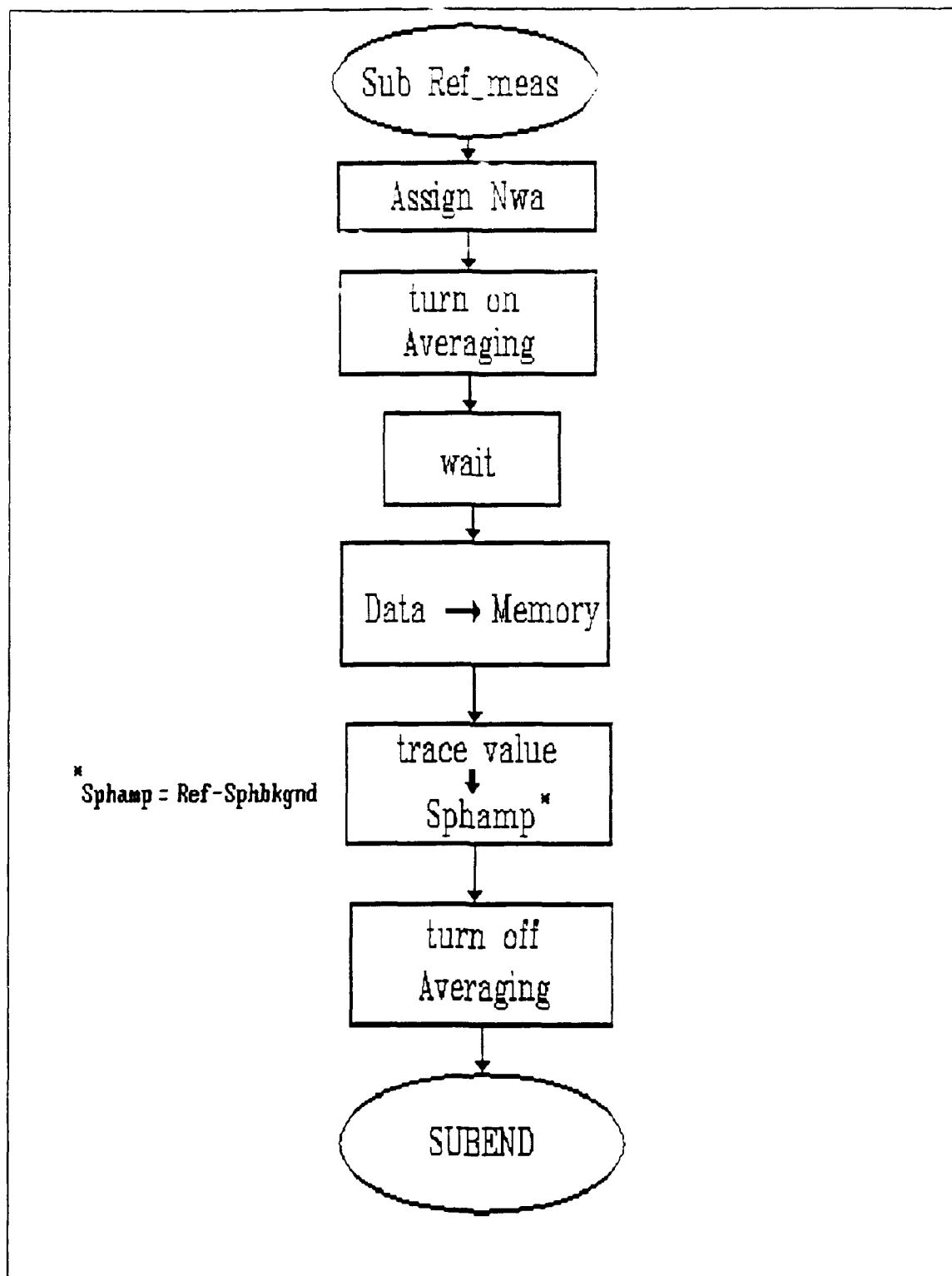


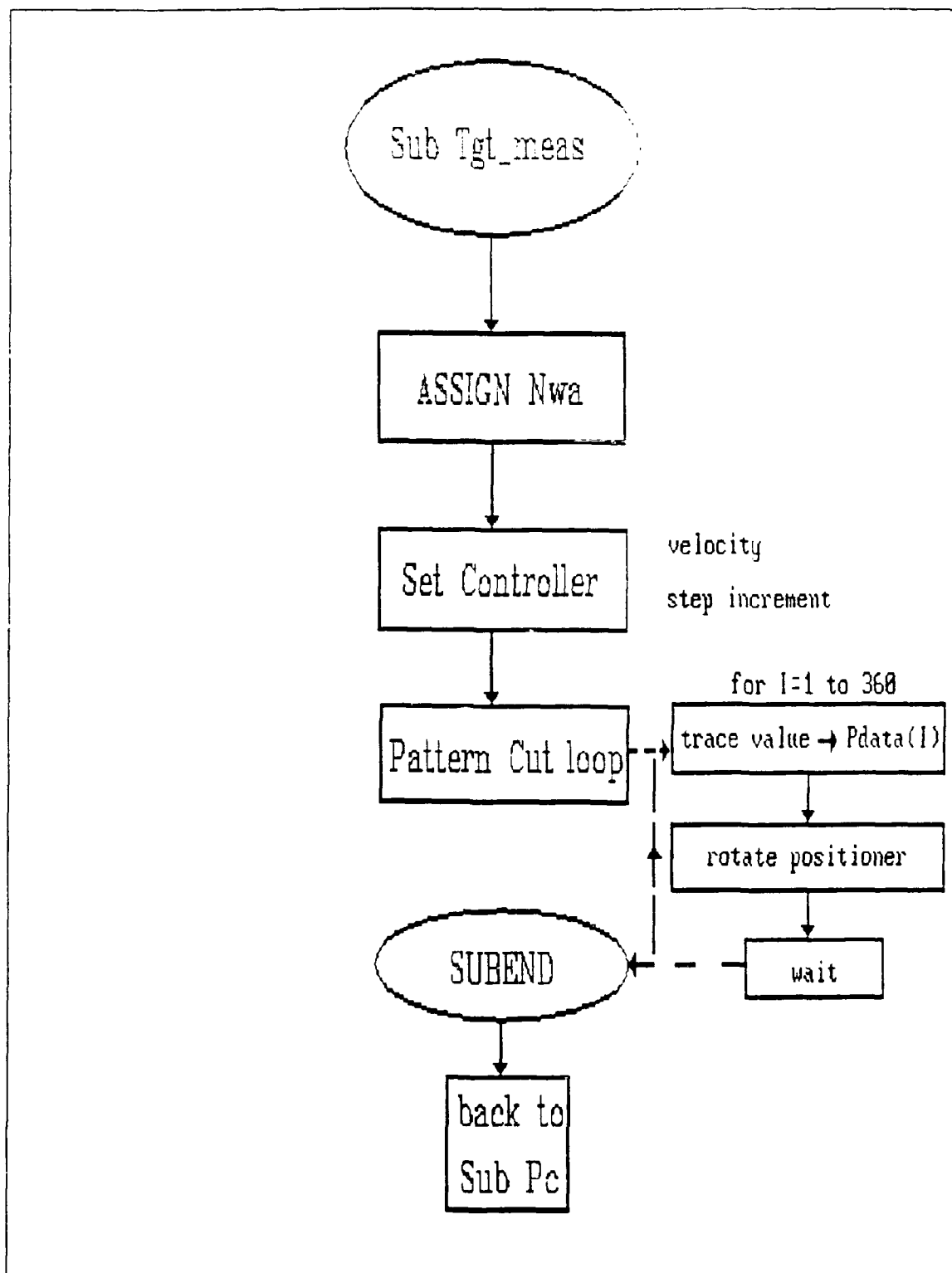


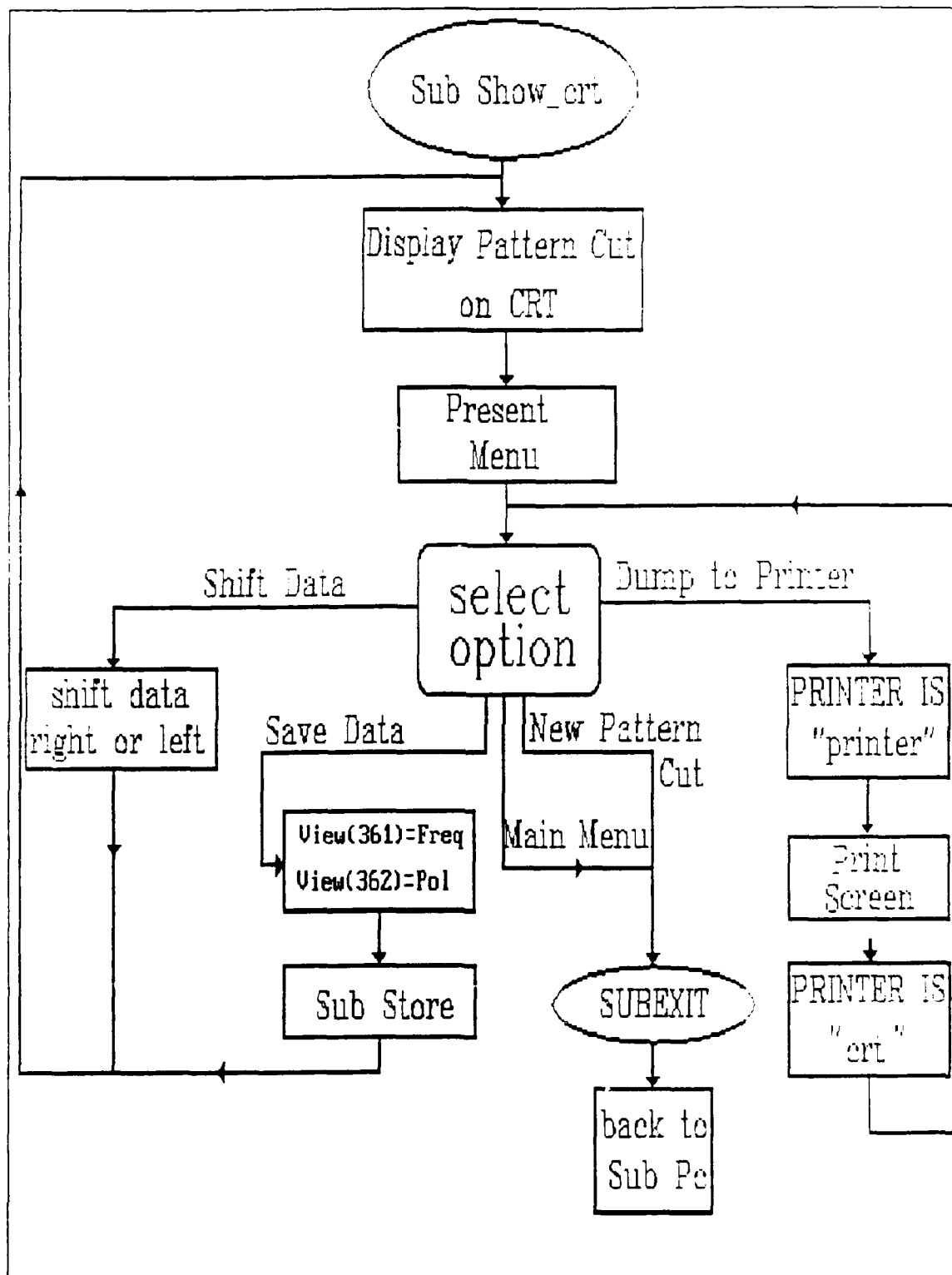


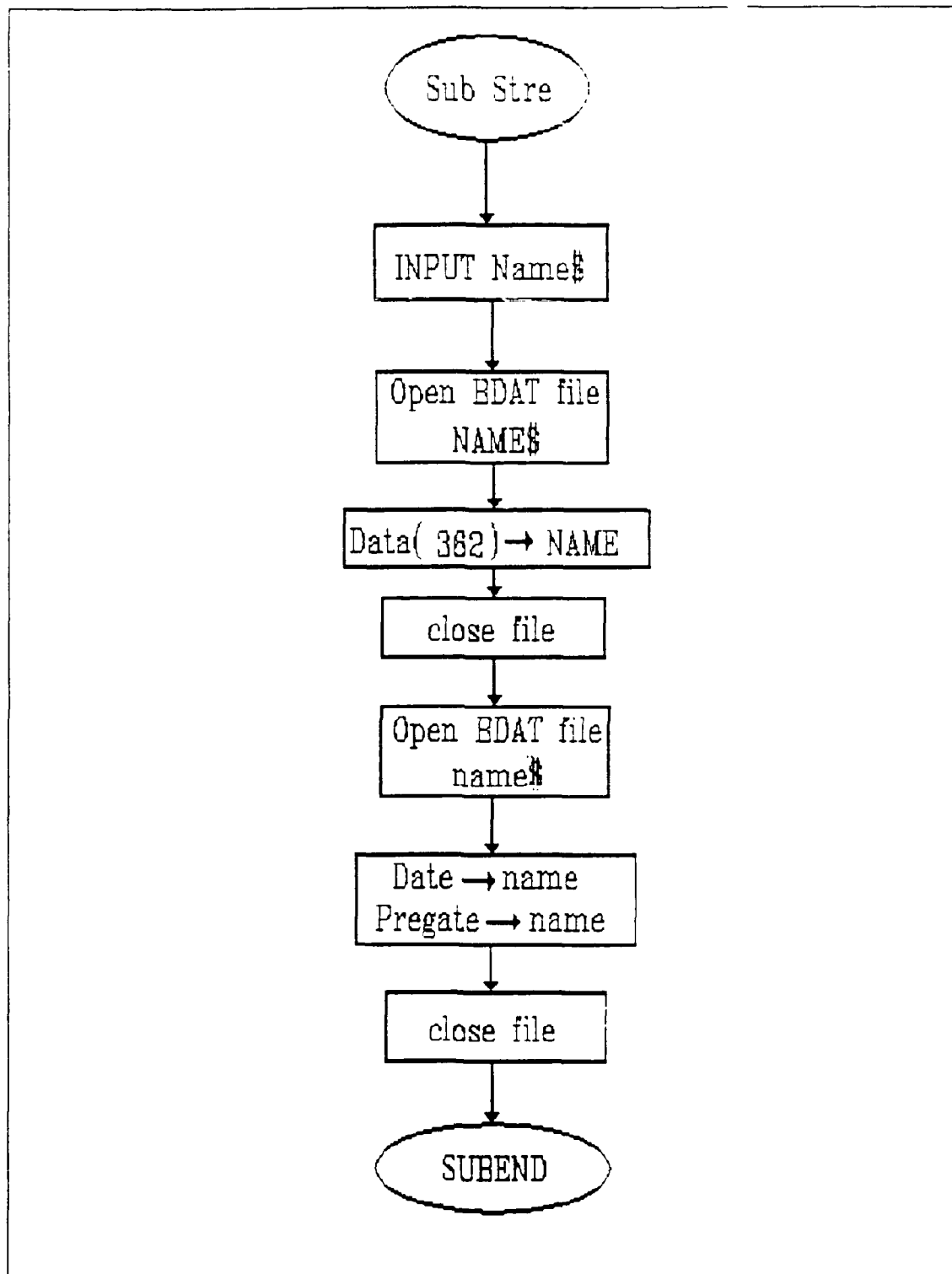


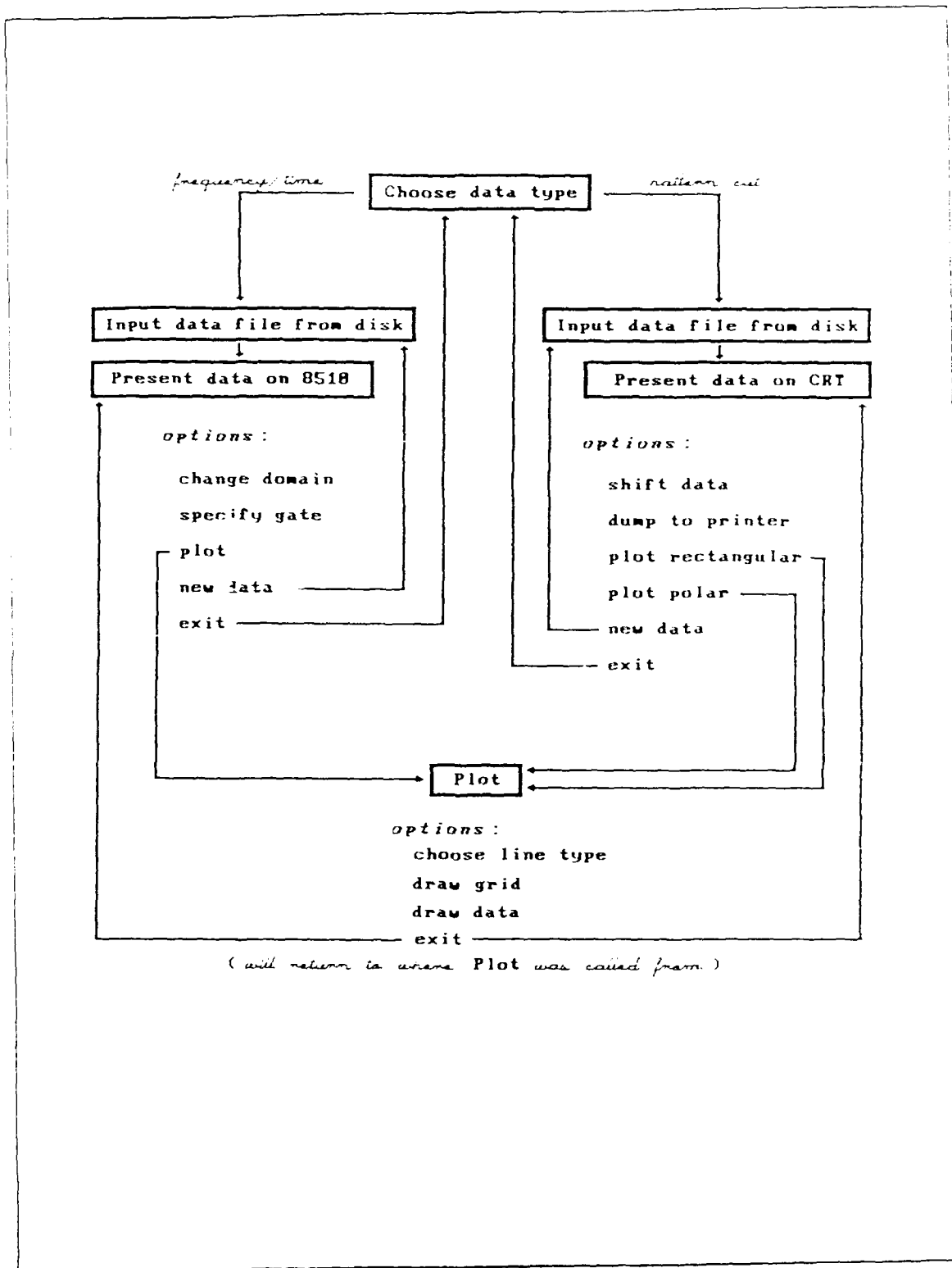












Appendix B: ARMS Code

```

10  * AFITACS version 1.1 May 1989
20  * LINES 30 TO 100 ARE THE MAIN PROGRAM
30  * OPTION BASE *
40  * INTEGER Preamble,Date,No points,Cals,On
50  * PASS STORAGE TO "INTERNAL.4.1"
60  * OFF KEY
70  CALL ClearLcrt
80  CALL Start(Date5)
90  PRINT "You are now back in BASIC."
100 END
110
120 * THIS SUBROUTINE IS THE MAIN MENU FOR "AFITACS".
130 *
140 SUB Start(Date5)
150 PRINT ""
160 CALL ClearLcrt
170 INPUT "Enter today's date: ",Date5
180 Start:DISP CHR$(129)
190 CALL ClearLcrt
200 PRINT ""
210 PRINT ""
220 PRINT "      <0 - Frequency response"
230 PRINT ""
240 PRINT "      <2 - Pattern Cut"
250 PRINT ""
260 PRINT "      <4 - Process/Plot stored files"
270 PRINT ""
280 PRINT "      <7 - Back to BASIC"
290 PRINT ""
300 PRINT ""
310 ON KEY 0 LABEL "Freq. Response" GOTO C_Fr
320 ON KEY 2 LABEL "Pattern Cut " GOTO C_Pc
330 ON KEY 4 LABEL "Plot / Proc " GOTO C_Pp
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 8 GOTO Idle
400 ON KEY 9 GOTO Idle
410 Idle:DISP "Please hit the appropriate sort key."
420 GOTO Idle
430 C_Fr: OFF KEY
440 CALL Fr(Date5)
450 GOTO Start
460 C_Pc: OFF KEY
470 CALL Pc(Date5)
480 GOTO Start
490 C_Pp: OFF KEY
500 CALL PpChoice
510 GOTO Start
520 C_Exit: OFF KEY
530 CALL ClearLcrt
540 GOTO Start
550
560 * THIS SUBROUTINE IS THE MAIN MENU FOR THE FREQUENCY RESPONSE.
570 *
580 SUB Fr(Date5)
590 * ASSIGN #Nua TO *F
600 * ASSIGN #Nua_data TO 716:FORMAT OFF
610 * OPTION BASE *

```

```

620  PRINT "What: RECA8:POIN801:"
630  IF (PREAMBLE,3,10,CALIS,NO_POINTS,0)
640  IF (X<0) THEN (X,0) ELSE (X,X)
650  IF (X<0) THEN (X,0) ELSE (X,X)
660  IF (X<0) THEN (X,0) ELSE (X,X)
670  IF (X<0) THEN (X,0) ELSE (X,X)
680  IF (X<0) THEN (X,0) ELSE (X,X)
690  IF (X<0) THEN (X,0) ELSE (X,X)
700  IF (X<0) THEN (X,0) ELSE (X,X)
710  IF (X<0) THEN (X,0) ELSE (X,X)
720  IF (X<0) THEN (X,0) ELSE (X,X)
730  IF (X<0) THEN (X,0) ELSE (X,X)
740  IF (X<0) THEN (X,0) ELSE (X,X)
750  IF (X<0) THEN (X,0) ELSE (X,X)
760  IF (X<0) THEN (X,0) ELSE (X,X)
770  IF (X<0) THEN (X,0) ELSE (X,X)
780  IF (X<0) THEN (X,0) ELSE (X,X)
790  IF (X<0) THEN (X,0) ELSE (X,X)
800  IF (X<0) THEN (X,0) ELSE (X,X)
810  IF (X<0) THEN (X,0) ELSE (X,X)
820  IF (X<0) THEN (X,0) ELSE (X,X)
830  IF (X<0) THEN (X,0) ELSE (X,X)
840  IF (X<0) THEN (X,0) ELSE (X,X)
850  IF (X<0) THEN (X,0) ELSE (X,X)
860  IF (X<0) THEN (X,0) ELSE (X,X)
870  IF (X<0) THEN (X,0) ELSE (X,X)
880  IF (X<0) THEN (X,0) ELSE (X,X)
890  IF (X<0) THEN (X,0) ELSE (X,X)
900  IF (X<0) THEN (X,0) ELSE (X,X)
910  IF (X<0) THEN (X,0) ELSE (X,X)
920  IF (X<0) THEN (X,0) ELSE (X,X)
930  IF (X<0) THEN (X,0) ELSE (X,X)
940  IF (X<0) THEN (X,0) ELSE (X,X)
950  IF (X<0) THEN (X,0) ELSE (X,X)
960  IF (X<0) THEN (X,0) ELSE (X,X)
970  IF (X<0) THEN (X,0) ELSE (X,X)
980  IF (X<0) THEN (X,0) ELSE (X,X)
990  IF (X<0) THEN (X,0) ELSE (X,X)
1000 IF (X<0) THEN (X,0) ELSE (X,X)

```

```

1190 PRINT "          Start frequency is "Fmin;" GHz."
1200 PRINT "          Stop frequency is "Fmax;" GHz."
1210 PRINT "          Polarization is "Pols;" "
1220 PRINT "          The oscillator is in "SweepS;" mode."
1230 PRINT "          The gate width is "Inegte;" nsec."
1240 PRINT "          The averaging is "Aver;" "
1250 PRINT ""
1260 PRINT ""
1270 PRINT "          ARE THE CORRECT ANTENNAS INSTALLED?"
1280 AnsS="N"
1290 INPUT "Do you want to change anything? (Enter Y, or Default is NO).":AnsS
1300 IF AnsS="Y" THEN GOTO 570
1310 !
1320 ! SEND THE INPUT INFORMATION TO THE HP 8510.
1330 !
1340 PRINT "          PLEASE WAIT"
1350 PRINT "          "
1360 OUTPUT #Nwa:"STAR":Fmin:"GHz":STOP:Fmax:"GHz":
1370 OUTPUT #Nwa:"GATESPAN":Inegte:"ns":
1380 IF SweepS="RAMP" THEN
1390 OUTPUT #Nwa:"RAMP:"
1400 ELSE
1410 OUTPUT #Nwa:"STEP:"
1420 END IF
1430 OUTPUT #Nwa:"ENTO:"
1440 WAIT 5
1450 !
1460 ! THE FOLLOWING LINES CALL THE HEADER AND MEASUREMENT SUBROUTINES. THE
      DATA COMES IN 801 REAL/IMAGINARY DATA PAIRS.
1470 !
1480 MeasurementS="Fr"
1490 CALL Ref_hdr(Pols,MeasurementS)
1500 CALL Measure(Reference(*),Aver,SweepS)
1510 BEEP
1520 CALL Refbkgnd_hdr(Pols,MeasurementS)
1530 CALL Measure(Bkgdtr(*),Aver,SweepS)
1540 BEEP
1550 PRINT ""
1560 Same:BckS="N"
1570 PRINT "          Do you want to measure a separte target background?"
1580 INPUT "Enter Y or N: default is no.":BckS
1590 CALL Clear ""
1600 IF BckS="Y" THEN BckS="y" THEN
1610 CALL Ref_hdr
1620 CALL Measure(Bkgdt(*),Aver,SweepS)
1630 BEEP
1640 !
1650 ! IF L=1 TO 801
1660 !   Bkgdt(L,*)=Bkgdtr(L,*)
1670 !   NEXT L
1680 !
1690 ! IF L=1 TO 801
1700 !   Target_hdr(BckS)
1710 !   CALL Measure(Target(*),Aver,SweepS)
1720 !
1730 ! THE FOLLOWING LINES SUBTRACT THE REFERENCE AND TARGET BACKGROUNDS FROM
      REFERENCE AND TARGET MEASUREMENTS, RESPECTIVELY.
1740 !
1750 PRINT "          Please wait while the system is number crunching."

