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NEAR FIELD ANTENNA MEASUREMENT SYSTEM.(U)

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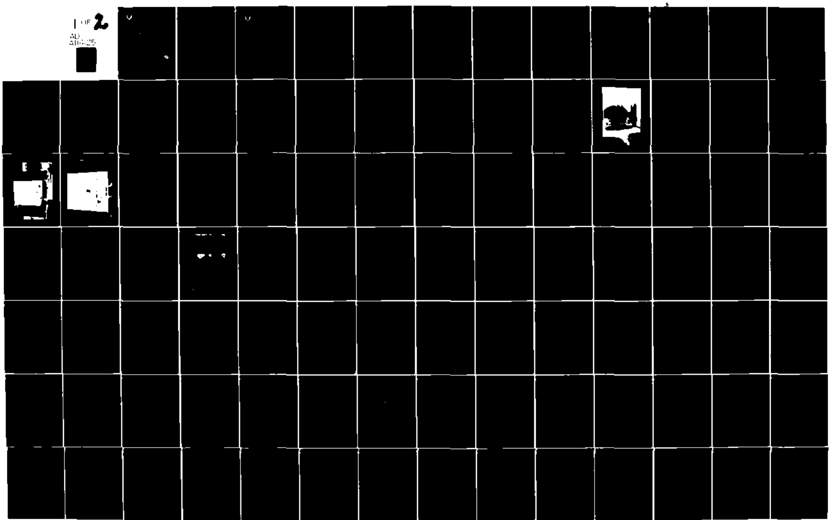

Research and Development Technical Report

DAAB07-77-C-0587-F1

NEAR FIELD ANTENNA MEASUREMENT SYSTEM

A.E. Holley

HUGHES AIRCRAFT COMPANY
1901 W. MALVERN
FULLERTON, CALIFORNIA 92634

MARCH 1982

FINAL REPORT FOR PERIOD 29 AUGUST 1977-29 OCTOBER 1981

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FINAL REPORT

NEAR FIELD ANTENNA MEASUREMENT SYSTEM

29 AUGUST 1977 TO 29 OCTOBER 1981

CONTRACT DAAB07-77-C-0587

Placed by: Director ET&D Laboratory
Attn: DELET-RM
Fort Monmouth, New Jersey 07703

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This report describes the development and evaluation of a fully automated self-contained near field antenna measurement facility. A description of the system and its normal operation is included. The development of each major subsystem is described and the evaluation procedures and results are detailed. Finally, recommendations for further development are given. In summary, the system has shown the feasibility of performing complex antenna measurements in a highly time-effective production mode while retaining accuracies comparable to typical far field ranges.

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ABSTRACT

This report describes the development and evaluation of a fully automated self-contained near field antenna measurement facility. A description of the system and its normal operation is included. The development of each major subsystem is described and the evaluation procedures and results are detailed. Finally, recommendations for further development are given. In summary, the system has shown the feasibility of performing complex antenna measurements in a highly time-effective production mode while retaining accuracies comparable to typical far field ranges.

TABLE OF CONTENTS

1. PURPOSE

The measurement of antenna characteristics is a significant cost item in the development, manufacturing, and field use of many radar and communication systems. Such costs are particularly high for phased array radar systems where a large amount of information, such as beam position data, is required on each individual antenna in order to provide system calibrations.

The conventional approach to such requirements involves transporting the antennas and beam steering control equipment to a high performance outdoor pattern range, often at a considerable distance from the manufacturing site. Even if the pattern range is automated so that data acquisition is computer controlled, a relatively long test program is required to properly evaluate typical phased arrays. If problems arise, far field pattern measurements provide little insight into the difficulty--a single miswired phase shifter or an open connection in a complex array may be almost impossible to diagnose without dismantling the system.

In recent years, a measurement technique called near field probing has been developed to the point where it can provide an effective alternate to the far field range. The National Bureau of Standards, Boulder, Colorado [1,2,3], and the Georgia Institute of Technology, Atlanta, Georgia [4,5], have pioneered in the development of the hardware and computational techniques necessary to make this approach practical. Both organizations have built and demonstrated systems which provide accurate measurements on typical array antennas.

The near field technique involves the sampling of the vector RF field on a periodic grid near the antenna radiating aperture. These data are converted to a far field pattern by a mathematical algorithm equivalent to the actual creation of the far field pattern in space from the field distribution. Although the sampling must be periodic, and approximately at half wavelength intervals, an absolute position reference to the antenna aperture is not required. This feature makes the technique extremely cost effective for measurements of phased arrays since many beam positions can be interlaced during a single scan of the near field probe. Fast RF switching may also be used to allow sum and difference or multiple beam antenna ports to be properly sampled during a single scan.