```

```

1780 No_points=801
1790 FOR I=1 TO No_points
1800   FOR J=1 TO No_points
1810     Target(J,I)=Target(J,I)-Bkgd(J,I)
1820     Referenc(J,I)=Reference(J,I)-Bkgd(J,I)
1830   NEXT J
1840 NEXT I
1850 !
1860 !THE FOLLOWING LINES CALCULATE (Target-Bkgnd)/(Reference-Bkgnd).
1870 !
1880 FOR L=1 TO No_points
1890   Den=Referenc(L,1)^2+Referenc(L,2)^2
1900   Cal_tgt(L,1)=(Target(L,1)-Referenc(L,1)+Target(L,2)*Referenc(L,2))/Den
1910   Cal_tgt(L,2)=(Target(L,2)-Referenc(L,1)-Target(L,1)*Referenc(L,2))/Den
1920 NEXT L
1930 !
1940 !THE FOLLOWING LINES READ IN THE EXACT SOLUTION FOR THE 5 INCH SPHERE.
1950 !
1960 IF E_data(1)<>0 THEN 2070
1970   ASSIGN @Dt TO Dfs
1980   ENTER @Dt:E_data(*)
1990   ASSIGN @Dt TO *
2000   FOR i=1 TO No_points
2010     Ex_sphere(i,1)=E_data(i)
2020     Ex_sphere(i,2)=E_data(i+No_points)
2030   NEXT i
2040 !
2050 !THE NEXT LINES CALCULATE (exact_sphere*sub_fields)
2060 !
2070   FOR K=1 TO No_points
2080     Cal_tgt2(K,1)=Cal_tgt(K,1)*Ex_sphere(K,1)-Cal_tgt(K,2)*Ex_sphere(K,2)
2090     Cal_tgt2(K,2)=Cal_tgt(K,1)*Ex_sphere(K,2)+Cal_tgt(K,2)*Ex_sphere(K,1)
2100   NEXT K
2110 !
2120   SEND ANSWER TO THE HP 8510.  SE=(Target-Bkgd)/(Reference-Bkgd)
2130 !
2140   OUTPUT @Nwa:"FORM3:OUTPDATA"
2150   ENTER @Nwa_data:Preamble.Size.Bkgtr(*)
2160   OUTPUT @Nwa:"AVEROFF:GATEOFF"
2170   On=1
2180   OUTPUT @Nwa:"HOLD:"
2190   OUTPUT @Nwa:"FORM3:INPURAW:"
2200   OUTPUT @Nwa_data:Preamble.Size.Cal_tgt2(*)
2210   BEEP
2220   CALL To_menu(Fmin,Fmax,Poi,Cal_tgt2(*).Date$,Pre_gate$.Return)
2230   IF Return=1 THEN GOTO New
2240   IF Return=2 THEN GOTO Same
2250   CALL Clear_scr
2260   GOSUB
2270 !
2280 ! THIS SUBROUTINE IS A HEADER FOR BOTH THE FREQUENCY RESPONSE AND PATTERN
2290 ! OUT REFERENCE TARGET BACKGROUND MEASUREMENTS.
2300 !
2310   ! Referenc_hdr(Poi$,Measurements$)
2320   CALL Clear_scr
2330   IF Measurements$="F" THEN
2340     PRINT "           The sphere measurement is complete."
2350     PRINT "           Get ready to measure the sphere background."
2360   ELSE
2370     ELSE

```

```

2380 PRINT " Put out the sphere background."
2390 PRINT ""
2400 PRINT " Are the antennas aligned for ".Pols." polarization?"
2410 PRINT ""
2420 PRINT ""
2430 END IF
2440 PRINT " Hit CONTINUE when you are ready."
2450 PAUSE
2460 CALL Clear_crt
2470 PRINT ""
2480 PRINT ""
2490 PRINT " ":CHR$(130);"Measuring "":CHR$(129);"the sphere ba
ckground."
2500 SUBEND
2510 !
2520 ! THIS SUBROUTINE PERFORMS ALL THE FREQUENCY RESPONSE MEASUREMENTS. THE
SET-UP OF THE CHAMBER IS PASSED VIA THE ARRAY CALLED "Data(*)".
2530 !
2540 SUB Measure(Data(*).Aver,Sweep$)
2550 OPTION BASE 1
2560 INTEGER Preamble,Size
2570 ASSIGN @Nwa TO 716
2580 ASSIGN @Nwa_data TO 716:FORMAT OFF
2590 OUTPUT @Nwa:"AVERON:".Aver
2600 IF Sweep$="RAMP" THEN OUTPUT @Nwa:"NUMG:".Aver+1
2610 OUTPUT @Nwa:"FORM3:OUTPDATA"
2620 ENTER @Nwa_data:Preamble,Size,Data(*)
2630 OUTPUT @Nwa:"AVEROFF;"
2640 CALL Clear_crt
2650 SUBEND
2660 !
2670 ! THIS SUBROUTINE IS A HEADER FOR THE FREQUENCY RESPONSE TARGET
MEASUREMENT.
2680 !
2690 SUB Target_hdr(Bck$)
2700 CALL Clear_crt
2710 IF Bck$="N" OR Bck$="" THEN GOTO 2740
2720 PRINT " The target background measurement is complete."
2730 PRINT ""
2740 PRINT " Get ready to measure the target."
2750 PRINT " Press CONTINUE when ready."
2760 PAUSE
2770 CALL Clear_crt
2780 PRINT ""
2790 PRINT ""
2800 PRINT " ":CHR$(130);"Measuring "":CHR$(128);"t
he target."
2810 SUBEND
2820 !
2830 ! THIS SUBROUTINE IS A HEADER FOR BOTH THE FREQUENCY RESPONSE AND PATTERN
TARGET BACKGROUND MEASUREMENT OPTIONS.
2840 !
2850 SUB Target_and_opt
2860 PRINT " Hit CONTINUE when the target background is set."
2870 PAUSE
2880 CALL Clear_crt
2890 PRINT ""
2900 PRINT " ":CHR$(130);"Measuring "":CHR$(128);"the targe
t background."
2910 SUBEND
2920 !

```

```

2930 ' THIS SUBROUTINE IS A MENU PRESENTED AFTER THE FREQUENCY RESPONSE IS
      COMPLETE.
2940 '
2950 SUB Fr_menu(Fmin,Fmax,Pol,Cal_tgt2(*),Date$,Pre_gate$,Return)
2960 OPTION BASE 1
2970 ASSIGN @Nwa TO 716
2980 ASSIGN @Nwa_data TO 716:FORMAT OFF
2990 DIM S_data(1605)
3000 CALL Clear_crt
3010 Dm=1
3020 Menu: PRINT "Please select an option from the menu."
3030 PRINT ""
3040 PRINT ""
3050 PRINT ""
3060 PRINT "      K0 - View the other domain."
3070 PRINT ""
3080 PRINT "      K2 - Store the frequency response data."
3090 PRINT ""
3100 PRINT "      K4 - Continue frequency response with a new target."
3110 PRINT ""
3120 PRINT "      K6 - Completely new frequency response."
3130 PRINT ""
3140 PRINT "      K8 - Back to the main menu."
3150 PRINT ""
3160 PRINT ""
3170 ON KEY 0 LABEL "Toggle Domain" GOTO C_td
3180 ON KEY 2 LABEL "Store Data" GOTO C_store
3190 ON KEY 4 LABEL "New Target " GOTO C_same
3200 ON KEY 6 LABEL "New Fred Resp" GOTO C_new
3210 ON KEY 8 LABEL "Main Menu" GOTO C_strt
3220 ON KEY 1 GOTO Again
3230 ON KEY 3 GOTO Again
3240 ON KEY 5 GOTO Again
3250 ON KEY 7 GOTO Again
3260 ON KEY 9 GOTO Again
3270 Again:DISP "Please hit the appropriate soft key."
3280 GOTO Again
3290 C_td: OFF KEY
3300 Dm=-1*Dm
3310 IF Dm=1 THEN OUTPUT @Nwa:"FREQ:"
3320 IF Dm=-1 THEN OUTPUT @Nwa:"TIMB:LOGM:"
3330 CALL Clear_crt
3340 GOTO Menu
3350 C_same: OFF KEY
3360 Return=2
3370 CALL Clear_crt
3380 CALL @freq(@Nwa)
3390 IF Dm=1 THEN GOTO C_store
3400 IF Dm=-1 THEN OUTPUT @Nwa:"FREQ:"
3410 OUTPUT @Nwa:"CONT:GATEON:"
3420 GOTO Menu
3430 C_strt: OFF KEY
3440 CALL Clear_crt
3450 CALL @freq(@Nwa)
3460 IF Dm=1 THEN GOTO C_store
3470 IF Dm=-1 THEN OUTPUT @Nwa:"FREQ:"
3480 OUTPUT @Nwa:"CONT:GATEON:"
3490 GOTO Menu
3500 CALL @freq(@Nwa)
3510 CALL @freq(@Nwa)
3520 CALL @freq(@Nwa)

```

```

3530 CALL Store(S_data(*),Date$,Pre_gate$)
3540 CALL Clear_crt
3550 GOTO Menu
3560 C_new: OFF KEY
3570 Return=1
3580 CALL Clear_crt
3590 CALL Check(Chk$)
3600 IF Chk$="Y" THEN GOTO C_store
3610 IF Dm=-1 THEN OUTPUT @Nua:"FREQ:"
3620 OUTPUT @Nua:"CONT:GATEON:"
3630 WAIT 5
3640 SUBEXIT
3650 C_strt: OFF KEY
3660 Return=0
3670 CALL Clear_crt
3680 CALL Check(Chk$)
3690 IF Chk$="Y" THEN GOTO C_store
3700 OUTPUT @Nua:"RECA8:"
3710 SUBEND
3720 !
3730 ! THIS SUBROUTINE STORES A FREQUENCY SWEEP FILE.
3740 !
3750 SUB Store(S_data(*),Date$,Pre_gate$)
3760 OPTION BASE 1
3770 CALL Clear_crt
3780 PRINT ""
3790 PRINT ""
3800 PRINT ""
3810 PRINT ""
3820 PRINT "          Insert storage disk into the right-hand disk drive."
3830 PRINT ""
3840 PRINT "          Press  ";CHR$(129);"CONTINUE";CHR$(128);"          when yo
u are ready."
3850 PAUSE
3860 CALL Clear_crt
3870 Name:PRINT "The file name must have at least one UPPER CASE letter."
3880 PRINT ""
3890 INPUT " Enter the file name for the current set of data.",Dt_file1$
3900 File_name1$=LWC$(Dt_file1$)
3910 Disk: CREATE BDAT Dt_file1$.1.12964
3920 ASSIGN @Dt_file1 TO Dt_file1$
3930 OUTPUT @Dt_file1:S_data(*)
3940 ASSIGN @Dt_file1 TO *
3950 CREATE BDAT File_name1$.2.30
3960 ASSIGN @File_name1 TO File_name1$
3970 OUTPUT @File_name1.1:Date$
3980 OUTPUT @File_name1.2:Pre_gate$
3990 ASSIGN @File_name1 TO *
4000 SUBEND
4010 !
4020 ! THIS SUBROUTINE IS THE MAIN MENU FOR THE PATTERN CUT.
4030 !
4040 SUB Pc(Date$)
4050 OPTION BASE 1
4060 DIM A(2),Pcbkgdt(365,1),Pcpreference(365,2),Plot_pt(365),Pcpilot(370)
4070 DIM View(365),View1(365),Pctrace_data(365),Pdata(365)
4080 ASSIGN @Nua TO 716
4090 ASSIGN @Nua_data1 TO 716:FORMAT OFF
4100 INTEGER Preamble.Size:3
4110 New: CALL Clear_crt
4120 PRINT "At present, only the 360 degree option is active."

```

```

4130 PRINT "Input the parameters for the pattern cut."
4140 PRINT ""
4150 PRINT ""
4160 INPUT "      Operating frequency? (Between 2 and 18 GHz)".Freq
4170 IF Freq<2 OR Freq>18 THEN GOTO 4160
4180 CALL Clear_crt
4190 INPUT "What gate do you want (ns)? (Default is 7 ns)".Tmegte
4200 IF Tmegte=0 THEN Tmegte=7
4210 Pre_gateS=VALS(Tmegte)
4220 PolS=""
4230 INPUT "      Polarization? (Enter V or H: Default is horizontal)".PolS
4240 IF PolS<>"" AND PolS<>"H" AND PolS<>"V" THEN GOTO 4230
4250 IF PolS="H" OR PolS="" THEN
4260   PolS="HORIZONTAL"
4270   Pol=0
4280 ELSE
4290   PolS="VERTICAL"
4300   Pol=1
4310 END IF
4320 CALL Clear_crt
4330 Speed=0
4340 PRINT "                        What is the rotation speed of the target?"
4350 PRINT "                        (Default is 1.5)"
4360 PRINT ""
4370 PRINT "                        SLOWEST -----> FASTEST"
4380 PRINT "                        1.5           0.1"
4390 INPUT Speed
4400 INPUT Speed
4410 IF Speed=0 THEN Speed=1.5
4420 IF Speed<.1 OR Speed>1.5 THEN GOTO 4400
4430 CALL Clear_crt
4440 Angle1=0
4450 Angle2=360
4460 Resolution=1
4470 INPUT "      Starting aspect angle?".Angle1
4480 CALL Clear_crt
4490 INPUT "      Ending aspect angle?".Angle2
4500 CALL Clear_crt
4510 INPUT "      Angular resolution? (Default is 1 degree)".Resolution
4520 IF Resolution=0 THEN Resolution=1
4530 CALL Clear_crt
4540 PRINT "You have input the following parameters."
4550 PRINT ""
4560 PRINT ""
4570 PRINT "      Operating frequency .....".Freq."GHz."
4580 PRINT "      Gate width .....".Tmegte."nsec."
4590 PRINT "      Polarization .....".PolS."."
4600 PRINT "      Starting aspect angle ...".Angle1."degrees."
4610 PRINT "      Ending aspect angle .....".Angle2."degrees."
4620 PRINT "      Angular resolution .....".Resolution."degree."
4630 PRINT "      Target rotation rate .....".Speed
4640 PRINT ""
4650 PRINT ""
4660 AnsS=""
4670 INPUT "Do you want to change anything? (Enter Y or N: Default is no)".AnsS
4680 IF AnsS<>"" AND AnsS<>"Y" AND AnsS<>"N" THEN GOTO 4670
4690 IF AnsS="Y" THEN GOTO 4110
4700 '
4710 'THE FOLLOWING LINES SEND THE INPUT INFORMATION TO THE HP 9510.
4720 '
4730 OUTPUT #Nwa:"MARK1":Freq:"G-Hz":

```

```

4740      OUTPUT @Nwa:"GATESPAN":Tmegte:"ns:"
4750      OUTPUT @Nwa:"ENTO:"
4760      No_degs=Angle2-Angle1
4770      No_incrmts=No_degs/Resolution
4780      PRINT "                               PLEASE WAIT"
4790      WAIT 3
4800      !
4810      ! THE NEXT SECTION CALLS THE HEADER AND MEASUREMENT SUBROUTINES.
4820      !
4830      Measurement$="PC"
4840      CALL Refbkgnb_hdr(PoIs,Measurement$)
4850      Rep$=""
4860      CALL Background_meas(Rep$)
4870      CALL Ref_hdr(PoIs,Measurement$)
4880      CALL Ref_meas(Sphamp)
4890      !
4900      ! ASK IF THERE IS A DIFFERENT TARGET BACKGROUND
4910      !
4920      PRINT "                               Do you need a separate target background?"
4930      PRINT ""
4940      Rep$=""
4950      INPUT "Enter Y or N (Default is no).":Rep$
4960      IF Rep$="N" OR Rep$="" THEN GOTO 5010
4970      IF Rep$<>"Y" THEN GOTO 4950
4980      CALL Clear_crt
4990      CALL Tgtbkgnb_hdr
5000      CALL Background_meas(Rep$)
5010      CALL Tgt_hdr
5020      CALL Tgt_meas(Pdata(*),No_incrmts,Speed)
5030      !
5040      ! THE FOLLOWING LINES CALCULATE THE RCS OF THE TARGET.
5050      !
5060      ! Plot_dt(J) ..... RCS of the target (dBsm)
5070      ! Rcs ..... exact RCS of the 5 inch sonar (dBsm)
5080      ! Pdata(J) ..... target - target background (dBsm)
5090      ! Sphamp ..... reference target - reference target background (dBsm)
5100      !
5110      Diam=5
5120      Rcs=10*LGT(PI*(Diam*.0254/2)^2)
5130      FOR J=1 TO 360
5140          Plot_dt(J)=Rcs+Pdata(J)-Sphamp
5150      NEXT J
5160      !
5170      ! THIS SUBROUTINE DISPLAYS THE PATTERN CUT ON THE CRT.
5180      !
5190      CALL Show_crt(Freq,PoIs,Data$,Pre_gate$,Choice,Plot_dt(*))
5200      IF Choice=1 THEN GOTO 490
5210      CALL Clear_crt
5220      SUBEND
5230      !
5240      ! THIS SUBROUTINE CLEARS THE CRT.
5250      !
5260      SUB Clear_crt
5270      CLS
5280      SUBEND
5290      !
5300      ! THIS SUBROUTINE PERFORMS THE PATTERN CUT TARGET MEASUREMENT.
5310      !
5320      SUB Tgt_meas(Pdata(*),No_incrmts,Speed)
5330      OPTION BASE 1
5340      ASSIGN @Nwa TO 716

```

```

5350      ASSIGN @Nwa_data1 TO 716:FORMAT OFF
5360      OUTPUT 709 USING "K":"V44.0"
5370      OUTPUT 709 USING "K":"S41.0"
5380      OUTPUT 709 USING "K":"C40.0"
5390      PRINT "                                ":CHR$(130):"MEASURING":CHR$(128):" the target
5400      FOR I=1 TO 360
5410          OUTPUT @Nwa:"OUTPMARK:"
5420          ENTER @Nwa:Pdata(I).8
5430          OUTPUT 709 USING "K":"I4"
5440          WAIT Speed
5450      NEXT I
5460      CALL Clear_crt
5470      BEEP
5480      SUBEND
5490      !
5500      ! THIS SUBROUTINE IS A HEADER FOR THE PATTERN CUT TARGET MEASUREMENT.
5510      !
5520      SUB Tgt_hdr
5530      CALL Clear_crt
5540      PRINT "                                Get ready to measure the target."
5550      PRINT ""
5560      PRINT "                                Has the controller been assigned to the HP 8510?"
5570      PRINT "                                (Enter 'QUIT 2' on the handheld)"
5580      PRINT ""
5590      PRINT ""
5600      PRINT ""
5610      PRINT "                                Hit CONTINUE when the target is in place."
5620      PAUSE
5630      CALL Clear_crt
5640      SUBEND
5650      !
5660      ! THIS SUBROUTINE PERFORMS THE PATTERN CUT REFERENCE AND TARGET BACKGROUND
      MEASUREMENTS.
5670      !
5680      SUB Background_meas(Rep5)
5690          ASSIGN @Nwa TO 716
5700          OUTPUT @Nwa:"DISPDATA:AVERDN32:"
5710          WAIT 6
5720          OUTPUT @Nwa:"DATI:MINU:DISPMATH:AVEROFF:"
5730      BEEP
5740      SUBEND
5750      !
5760      ! THIS SUBROUTINE PERFORMS THE PATTERN CUT REFERENCE TARGET MEASUREMENT.
5770      !
5780      SUB Ref_meas(Sphamp)
5790          ASSIGN @Nwa TO 716
5800          OPTION BASE 1
5810          OUTPUT @Nwa:"AVERDN32:"
5820          WAIT 6
5830          OUTPUT @Nwa:"OUTPMARK:AVEROFF:"
5840          ENTER @Nwa:Sphamp.8
5850      BEEP
5860      CALL Clear_crt
5870      SUBEND
5880      !
5890      ! THIS SUBROUTINE IS A HEADER FOR BOTH THE FREQUENCY RESPONSE AND PATTERN
      CUT REFERENCE TARGET MEASUREMENTS.
5900      !
5910      SUB Ref_hdr(Pol5,Measurements)
5920      CALL Clear_crt

```

```

5930 IF Measurement$="PC" THEN GOTO 5970
5940 PRINT " Are the antennas aligned for",Pol$," polarization?"
5950 PRINT ""
5960 PRINT ""
5970 PRINT " Put out the reference target."
5980 PRINT " Hit CONTINUE when you are ready."
5990 PAUSE
6000 CALL Clear_crt
6010 PRINT " ";CHR$(130);"Measuring ";CHR$(129);" the sp
here."
6020 SUBEND
6030 !
6040 ! THIS SUBROUTINE STORES A PATTERN CUT FILE.
6050 !
6060 SUB Stre(Date$,Pre_gate$,View(.*))
6070 OPTION BASE 1
6080 CALL Clear_crt
6090 PRINT ""
6100 PRINT ""
6110 PRINT ""
6120 PRINT ""
6130 PRINT " Insert storage disk into the right-hand disk drive."
6140 PRINT ""
6150 PRINT " Press ";CHR$(129);"CONTINUE";CHR$(129);" when yo
u are ready."
6160 PAUSE
6170 CALL Clear_crt
6180 Name:PRINT "The file name must have at least one UPPER CASE letter."
6190 PRINT ""
6200 INPUT " Enter the file name for the current set of data.",Dt_file2$
6210 File_name2$=LWC$(Dt_file2$)
6220 Disk: CREATE BDAT Dt_file2$.1.2960
6230 ASSIGN @Dt_file2 TO Dt_file2$
6240 OUTPUT @Dt_file2:View(.*))
6250 ASSIGN @Dt_file2 TO *
6260 CREATE BDAT File_name2$.2.00
6270 ASSIGN @File_name2 TO File_name2$
6280 OUTPUT @File_name2.1:Date$
6290 OUTPUT @File_name2.2:Pre_gate$
6300 ASSIGN @File_name2 TO *
6310 CALL Clear_crt
6320 SUBEND
6330 !
6340 ! THIS SUBROUTINE MAKES SURE THE USER HAS REMEMBERED TO SAVE THE DATA.
6350 !
6360 SUB Check(Chk$)
6370 PRINT ""
6380 PRINT ""
6390 PRINT ""
6400 PRINT ""
6410 PRINT " Have you saved your data? It will be lost if you haven't."
6420 PRINT ""
6430 Chk$=""
6440 INPUT "DO YOU WANT TO SAVE DATA? (Enter Y or N) (Default is no)",Chk$
6450 CALL Clear_crt
6460 SUBEND
6470 !
6480 ! THIS SUBROUTINE DISPLAYS THE PATTERN CUT ON THE CRT.
6490 !
6500 SUB Show_crt(Spec,Pol,Date$,Pre_gate$,Choice,View(.*))
6510 Start: CALL Clear_crt

```

```

6520      INIT
6530      PLOTTER IS 3,"INTERNAL"
6540      Ymin=View(1)
6550      Ymax=Ymin
6560      FOR I=1 TO 361
6570          IF View(I)<Ymin THEN Ymin=View(I)
6580          IF View(I)>Ymax THEN Ymax=View(I)
6590      NEXT I
6600      Ymax=Ymax+10
6610      Ymax=PROUND(Ymax,1)
6620      Ymin=Ymin-10
6630      Ymin=PROUND(Ymin,1)
6640      Range=Ymax-Ymin
6650      GRAPHICS ON
6660      MOVE 0.95
6670      CSIZE 3
6680      LABEL Names
6690      CSIZE 6
6700      LORG 6
6710      FOR I=-.3 TO .3 STEP .1
6720          MOVE 70+I,100
6730          LABEL "LOW OBSERVABLES"
6740      NEXT I
6750      LORG 1
6760      CSIZE 4
6770      MOVE 0.62
6780      Labels="RCS"
6790      FOR I=1 TO 3
6800          LABEL Labels(I,1)
6810      NEXT I
6820      MOVE 56.15
6830      LABEL "ASPECT ANGLE"
6840      VIEWPORT 15,125,30,90
6850      FRAME
6860      WINDOW 0,360,Ymin,Ymax
6870      AXES 5,2,0,Ymin,9,5,2
6880      CSIZE 3
6890      LORG 6
6900      CLIP OFF
6910      FOR I=0 TO 360 STEP 45
6920          MOVE I,Ymin-1
6930          LABEL I
6940      NEXT I
6950      LORG 8
6960      FOR I=Ymin TO Ymax STEP 10
6970          MOVE -1,I
6980          LABEL I
6990      NEXT I
7000      FOR I=0 TO 359
7010          PLOT I,View(I+1)
7020      NEXT I
7030      ON KEY 0 LABEL "SHIFT DATA" GOTO Shift
7040      ON KEY 1 GOTO Idle
7050      ON KEY 2 LABEL "STORE THE PC" GOTO C_store
7060      ON KEY 3 GOTO Idle
7070      ON KEY 4 LABEL "NEW PC" GOTO C_new
7080      ON KEY 5 LABEL "DUMP TO PRNTR" GOTO Dump
7090      ON KEY 6 GOTO Idle
7100      ON KEY 7 GOTO Idle
7110      ON KEY 8 GOTO Idle
7120      ON KEY 9 LABEL "MAIN MENU" GOTO C_main