This program has developed the hardware and software necessary to provide a near field measurement system capable of meeting the requirements for measurements of planar array antennas such as the AN/TPQ-36 and AN/TPQ-37.

2. NARRATIVE

a. System Description

The near field probe (NFP) developed consists of a two axis XY antenna probe positioner, an antenna mounting structure, a signal source, a phase amplitude detector, and a computer display and control system. The system is entirely self sufficient with only special control devices for the antenna under test required to perform a full measurement of all pertinent antenna paraneters.

The basic design of the positioner is similar to the very successful NBS facility except for modifications necessary to make the positioner relocatable and changes to the horizontal drive mechanism. Instead of attaching the XY positioner to a reinforced concrete wall as NBS has done, the positioner uses A-frames at both ends to support the structure and for attaching the positioner to a concrete pad. NBS used a combination chain/cable arrangement for the horizontal drive that was thought to be too flexible, so the mechanism employed to drive the carriage uses roller chains at both top and bottom. The chains are connected to sprockets at the top and bottom of a rigid vertical drive shaft to insure that the motion of the top and bottom of the carriage is the same. The positioner scans in a vertical plane and is capable of traversing 13 feet in the X (horizontal) direction and 15 feet in the Y (vertical) direction. Simple scaling of the design could be used to obtain different area coverage. Lateral displacement of the probe with respect to the antenna under test (Z direction) is accomplished by movement of the antenna mount.

The artist's sketch in Figure 2-1 shows the positioner structure.

The antenna mounting fixture, while designed primarily to support the AN/TPQ-36 and AN/TPQ-37 antennas, can readily be used with other antennas. This antenna mount has the capability of linear travel in the lateral (Z) direction and rotation about a Y (vertical) axis. The lateral motion is provided by Roundway bearings riding on hardened and ground chrome plated steel bearing shafts. The lateral travel is sufficient to allow rotation of the mount and convenient installation or removal of the AN/TPQ-36 and AN/TPQ-37 antennas without interference with the probe positioning structure. The rotation about a Y-axis is provided by a large turntable bearing. Locking mechanisms are provided to prohibit lateral and rotational movement while measurements are being taken.