```

```

7130      'ON KBD GOTO Bottom
7140 Idle:DISP CHR$(131):"":CHR$(129):"":TIMES(TIMEDATE)
7150      WAIT
7160      GOTO Idle
7170 Down:PRINTER IS 701
7180      OUTPUT KBD:" Y":
7190      PRINTER IS CRT
7200      GOTO Idle
7210 Shift: OFF KEY
7220      GRAPHICS OFF
7230      CALL Clear_crt
7240      DIM View2(361).Plot_pt(365)
7250      INPUT "How many degrees should the data be shifted? (- for shift left)".
Shft
7260      IF Shft<-360 OR Shft>360 THEN GOTO 7270
7270      IF Shft>0 THEN
7280          Shft=360-Shft
7290      ELSE
7300          Shft=Shft*(-1)
7310      END IF
7320      FOR I=1 TO 360-Shft
7330          View2(I)=View(I+Shft)
7340      NEXT I
7350      FOR I2=1 TO Shft
7360          View2(360-Shft+I2)=View(I2)
7370      NEXT I2
7380      FOR I3=1 TO 360
7390          Plot_pt(I3)=View2(I3)
7400          View(I3)=View2(I3)
7410      NEXT I3
7420      GOTO Start
7430 C_stre: OFF KEY
7440      CALL Clear_crt
7450      GRAPHICS OFF
7460          View(361)=Freq
7470          View(362)=Pol
7480      CALL Stre(Date$,Pre_gate$,View(361))
7490      CALL Clear_crt
7500      GOTO Start
7510 C_new: OFF KEY
7520      GRAPHICS OFF
7530      CALL Clear_crt
7540      Choice=1
7550      CALL Check(Chk$)
7560      IF Chk$="Y" THEN GOTO C_stre
7570      SUBEXIT
7580 C_strt: GRAPHICS OFF
7590      CALL Clear_crt
7600      Choice=0
7610      CALL Check(Chk$)
7620      IF Chk$="Y" THEN GOTO C_stre
7630      SUBEXIT
7640 Bottom:GRAPHICS OFF
7650      CALL Clear_crt
7660      SUBEND
7670      !
7680      !
7690      SUB Proc_choice
7700      'Written by Dana J. Bergey, May 1969
7710      CALL L1:SET
7720      Choice: PRINT

```

```

7730 PRINT
7740 PRINT
7750 PRINT "          WHAT TYPE OF FILE DO YOU WISH TO PROCESS?"
7760 PRINT "          FREQUENCY/TIME DATA OR PATTERN DATA"
7770 ON KEY 0 LABEL "FREQ/TIM" GOTO Freqtim
7780 ON KEY 1 GOTO Idle
7790 ON KEY 2 LABEL "PATTERN" GOTO Pattern
7800 ON KEY 3 GOTO Idle
7810 ON KEY 4 GOTO Idle
7820 ON KEY 5 GOTO Idle
7830 ON KEY 6 GOTO Idle
7840 ON KEY 7 GOTO Idle
7850 ON KEY 8 GOTO Idle
7860 ON KEY 9 LABEL "EXIT" GOTO Exit
7870 Idle: DISP "          PRESS APPROPRIATE SOFT KEY"
7880 GOTO Idle
7890 Freqtim: CALL Clr_scr
7900 PRINT "          Please "CHR$(130);"wait";CHR$(126);" while the syste
m is being configured."
7910 OFF KEY
7920 CALL Procplot
7930 GOTO Choice
7940 Pattern: CALL Clr_scr
7950 OFF KEY
7960 CALL Pat_procplot
7970 GOTO Choice
7980 Exit: CALL Clr_scr
7990 OFF KEY
800 SUBEND
8010 !
8020 !
8030 SUB Procplot
8040 ' Written by Dana J. Bergey, May 1989
8050 OPTION BASE 1
8060 ASSIGN @Nwa TO 716
8070 ASSIGN @Nwa_data TO 716:FORMAT OFF
8080 DIM Trace_data(801,2),Plot_dt(801),Data(801,2)
8090 OUTPUT @Nwa:"RECA8:POIN801:"
8100 WAIT 11
8110 CALL Clear_crt
8120 Input: CALL Input(Trace_data(*),Date$,File_names$,Fr1,Fr2,Polarity,Pre_gate$)
8130 CALL Present_data(Fr1,Fr2,Trace_data(*))
8140 OUTPUT @Nwa:"GATECENT 0:ENTO:"
8150 On=1
8160 Gate=-1
8170 CALL Clear_crt
8180 Menu: PRINT
8190 PRINT
8200 PRINT "-----"
8210 PRINT
8220 PRINT
8230 PRINT
8240 PRINT
8250 IF On=1 THEN
8260 PRINT "          "CHR$(129);"YOU ARE NOW VIEWING THE FREQUENCY DOMAIN"
8270 ON KEY 0 LABEL "TIME DOMAIN" GOTO Domain
8280 ON KEY 5 LABEL "NEW DATA" GOTO New_data
8290 ELSE

```

```

3300 PRINT " " ":\CHR$(129):"YOU ARE NOW VIEWING THE TIME DOMAIN":CHR$(
3310 ON KEY 0 LABEL "FREQ. DOMAIN" GOTO Domain
3320 ON KEY 5 LABEL "SPECIFY GATE" GOTO Gate
3330 END IF
3340 PRINT
3350 PRINT
3360 IF Gate=1 THEN PRINT " " ":\CHR$(129):"A TIME GATE HAS BEEN APPLIED TO
THE DATA":CHR$(129)
3370 ON KEY 2 LABEL " " PLOT" GOTO Plot
3380 ON KEY 3 GOTO Idle
3390 ON KEY 9 LABEL " " EXIT" GOTO Exit
3400 ON KEY 7 GOTO Idle
3410 ON KEY 4 GOTO Idle
3420 ON KEY 6 GOTO Idle
3430 ON KEY 7 GOTO Idle
3440 ON KEY 9 GOTO Idle
3450 Idle: DISP "ENTER APPROPRIATE SOFT KEY."
3460 GOTO Idle
3470 Domain: Dn=-1-Dn
3480 IF Dn=1 THEN
3490 OUTPUT %Nua:"FREQ:"
3500 ELSE
3510 OUTPUT %Nua:"TIMB:LOGM:"
3520 WAIT 2
3530 END IF
3540 CALL Clr_scr
3550 GOTO Menu
3560 New_data: CALL Clr_scr
3570 OFF KEY
3580 OUTPUT %Nua:"FREQ:CONT:GATEDOFF:"
3590 GOTO Input
3600 Exit: CALL Clr_scr
3610 OFF KEY
3620 OUTPUT %Nua:"RECA8:POIN801:"
3630 SUBEXIT
3640 Gate: CALL Clr_scr
3650 ON KEY 5 LABEL "ACTIVATE GATE" GOTO Gnoff
3660 ON KEY 7 LABEL " " CENTER" GOTO Center
3670 ON KEY 9 LABEL " " SPAN " GOTO Span
3680 ON KEY 0 GOTO Idle2
3690 ON KEY 1 GOTO Idle2
3700 ON KEY 2 GOTO Idle2
3710 ON KEY 3 GOTO Idle2
3720 ON KEY 4 GOTO Idle2
3730 ON KEY 6 GOTO Idle2
3740 ON KEY 8 GOTO Idle2
3750 Idle2: DISP "ENTER APPROPRIATE SOFT KEY"
3760 GOTO Idle2
3770 Gnoff: CALL Clr_scr
3780 Gate=-1-Gate
3790 IF Gate=1 THEN OUTPUT %Nua:"GATEDON:"
3800 IF Gate=-1 THEN OUTPUT %Nua:"GATEDOFF:"
3810 GOTO Menu
3820 Center: CALL Clr_scr
3830 IF Dn=1 THEN OUTPUT %Nua:"TIME:LOGM:"
3840 Dn=-1
3850 IF Gate=1 THEN OUTPUT %Nua:"GATEDOFF:"
3860 Gate=-1
3870 OUTPUT %Nua:"GATECENT:"
3880 LOCAL 7:5

```

```

8890 PRINT
8900 PRINT
8910 PRINT
8920 PRINT "      USE KNOB ON 9510 TO CENTER GATE. THEN PRESS CONTINUE."
8930 PAUSE
8940 OUTPUT @Nwa: "ENT0:"
8950 GOTO Gate
8960 Span: CALL Clr_scr
8970 IF Dm=1 THEN OUTPUT @Nwa: "TIMB:LOGM:"
8980 Dm=-1
8990 IF Gate=1 THEN OUTPUT @Nwa: "    15:"
9000 Gate=-1
9010 OUTPUT @Nwa: "GATESPAN:"
9020 LOCAL 716
9030 PRINT
9040 PRINT
9050 PRINT
9060 PRINT "      USE KNOB ON 9510 TO SET GATE SPAN. THEN PRESS CONTINUE."
9070 PAUSE
9080 OUTPUT @Nwa: "ENT0:"
9090 GOTO Gate
9100 Plot: CALL Clr_scr
9110 PRINT "                                     Please 10CHRS(100):Wait 10CHRS
(128):
9120 OFF KEY
9130 ASSIGN @Nwa_data2 TO 716:FORMAT ON
9140 OUTPUT @Nwa: "FORM4:OUTFORM:"
9150 ENTER @Nwa_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 @Nwa: "GATECENT:OUTPACT1:"
9210 ENTER @Nwa_data2:Gate_cent
9220 OUTPUT @Nwa: "GATESPAN:OUTPACT1:"
9230 ENTER @Nwa_data2:Gate_span
9240 OUTPUT @Nwa: "ENT0:"
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 Fr=2 THEN BandwidthS="2-13 GHz"
9310 IF Fr=5 THEN BandwidthS="5-13"
9320 IF Fr=9 THEN BandwidthS="8-13"
9330 Plotnend: CALL Clr_scr
9340 Plot=0
9350 Plot=1
9360 ON KEY 1 LABEL "PLOT" Plot=1
9370 ON KEY 2 LABEL "NO PLOT" Plot=0
9380 ON KEY 3 LABEL "EXIT" Plot=0
9390 ON KEY 4 LABEL "GATE" Gate=1
9400 ON KEY 5 LABEL "NO GATE" Gate=0
9410 ON KEY 6 LABEL "GATE THEN" GOTO Lin_typ
9420 ON KEY 7 LABEL "GATE" Gate=1
9430 ON KEY 8 LABEL "NO GATE" Gate=0
9440 ON KEY 9 LABEL "GATE" Gate=1
9450 ON KEY 0 LABEL "NO GATE" Gate=0
9460 GOTO 1000 IF "ENTER APPROPRIATE SOFT KEY"
9470 GOTO 1000
9480 Lin_typ: CALL Clr_scr

```

```

9490 PRINT "          LINE TYPE      DESCRIPTION"
9500 PRINT ""
9510 PRINT "          ) -      Solid line"
9520 PRINT ""
9530 PRINT "          . -      Short dashed line"
9540 PRINT ""
9550 PRINT "          2 to 6 -      Progressively longer dashes"
9560 ON KEY 0 LABEL "0" GOTO Zero
9570 ON KEY 1 LABEL "1" GOTO One
9580 ON KEY 2 LABEL "2" GOTO Two
9590 ON KEY 3 LABEL "3" GOTO Three
9600 ON KEY 4 LABEL "4" GOTO Four
9610 ON KEY 5 LABEL "5" GOTO Five
9620 ON KEY 6 LABEL "6" GOTO Six
9630 ON KEY 7 GOTO Lidle
9640 ON KEY 8 GOTO Lidle
9650 ON KEY 9 GOTO Lidle
9660 Lidle: DISP "SELECT LINE TYPE"
9670 GOTO Lidle
9680 Zero: Lin_typ=0
9690 GOTO Plotmenu
9700 One: Lin_typ=1
9710 GOTO Plotmenu
9720 Two: Lin_typ=2
9730 GOTO Plotmenu
9740 Three: Lin_typ=3
9750 GOTO Plotmenu
9760 Four: Lin_typ=4
9770 GOTO Plotmenu
9780 Five: Lin_typ=5
9790 GOTO Plotmenu
9800 Six: Lin_typ=6
9810 GOTO Plotmenu
9820 Plot_grid: CALL Clr_scr
9830 OFF KEY
9840 CALL Scale_cn(Ymax,Ymin,Plot_dt(*))
9850 CALL Clr_scr
9860 IF Dm=1 THEN CALL Draw_pl(Ymax,Ymin,Fr1,Fr2,Dm,Num_traces)
9870 IF Dm=1 THEN CALL Draw_pl(Ymax,Ymin,T1,T2,Dm,Num_traces)
9880 GOTO Plotmenu
9890 Plot_data: CALL Clr_scr
9900 PRINT "          Please ":CHR$(130); "wait";CHR$(128); " while the da
ta is plotted."
9910 OFF KEY
9920 CALL Draw_data(Plot_dt(*),Ymax,Ymin,File_names,Bandwidth5,F
eS,Gate_cent,Gate_span,DateS,Num_traces,Lin_typ)
9930 CALL Clear_crt
9940 GOTO Plotmenu
9950 Plot_exit: CALL Clr_scr
9960 GOTO Menu
9970 SUBEND
9980
9990
10000 SUB Inout(Trace_data(*),DateS,File_names,Fr1,Fr2,Polarity,Pre_gates)
10010 ! Written by Dana J. Bergey, May 1986
10020 OPTION BASE 1
10030 DIM Data(1605)
10040 CALL Clear_crt
10050 Start:PRINT ""
10060 PRINT ""
10070 PRINT "          Insert disc containing data files into drive 1 and dis

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five."
10080 PRINT ""
10090 PRINT "                                     Press ":CHR$(13):"CONTINUE":CHR$(128):
" when ready."
10100 PAUSE
10110 ON ERROR GOTO Err1
10120 CALL Clear_crt
10130 INPUT "Do you wish to see listing of disk (Y or N)? Default is NO.".L1:
sts
10140 IF L1sts="Y" THEN
10150 CAT
10160 ON KBD GOTO Again
10170 DISP CHR$(10):"Press space bar when ready.":CHR$(128)
10180 Loop:GOTO Loop
10190 ELSE
10200 GOTO Again
10210 END IF
10220 Again:CALL Clear_crt
10230 OFF KBD
10240 OFF ERROR
10250 Name:INPUT "Enter the file name of the stored file.":File_name$
10260 ON ERROR GOTO Err1
10270 GOTO Inbound
10280 Err1:PRINT ERRMS
10290 GOTO Name
10300 Inbound:PRINT "           Please":CHR$(13):" wait":CHR$(128):" while your
file is being loaded and processed."
10310 ASSIGN #File1 TO File_name$
10320 ENTER #File1:Data(*)
10330 ASSIGN #File1 TO *
10340 FOR I=1 TO 801
10350   Trace_data(I,1)=Data(I)
10360   Trace_data(I,2)=Data(I+801)
10370 NEXT I
10380 Fp1=Data(1603)
10390 Fp2=Data(1604)
10400 Polarity=Data(1605)
10410 Date_files=LWCS(File_name$)
10420 ASSIGN #File2 TO Date_files
10430 ENTER #File2,1:Date$
10440 ENTER #File2,2:Pre_gates
10450 ASSIGN #File2 TO *
10460 SUBEXIT
10470 Err2:CALL Clear_crt
10480 DISP ERRMS
10490 BEEP
10500 OFF ERROR
10510 GOTO Start
10520 SUBEND
10530 '
10540 '
10550 SUB Present_data(Fp1,Fp2,Trace_data(*))
10560 '  Written by Dana C. Bergey, May 1989
10570 OPTION BASE 1
10580 INTEGER Preamble_size
10590 DIM Junk(801,2)
10600 ASSIGN #Nua TO 716
10610 ASSIGN #Nua_data TO 716:FORMAT OFF
10620 OUTPUT #Nua:"FORM2:1:1:DATA"
10630 ENTER #Nua_data:Preamble_size,Junk(*)
10640 WAIT 3

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10650 OUTPUT #Nwa:"STAR":F:1:"GHz:"
10660 WAIT 3
10670 OUTPUT #Nwa:"STOP":F:2:"GHz:"
10680 WAIT 3
10690 On=1
10700 OUTPUT #Nwa:"HOLD:GATEDOFF:"
10710 OUTPUT #Nwa:"FORM3:INPURAW:"
10720 OUTPUT #Nwa_data:Preamble,Size,Trace,....*)
10730 SUBEND
10740 !
10750 !
10760 SUB Scale_ch(Ymax,Ymin,Plot_dt(*)
10770 ! Written by Dana J. Bergey, May 1989
10780 ! OPTION BASE 1 !
10790 Ymin=Plot_dt(1) ! INITIALIZE
10800 Ymax=Ymin
10810 FOR J=1 TO 801
10820 IF Plot_dt(J)<Ymin THEN Ymin=Plot_dt(J)
10830 IF Plot_dt(J)>Ymax THEN Ymax=Plot_dt(J)
10840 NEXT J
10850 CALL Clear_crt
10860 PRINT "
"
10870 PRINT " * SCALING CHOICES
"
10880 PRINT " *
"
10890 PRINT " .....
"
10900 PRINT ""
10910 PRINT " The maximum value of the current data is ":Ymax:" (dBsm)."
10920 PRINT " The minimum value of the current data is ":Ymin:" (dBsm)."
10930 PRINT ""
10940 PRINT " ":CHR$(129):"AUTO SCALE":CHR$(129):".....Computer ge-
erates scale."
10950 PRINT ""
10960 PRINT " ":CHR$(129):"USER":CHR$(128):".....User defines
scale."
10970 PRINT ""
10980 PRINT " ":CHR$(129):"MAIN MENU":CHR$(128):".....Exit back to
main menu."
10990 ON KEY 5 LABEL " AUTO SCALE" GOTO Auto
11000 ON KEY 7 LABEL " USER" GOTO User
11010 ON KEY 9 LABEL " MAIN MENU" GOTO M-
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 6 GOTO Idle
11080 ON KEY 8 GOTO Idle
11090 Idle:DISP "Enter appropriate soft key."
11100 GOTO Idle
11110 M-:OFF KEY
11120 help=1
11130 SUBEXIT
11140 User:CALL Clear_crt
11150 PRINT "
"
"
11160 PRINT " * USER DEFINED SCALE
"

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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=Ymax-Ymin
11240 IF Range>0 THEN GOTO Good_rge
11250 BEEP
11260 IF Range=0 THEN PRINT "          You have entered the same value fo
r Ymin and Ymax."
11270 IF Range<0 THEN PRINT "          Your Ymin is greater than y
our Ymax."
11280 PRINT ""
11290 PRINT "          Try again!"
11300 GOTO 11210
11310 Good_rge:CALL Clear_crt
11320 OFF KEY
11330 SUBEXIT
11340 Auto:CALL Clear_crt
11350 Ymax=Ymax+10
11360 Ymax=PROUND(Ymax,1)
11370 Ymin=Ymin-10
11380 Ymin=PROUND(Ymin,1)
11390 OFF KEY
11400 SUBEND
11410 !
11420 !
11430 SUB Heading
11440 CALL Clear_crt
11450 PRINT "          ":CHR$(129):"-----
          ":CHR$(128)
11460 PRINT "          ":CHR$(129):"-
          ":CHR$(128)
11470 PRINT "          ":CHR$(129):"-          AFIT'S AUTOMATED SCATTERING MEASUREM
ENT FACILITY          ":CHR$(128)
11480 PRINT "          ":CHR$(129):"*
          ":CHR$(128)
11490 PRINT "          ":CHR$(129):"-----
          ":CHR$(128)
11500 SUBEND
11510 !
11520 !
11530 SUB Draw_p1(Ymax,Ymin,Xmin,Xmax,Dm,Num_traces)
11540 ! Written by Dana G. Bergey, May 1988
11550 Num_traces=0
11560 CALL Clear_crt
11570 Num_div=8
11580 IF Xmin=6 THEN Num_div=4
11590 IF Dm=-1 THEN Num_div=10
11600 PRINT ""
11610 PRINT ""
11620 PRINT ""
11630 PRINT "          Ensure that paper and two pens are in the plotter at th
is time."
11640 PRINT ""
11650 PRINT "          Press ":CHR$(129):"CONTINUE":CHR$(129)
when ready."
11660 PRINT ""

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11670 CALL Clear_crt
11680 PRINT "                                     Please "CHR$(130);"Wait";CHR$(123);" while -
the grid is plotted."
11690 PRINTER IS 705
11700 ES=CHR$(3)
11710 PRINT "IN:SP1:IP 1500.2000.9500.7500:"
11720 PRINT "SC0.801.0.100:"
11730 PRINT "PU 0.0 PD.801.0.801.100.0.100.0.0 PU:"
11740 PRINT "SI .2..3:TL 3.0:"
11750 FOR X=0 TO 801 STEP 801/Num_div
11760 PRINT "PA".X."0.XT:"
11770 NEXT X
11780 PRINT "TL 1.5.0"
11790 FOR X=0 TO 801 STEP 801/(Num_div*10)
11800 PRINT "PA".X."0.XT"
11810 NEXT X
11820 PRINT "TL 0.3:"
11830 FOR X=0 TO 801 STEP 801/Num_div
11840 PRINT "PA".X."100.XT:"
11850 NEXT X
11860 PRINT "TL 0.1.5"
11870 FOR X=0 TO 801 STEP 801/(Num_div*10)
11880 PRINT "PA".X."100.XT"
11890 NEXT X
11900 FOR X=0 TO 1 STEP 1/Num_div
11910 P=801*X
11920 PRINT "PA".P."0"
11930 V=Xmin+(Xmax-Xmin)*X
11940 V=PROUND(V,-2)
11950 PRINT "CP -1.5,-1;LB":V;ES
11960 NEXT X
11970 IF Dm=1 THEN PRINT "PA".801/2."0:CP -3,-2.5: LBFREQUENCY (GHz)":ES
11980 IF Dm=-1 THEN PRINT "PA".801/2."0:CP -5,-2.5: LBTIME (ns)":ES
11990 PRINT "SC0.1".Ymin.Ymax:"TL 3.0"
12000 Range=Ymax-Ymin
12010 FOR Y=Ymin+10 TO Ymax-10 STEP 10
12020 PRINT "PA0".Y."YT"
12030 NEXT Y
12040 PRINT "TL 1.5.0"
12050 IF Range>49 THEN Little_tick=2.5
12060 IF Range<51 THEN Little_tick=2
12070 IF Range<31 THEN Little_tick=1
12080 FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
12090 PRINT "PA 0".Y."YT"
12100 NEXT Y
12110 PRINT "TL 0.3"
12120 FOR Y=Ymin+10 TO Ymax-10 STEP 10
12130 PRINT "PA 1".Y."YT"
12140 NEXT Y
12150 PRINT "TL 0.1.5"
12160 FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
12170 PRINT "PA 1".Y."YT"
12180 NEXT Y
12190 PRINT "TL 0.1.5"
12200 FOR Y=Ymin+10 TO Ymax-10 STEP 10
12210 PRINT "PA 0".Y."YT"
12220 Ynum=Y
12230 Ynum=PROUND(Ynum,-3)
12240 IF Ynum=-3.99 THEN Offset=5
12250 IF Ynum=-3.99 AND Ynum<-3.99 THEN Offset=5
12260 IF Ynum>-10 AND Ynum<-3.99 THEN Offset=4

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12270 IF Ynum>-1 AND Ynum<0 THEN Offset=3
12280 IF Ynum=0 THEN Offset=0
12290 IF Ynum>0 AND Ynum<1 THEN Offset=2
12300 IF Ynum>.99 AND Ynum<10 THEN Offset=3
12310 IF Ynum>9.99 AND Ynum<100 THEN Offset=4
12320 IF Ynum>99.99 THEN Offset=5
12330 PRINT "CP",(-2.5)-Offset,"-.25:LB";Ynum;C:
12340 NEXT Y
12341 IF Dm=1 THEN
12342 PRINT "PA0".Ymin+Range/2:"DIO.1:CP -5.5"
12343 PRINT "LBRC5 (dBsm)":ES
12344 ELSE
12350 PRINT "PA0".Ymin+Range/3:"DIO.1:CP -5.5"
12360 PRINT "LBIMPULSE RESPONSE (dBsm)":ES
12361 END IF
12370 PRINT "DI1.0"
12380 PRINT "PU:PA0".Ymin,"SI .1S..22S:CP-5,-5:"
12390 PRINT "LBFile Name Bandwidth Polarity Soft gate Gate Cent
er":ES
12400 PRINT "LB Gate Width Date":ES
12410 PRINT "SP0"
12420 PRINTER IS CRT
12430 SUBEND
12440 !
12450 !
12460 SUB Draw_data(Plot_dt(*),Ymax,Ymin,File_names,Bandwidths,Polarity,Pre_gate
S,Gate_cent,Gate_span,DateS,Num_traces,Lin_typ)
12470 ! Written by Dana J. Bergey, May 1989
12480 PRINTER IS 705
12490 PRINT "SC0.801".Ymin,Ymax
12500 PRINT "SP2:"
12510 IF Plot_dt(1)<Ymin THEN Plot_dt(1)=Ymin
12520 IF Plot_dt(1)>Ymax THEN Plot_dt(1)=Ymax
12530 PRINT "PU0".Plot_dt(1);
12540 PRINT "LT2":Lin_typ:";"
12550 IF Lin_typ=0 THEN PRINT "LT:"
12560 FOR I=1 TO 801
12570 IF Plot_dt(I)<Ymin THEN Plot_dt(I)=Ymin
12580 IF Plot_dt(I)>Ymax THEN Plot_dt(I)=Ymax
12590 PRINT "P0".I,Plot_dt(I)
12600 NEXT I
12610 Num_traces=Num_traces+1
12620 PRINT "PU:PA0".Ymin,"SI .1S..22S:CP-5,-5:"
12630 ES=CHR$(3)
12640 IF Polarity=0 THEN
12650 Pols="HORIZONTAL"
12660 ELSE
12670 Pols="VERTICAL"
12680 END IF
12690 FOR I=0 TO Num_traces
12700 PRINT "CP:CP-5.5:"
12710 NEXT I
12720 PRINT "LB":File_names;ES
12730 PRINT "LB":Gate_cent;ES
12740 PRINT "LB":Bandwidths;ES
12750 PRINT "LB":CP;ES
12760 PRINT "LB":Pols;ES
12770 PRINT "LB":CP;ES;ES
12780 PRINT "LB":Pre_gates;ES
12790 IF Gate_span=" " THEN Goto No_gate
12800 PRINT "CP:CP-5.5:"

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12810 PRINT "LS";Gate_cent:ES
12820 PRINT "CP:CP67.1;";
12830 PRINT "LB";Gate_span:ES
12840 No_gate: PRINT "CP:CP78.1;";
12850 PRINT "LB";Dates:ES
12860 Bottom:PRINT "SI .2..3:PU0".Yain."SP :";
12870 PRINTER IS CRT
12880 SUBEND
12890 !
12900 !
12910 SUB Clr_scr
12920 OUTPUT KBD:" V";
12930 SUBEND
12940 !
12950 !
12960 SUB Pat_procplot
12970 ! Written by Dana J. Bergey, May 1989
12980 OPTION BASE 1
12990 DIM Ptrace_data(360),View(365)
13000 Input:CALL Pat_input(Ptrace_data(*),Fr,Dates$.File_name2$.Poi,Pre_gate$)
13010 View:CALL View_crt(Ptrace_data$,File_name2$,Retrn,Coord)
13020 IF Retrn=2 THEN SUBEXIT
13030 IF Retrn=1 THEN GOTO Input
13040 Phenu:ON KEY 0 GOTO Idle
13050 ON KEY 1 LABEL "LINE TYPE" GOTO Lin_typ
13060 ON KEY 2 GOTO Idle
13070 ON KEY 3 GOTO Idle
13080 ON KEY 4 GOTO Idle
13090 ON KEY 5 LABEL "PLOT GRID" GOTO Pgrid
13100 ON KEY 6 GOTO Idle
13110 ON KEY 7 LABEL "PLOT DATA" GOTO Pdata
13120 ON KEY 8 GOTO Idle
13130 ON KEY 9 LABEL "EXIT" GOTO Pexit
13140 Idle:DISP "ENTER APPROPRIATE SOFT KEY"
13150 GOTO Idle
13160 Lin_typ:CALL Clr_scr
13170 ON KEY 0 LABEL "0" GOTO Zero
13180 ON KEY 1 LABEL "1" GOTO One
13190 ON KEY 2 LABEL "2" GOTO Two
13200 ON KEY 3 LABEL "3" GOTO Three
13210 ON KEY 4 LABEL "4" GOTO Four
13220 ON KEY 5 LABEL "5" GOTO Five
13230 ON KEY 6 LABEL "6" GOTO Six
13240 ON KEY 7 GOTO Lidle
13250 ON KEY 8 GOTO Lidle
13260 ON KEY 9 GOTO Lidle
13270 Lidle:DISP "SELEC LINE TYPE"
13280 GOTO Lidle
13290 Zero:Lin_typ=0
13300 GOTO Phenu
13310 One:Lin_typ=1
13320 GOTO Phenu
13330 Two:Lin_typ=2
13340 GOTO Phenu
13350 Three:Lin_typ=3
13360 GOTO Phenu
13370 Four:Lin_typ=4
13380 GOTO Phenu
13390 Five:Lin_typ=5
13400 GOTO Phenu
13410 Six:Lin_typ=6

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13120 GOTO Pmenu
13430 Pgrd: CALL Clr_scr
13440 CALL Pscale_ch(Ymax,fmin,Ptrace_data(*))
13450 CALL Clr_scr
13460 IF Coord=0 THEN CALL Pdraw_pl(Ymax,Ymin,Num_traces)
13470 IF Coord=1 THEN CALL Poldraw_pl(Ymax,fmin,Num_traces)
13480 GOTO Pmenu
13490 Pdata: CALL Clr_scr
13500 IF Coord=0 THEN CALL Pdraw_data(Ptrace_data(*),Ymax,Ymin,File_name2$,Fr,Po
l,Pre_gate$,Date$,Num_traces,Lin_typ)
13510 IF Coord=1 THEN CALL Poldraw_data(Ptrace_data(*),Ymax,Ymin,File_name2$,Fr,
Pol,Pre_gate$,Date$,Num_traces,Lin_typ)
13520 GOTO Pmenu
13530 Pexit: CALL Clr_scr
13540 GRAPHICS OFF
13550 GOTO View
13560 SUBEND
13570 !
13580 !
13590 SUB Pat_input(Ptrace_data(*),Fr,Date$,File_name2$,Pol,Pre_gate$)
13600 ! Written by Dana J. Bergey, May 1989
13610 OPTION BASE 1
13620 DIM View(365)
13630 CALL Clr_scr
13640 Start:PRINT ""
13650 PRINT ""
13660 PRINT "          Insert disc containing data file into right hand disk d
rive."
13670 PRINT ""
13680 PRINT "          Press ";CHR$(131);"CONTINUE";CHR$(128):
" when ready."
13690 PAUSE
13700 ON ERROR GOTO Err2
13710 CALL Clr_scr
13720 INPUT "Do you wish to see listing of disk (Y or N)? Default is NO."Ll
st$
13730 IF Llist$="Y" THEN
13740 CAT
13750 ON KBD GOTO Again
13760 DISP CHR$(131);"Press space bar when ready.";CHR$(128)
13770 Lloop:GOTO Lloop
13780 ELSE
13790 GOTO Again
13800 END IF
13810 Again:CALL Clr_scr
13820 OFF KBD
13830 OFF ERROR
13840 Name:INPUT "Enter the file name of the stored file."File_name2$
13850 ON ERROR GOTO Err1
13860 GOTO Inbound
13870 Err1:PRINT ERRMS
13880 GOTO Name
13890 Inbound:POSITION #File1 TO File_name2$
13900 ENTER #File1v,OUT#
13910 POSITION #File2 TO *
13920 FOR I=1 TO 360
13930 Ptrace_data(I)=View(I)
13940 NEXT I
13950 View(361)
13960 View(362)
13970 LFile2$=Lx03(File_name2$)

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13980 ASSIGN #Dte_file2 TO Dte_file2S
13990 ENTER #Dte_file2.1:Dates
14000 ENTER #Dte_file2.2:Pre_gates
14010 ASSIGN #Dte_file2 TO *
14020 SUBEXIT
14030 Err2:CALL Clr_scr
14040 DISP ERRMS
14050 BEEP
14060 OFF ERROR
14070 GOTO Start
14080 SUBEND
14090 !
14100 !
14110 SUB Pscale_ch(Ymax,fmin,Ptrace_data(*))
14120 ! Written by Dana J. Bergey, May 1989
14130 GRAPHICS OFF
14140 Ymin=Ptrace_data(1) ! INITIALIZE
14150 Ymax=Ymin
14160 FOR J=1 TO 360
14170 IF Ptrace_data(J)<Ymin THEN Ymin=Ptrace_data(J)
14180 IF Ptrace_data(J)>Ymax THEN Ymax=Ptrace_data(J)
14190 NEXT J
14200 CALL Clr_scr
14210 PRINT "
"
14220 PRINT " SCALING CHOICES
"
14230 PRINT "
"
14240 PRINT "
-----
14250 PRINT ""
14260 PRINT " The maximum value of the current data is ":Ymax:" (dBsm)."
14270 PRINT " The minimum value of the current data is ":Ymin:" (dBsm)."
14280 PRINT ""
14290 PRINT " ":CHR$(129):"AUTO SCALE":CHR$(128):".....Computer generated
scale."
14300 PRINT ""
14310 PRINT " ":CHR$(129):"USER":CHR$(128):".....User defines
scale."
14320 PRINT ""
14330 ON KEY 5 LABEL " AUTO SCALE" GOTO Auto
14340 ON KEY 7 LABEL " USER" GOTO User
14350 ON KEY 9 GOTO Idle
14360 ON KEY 0 GOTO Idle
14370 ON KEY 1 GOTO Idle
14380 ON KEY 2 GOTO Idle
14390 ON KEY 3 GOTO Idle
14400 ON KEY 4 GOTO Idle
14410 ON KEY 6 GOTO Idle
14420 ON KEY 8 GOTO Idle
14430 Idle:DISP "Enter appropriate soft key."
14440 GOTO Idle
14450 User:CALL Clear_scr
14460 PRINT "
"
14470 PRINT " USER DEFINED SCALE
"
14480 PRINT "
"
14490 PRINT "
-----

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*****
14500 PRINT ""
14510 INPUT "Enter the maximum value of RCS scale desired.",Ymax
14520 INPUT "Enter the minimum value of RCS scale desired.",Ymin
14530 Range=Ymax-Ymin
14540 IF Range>0 THEN GOTO Good_rge
14550 GOTO 14580
14560 IF Range=0 THEN PRINT "
You have entered the same value fo
r Ymin and Ymax."
14580 IF Range<0 THEN PRINT "
Your Ymin is greater than y
our Ymax."
14590 PRINT ""
14600 PRINT "
Try again!"
14610 GOTO 14520
14620 Good_rge:CALL Clear_crt
14630 OFF KEY
14640 SUBEXIT
14650 Auto:CALL Clear_crt
14660 Ymax=Ymax+10
14670 Ymax=PROUND(Ymax,1)
14680 Ymin=Ymin-10
14690 Ymin=PROUND(Ymin,1)
14700 OFF KEY
14710 SUBEND
14720 !
14730 !
14740 SUB Pdraw_pi(Ymax,Ymin,Num_traces)
14750 ! Written by Dana J. Bergey, May 1989
14760 Num_traces=0
14770 CALL Clr_scr
14780 PRINT ""
14790 PRINT ""
14800 PRINT ""
14810 PRINT "
Ensure that paper and two pens are in the plotter at thi
s time."
14820 PRINT ""
14830 PRINT "
Press ";CHR$(129);"CONTINUE";CHR$(128)
"; when ready."
14840 PAUSE
14850 CALL Clr_scr
14860 GRAPHICS=ON
14870 PRINTER TO 705
14880 CS=CHR$(9)
14890 PRINT "IN:SP1:IP 1500.2000.9500.7500;"
14900 PRINT "SC0.360.0.100;"
14910 PRINT "PD 0.0 PD 360.0.360.100.0.100.0.0 PU;"
14920 PRINT "Q1 12.13:U 3.0;"
14930 FOR Y=45 TO 315 STEP 45
14940 PRINT "PA".X."100.XT;"
14950 NEXT X
14960 PRINT " "
14970 FOR X=45 TO 315 STEP 5
14980 PRINT "PA".X."100.XT;"
14990 NEXT X
15000 PRINT " "
15010 FOR X=45 TO 315 STEP 45
15020 PRINT "PA".X."100.XT;"
15030 NEXT X
15040 PRINT " "
15050 FOR X=45 TO 315 STEP 5

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15060 PRINT "PA".X,"100.XT"
15070 NEXT X
15080 FOR X=0 TO 360 STEP 45
15090 PRINT "PA".X,"0"
15100 IF X<10 THEN PRINT "CP -1.5,-1;LB":X:ES
15110 IF X>9 AND X<100 THEN PRINT "CP -2,-1;LB":X:ES
15120 IF X>99 THEN PRINT "CP -2.5,-1;LB":X:ES
15130 NEXT X
15140 PRINT "PA 180.0;CP -11,-2.5; LBASPECT ANGLE (DEGREES)":ES
15150 PRINT "SC0.360".Ymin,Ymax:"TL 3.0"
15160 Range=Ymax-Ymin
15170 FOR Y=Ymin+10 TO Ymax-10 STEP 10
15180 PRINT "PA0".Y,"YT"
15190 NEXT Y
15200 PRINT "TL 1.5.0"
15210 IF Range>49 THEN Little_tick=2.5
15220 IF Range<51 THEN Little_tick=2
15230 IF Range<31 THEN Little_tick=1
15240 FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
15250 PRINT "PA 0".Y,"YT"
15260 NEXT Y
15270 PRINT "TL 0.3"
15280 FOR Y=Ymin+10 TO Ymax-10 STEP 10
15290 PRINT "PA 360 ".Y,"YT"
15300 NEXT Y
15310 PRINT "TL 0.1.5"
15320 FOR Y=Ymin+Little_tick TO Ymax-Little_tick STEP Little_tick
15330 PRINT "PA 360".Y,"YT"
15340 NEXT Y
15350 PRINT "TL 3.0"
15360 FOR Y=Ymin TO Ymax STEP 10
15370 PRINT "PA 0".Y:
15380 Ynum=Y
15390 Ynum=PROUND(Ynum,-2)
15400 IF Ynum<-99.99 THEN Offset=5
15410 IF Ynum>100 AND Ynum<-9.99 THEN Offset=5
15420 IF Ynum>-10 AND Ynum<-99 THEN Offset=4
15430 IF Ynum>-1 AND Ynum<0 THEN Offset=3
15440 IF Ynum=0 THEN Offset=0
15450 IF Ynum>0 AND Ynum<1 THEN Offset=2
15460 IF Ynum>.99 AND Ynum<10 THEN Offset=3
15470 IF Ynum>9.99 AND Ynum<100 THEN Offset=4
15480 IF Ynum>99.99 THEN Offset=5
15490 PRINT "CP",(-2.5)-Offset,"-.25;LB":Ynum:ES
15500 NEXT Y
15510 PRINT "PA0".Ymin+Range/2:"DIO.1;CP -5.5"
15520 PRINT "SERUG (Observed)"
15530 PRINT "DIO.1.0"
15540 PRINT "PA0".Ymin+Range/2:"DIO.1.0;CP5.-5:"
15550 PRINT "File Name Frequency Polarization Soft gate"
15560 PRINT "0000"
15570 PRINT "ENTER ID OF"
15580 PRINT " "
15590 PRINT " "
15600 PRINT " "
15610 SUB Draw_data(Ptrace_data(*),Ymax,Ymin,File_name2S,Fr,Poi,Pre_gateS,Date)
15620 PRINT "Data by Dana J. Bergey, May 1989"
15630 PRINT " "
15640 PRINT "SC0.360".Ymin,Ymax

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15650 PRINT "SP2:"
15660 PRINT "PU0",Ptrace_data(I):
15670 PRINT "LT2,";Lin_typ:";"
15680 IF Lin_typ=0 THEN PRINT "LT:"
15690 FOR I=1 TO 360
15700 IF Ptrace_data(I)<Ymin THEN Ptrace_data(I)=Ymin
15710 IF Ptrace_data(I)>Ymax THEN Ptrace_data(I)=Ymax
15720 PRINT "PD",I,Ptrace_data(I)
15730 NEXT I
15740 Num_traces=Num_traces+1
15750 PRINT "PU:PA0",Ymin,";SI .15,.225:CP5,-5:"
15760 ES=CHR$(3)
15770 IF Pol=1 THEN
15780 Pol$="VERTICAL"
15790 ELSE
15800 Pol$="HORIZONTAL"
15810 END IF
15820 FOR I=0 TO Num_traces
15830 PRINT "CP0,-I:"
15840 NEXT I
15850 PRINT "LB":File_name2$;ES
15860 PRINT "CP:CP20,I:"
15870 PRINT "LB":Fr:"GHz";ES
15880 PRINT "CP:CP38,I:"
15890 PRINT "LB":Pol$;ES
15900 PRINT "CP:CP59,I:"
15910 PRINT "LB":Pre_gate$;ES
15920 PRINT "CP:CP69,I:"
15930 PRINT "LB":Date$;ES
15940 Bottom:PRINT "SI .2,.3:PU0",Ymin,"SP :";
15950 PRINTER IS CRT
15960 SUBEND
15970 !
15980 !
15990 SUB View_crt(View(*),File_name2$,Retrn,Coord)
16000 ! Written by Dana J. Bergey, May 1989
16010 Start: CALL Ctr_scr
16020 GINIT
16030 CLOTTER IS 3,"INTERNAL"
16040 Ymin=View(1)
16050 Ymax=Ymin
16060 FOR 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 Ymax=Ymax+10
16110 Ymax=ROUND(Ymax,1)
16120 Ymin=Ymin+10
16130 Ymin=ROUND(Ymin,1)
16140 Range=Ymax-Ymin
16150 GRAPHICS ON
16160 MOVE 0,95
16170 CIRCLE 1
16180 CIRCLE 1
16190 LABEL File_name2$
16200 CIRCLE 5
16210 CIRCLE 6
16220 FOR I=-.13 TO .13 STEP .1
16230 MOVE 70+I,100
16240 LABEL "LOW OBSERVABLES"
16250 CIRCLE 1

```

```

6250      SIZE 1
6270      MOVE 0,1
6280      LABEL 63000
6290      FOR I=1 TO 3
6300          LABEL LABEL601,1
6310      NEXT I
6320      MOVE 0,1
6330      LABEL "ASPECT ANGLE"
6340      VIEWPORT 15,125,30,91
6350      FRAME
6360      WINDOW 0,0,360,Ymin,Ymax
6370      AXES 5,0,0,Ymin,9,5,0
6380      GSIZE 3
6390      DORG 6
6400      STOP OFF
6410      FOR I=0 TO 360 STEP 45
6420          MOVE I,Ymin-I
6430          LABEL 1
6440      NEXT I
6450      DORG 8
6460      FOR I=Ymin TO Ymax STEP 10
6470          MOVE -1,I
6480          LABEL 1
6490      NEXT I
6500      FOR I=0 TO 359
6510          PLOT I,View(I+1)
6520      NEXT I
6530      ON KEY 4 LABEL "DUMP TO PRNTR" GOTO Ddump
6540      ON KEY 0 LABEL "PLOT RECT." GOTO Plotr
6550      ON KEY 1 GOTO Idle
6560      ON KEY 2 LABEL "PLOT POLAR" GOTO Plotp
6570      ON KEY 3 GOTO Idle
6580      ON KEY 5 LABEL "NEW DATA" GOTO New_data
6590      ON KEY 6 GOTO Idle
6600      ON KEY 7 LABEL "SHIFT DATA" GOTO Shift
6610      ON KEY 8 GOTO Idle
6620      ON KEY 9 LABEL "EXIT" GOTO Exit
6630      Idle:DISP "PRESS APPROPRIATE SOFT KEY"
6640      GOTO Idle
6650      Ddump:PRINTER IS 701
6660      OUTPUT KBD:" N":
6670      PRINTER IS CRT
6680      GOTO Idle
6690      Shift: CALL Ctr_scr
6700      DIM View2(361)
6710      INPUT "How many degrees should the data be shifted ? (- for shift left)
        Dshift:
6720      ON ERROR GOTO 16710
6730      IF Dshift<-360 OR Dshift>360 THEN GOTO 16710
6740      IF Dshift>0 THEN
6750          Dshift=360-Dshift
6760      ELSE
6770          Dshift=-1+Dshift
6780      END IF
6790      FOR I=1 TO 360-Dshift
6800          View2(I)=View(I+Dshift)
6810      NEXT I
6820      FOR I2=1 TO Dshift
6830          View2(360-Dshift+I2)=View(I2)
6840      NEXT I2
6850      FOR I3=1 TO 360

```

```

16860 View(13)=View2(13)
16870 EXIT 13
16880 GOTO Start
16890 Plotr:CALL Clr_scr
16900 Retrn=0
16910 Coord=0
16920 SUBEXIT
16930 Plotr:CALL Clr_scr
16940 Retrn=0
16950 Coord=1
16960 SUBEXIT
16970 New_data: GRAPHICS OFF
16980 Retrn=1
16990 CALL Clr_scr
17000 SUBEXIT
17010 Exit: GRAPHICS OFF
17020 Retrn=2
17030 CALL Clr_scr
17040 SUBEND
17050 !
17060 !
17070 SUB Foldraw_p1(Ymax,(min,Num_traces)
17080 ! written by Dana J. Bergey, May 1989
17090 Num_traces=0
17100 CALL Clr_scr
17110 PRINT ""
17120 PRINT ""
17130 PRINT ""
17140 PRINT "          Ensure that paper and two pens are in the plotter at th
s time."
17150 PRINT ""
17160 PRINT "          Press ':'CHR$(129):"CONTINUE":CHR$(129)
:" when ready."
17170 PAUSE
17180 CALL Clr_scr
17190 PRINTER IS 705
17200 ES=CHR$(3)
17210 PRINT "IN:SP1:IP 1000,900,9000,8900"
17220 PRINT "SC",Ymin,Ymax,Ymin,Ymax
17230 Cntr=Ymax-(Ymax-Ymin)/2
17240 Numcirc=(Ymax-Ymin)/10
17250 Radmax=(Ymax-Ymin)/2
17260 FOR I=1 TO Numcirc
17270 FOR T=0 TO 2*PI STEP PI/50
17280 X=Cntr+(COS(T)*Radmax/Numcirc*I)*.81
17290 Y=Cntr+SIN(T)*Radmax/Numcirc*I
17300 PRINT USING 17310:"PA",X,Y,"PD:"
17310 IMAGE 2A,2(MDD,DDDD),3A
17320 NEXT T
17330 PRINT "PU"
17340 NEXT I
17350 PRINT "PU:LT2,1"
17360 FOR T=0 TO 2*PI-PI/18 STEP PI/18
17370 Strtx=Cntr+Radmax*(COS(T)*.81
17380 Strty=Cntr+Radmax*SIN(T)
17390 PRINT "PU:PA",Strtx,Strty
17400 Endx=Cntr+Radmax/Numcirc*(COS(T)*.81
17410 Endy=Cntr+Radmax/Numcirc*SIN(T)
17420 PRINT "PD:PA",Endx,Endy
17430 NEXT T
17440 PRINT "LT:DI1,0"

```

```

17450 Pos1=Cntr-Radmax/12
17460 PRINT "PU:PA".Pos1,Cntr
17470 PRINT "LB":Ymin:ES
17480 PRINT "LBdBsm":ES
17490 Pos2=Ymax-Radmax/6
17500 PRINT "PU:PA".Pos2,Cntr
17510 PRINT "LB":Ymax:ES
17520 PRINT "LBdBsm, 0 degrees":ES
17530 D90x=Cntr-(Ymax-Ymin)/20
17540 D90y=Cntr+Radmax
17550 ! PRINT "PU:PA".D90x,D90y
17560 ! PRINT "LB90 degrees":ES
17570 D180x=Cntr-Radmax*7/6
17580 D180y=Cntr
17590 PRINT "PU:PA".D180x,D180y
17600 PRINT "LB180 degrees":ES
17610 Wrdsx=Cntr-Radmax*.8
17620 Wrdsy=Cntr-Radmax*.8
17630 PRINT "PU:PA".Wrdsx,Wrdsy,";SI .15..225:CP0,-5;"
17640 PRINT "LBFile Name      Frequency      Polarization      Soft gate
      Date":ES
17650 PRINT "SP0"
17660 PRINTER IS CRT
17670 SUBEND
17680 !
17690 !
17700 SUB Poldraw_data(Ptrace_data(*),Ymax,Ymin,File_name$.Fr,Pol,Pre_gate$.Date
S,Num_traces,Lin_typ)
17710 ! Written by Dana J. Bergey, May 1989
17720 PRINTER IS 705
17730 PRINT "IP 1000,900.9000.8900:SC".Ymin,Ymax,Ymin,Ymax
17740 PRINT "SP2:"
17750 Numcirc=(Ymax-Ymin)/10
17760 Radmax=(Ymax-Ymin)/2
17770 Extra=Radmax/Numcirc
17780 Cntr=Ymax-(Ymax-Ymin)/2
17790 Xp=Cntr+.5*(Ptrace_data(1)-Ymin)*.81
17800 PRINT "PU".Xp,Cntr
17810 PRINT "LT2":Lin_typ:";"
17820 IF Lin_typ=0 THEN PRINT "LT:"
17830 FOR I=1 TO 360
17840 Theta=I/180*3.14159
17850 X=(Ptrace_data(I)-Ymin)*COS(Theta)*.81
17860 Xp=Cntr+X/2
17870 Y=(Ptrace_data(I)-Ymin)*SIN(Theta)
17880 Yp=Cntr+Y/2
17890 PRINT "PD".Xp,Yp
17900 NEXT I
17910 Num_traces=Num_traces+1
17920 Xp=Cntr+.5*(Ptrace_data(1)-Ymin)*.81
17930 PRINT "PD".Xp,Cntr
17940 Wrdsx=Cntr-Radmax*.8
17950 Wrdsy=Cntr-Radmax*.8
17960 PRINT "PU:PA".Wrdsx,Wrdsy,";SI .15..225:CP0,-4;"
17970 ES=CHR$(3)
17980 IF Pol=1 THEN
17990 Pol$="HORIZONTAL"
18000 ELSE
18010 Pol$="VERTICAL"
18020 END IF
18030 FOR I=0 TO Num_traces

```

```

18040     PRINT "CP0.-1;"
18050 NEXT I
18060 PRINT "LB":File_name$:E$
18070 PRINT "CP:CP16.1:"
18080 PRINT "LB":Fr:" GHz":E$
18090 PRINT "CP:CP33.1:"
18100 PRINT "LB":Pol$:E$
18110 PRINT "CP:CP52.1:"
18120 PRINT "LB":Pre_gate$:E$
18130 PRINT "CP:CP54.1:"
18140 PRINT "LB":Date$:E$
18150 Out=Cntr-Radmax
18160 PRINT "PU":Cntr.Out.";SP0:"
18170 PRINTER IS CRT
18180 SUBEND
18190 !

```

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Vita

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[REDACTED] [REDACTED]
[REDACTED] 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.

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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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