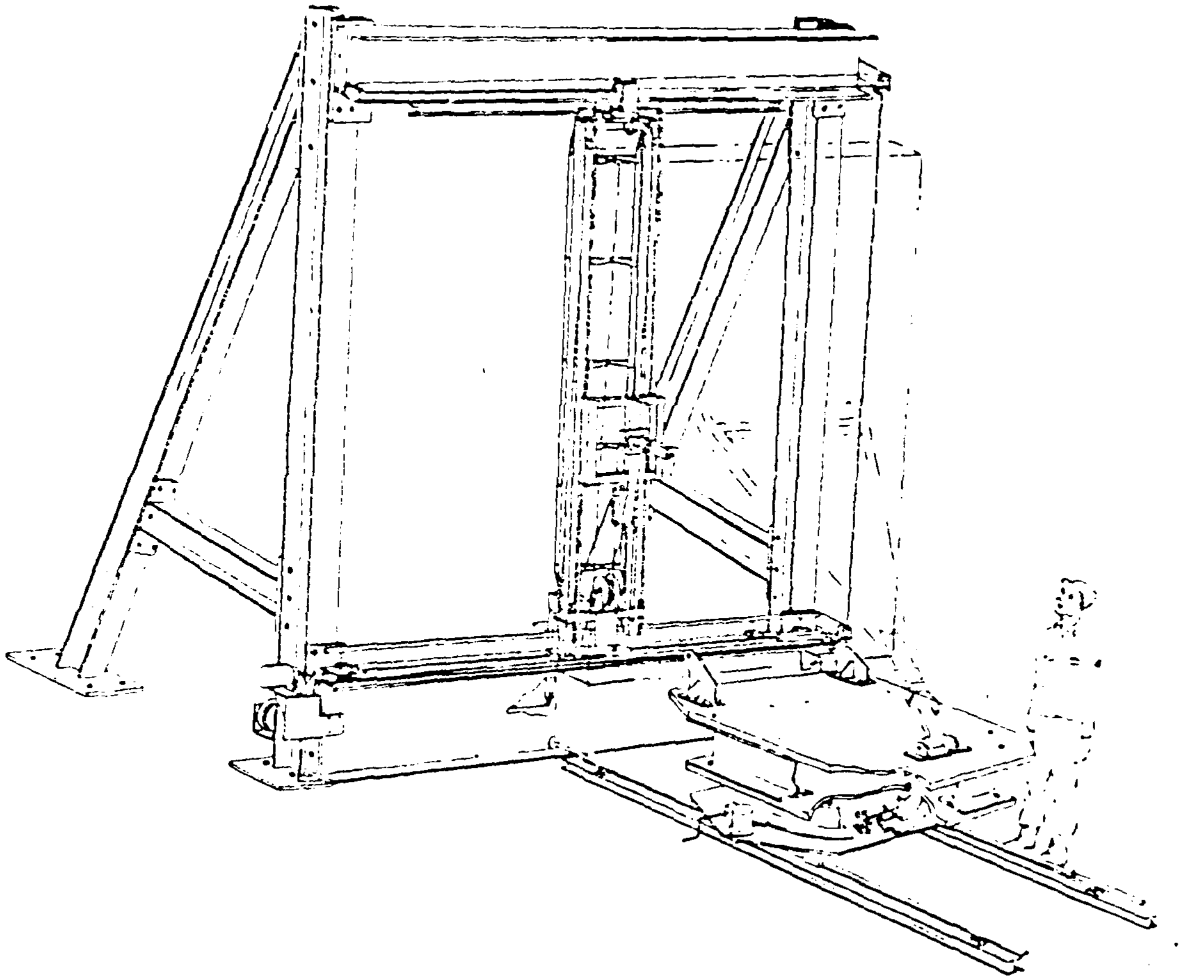

Figure 2.1
Positioner Mechanism with Antenna Mount.

Accurate position measurements in the X and Y direction are made by a Hewlett-Packard laser interferometer measuring system. The laser measuring system is more than adequate to provide the specified probe position resolution of .005 in. Each axis is monitored by the software operating system to allow on-line determination of the probe location while the probe is traveling across the antenna aperture.

The probe used to sample the radiated field mounts in a simple, manually adjusted fixture on the vertical carriage of the positioner. The fixture allows the probe to be rotated about a Z-axis for either horizontal or vertical polarization selection with 90 degree indexing provided to insure repeatability. The accuracy obtained in the computation of the far field patterns is strongly dependent on the accuracy of the probe characterization.

A frequency synthesizer (Hewlett-Packard 8672A) and network analyzer (Hewlett-Packard 8410) form the source and phase amplitude detector for the system. These specific units make it possible to realize measurement rates consistent with the concept of multiplexing and obtaining a full set of antenna data in a single scan, while meeting the stability and accuracy required to meet the system performance objectives. High performance analog to digital converters are used to translate the phase and amplitude data from the network analyzer into the computer.

A Hewlett-Packard 1000 computer system has been chosen for this application because of its sophisticated real-time executive operating system, extensive instrument interference capability, large and fast memory, complete subsystem software, and high-speed input/output. All normal operations are performed under the control of the real-time executive and Hughes-developed subsystem software.

The 50 megabyte on-line disc provides sufficient data storage for both the near-field probe data and software used in data collection and analysis. The disc also provides a medium for interactive software modification and program generation. A magnetic tape drive allows the system user the capability to store collected data and programs for off-line use, transfer to other computer systems, or for archives. The computer used provides adequate main memory to handle the special processing required for the efficient production of three-dimensional or contour plots.

Two devices are used for graphic display--a Hewlett-Packard CRT terminal display and a Versatec Model 1200 electrostatic printing/plotting device. The CRT has 1024 x 1024 addressable points; the hard copy unit provides 200 dots/inch, across the

11-inch page and may generate as long a plot as required. These graphic peripherals have dual functions since they are also used as the system console and line printer, respectively. Simple plots may be generated on both the CRT terminal and hard copy plotter while more sophisticated plots such as contours and three-dimensional isometrics are generated only on the electrostatic plotter.

Software developed specifically for the near field measurement system can be divided into four general categories:

- Control and measurement
- Analysis
- Display
- Utility

The control and measurement software involves mostly programming written specifically for the system. The analysis software is based on a number of FORTRAN subroutines which have already been developed by NBS and Georgia Tech and which have been extensively modified to operate on the HP1000 system. Display software involves a set of standard VERSATEC programs and a group of routines converted from a library made available by NCAR. Utility programs are provided to simplify setting up tests and to check out both the system and the antenna to be tested.

This standard software provided with the selected minocomputer system is among the most complete and capable of any currently available for a minicomputer including many functions normally not associated with minicomputers. The real-time operating system is the most appropriate computer operating software available for automated test applications.

b. <u>System Operation</u>

The operation of the X-Y positioner including the laser interferometer, selection of the RF source frequency, and recording and storing probe data is completely controlled by software subroutines. The control programming operates in two basic modes, with all operator dialog being performed through a conversational command sequence. One mode is normally used for making a measurement on either an AN/TPQ-36 or AN/TPQ-37 antenna using a predetermined set of frequencies and beam positions. In this mode, all parameters, such as positioner speed, measurement intervals, data file allocation, and number of antenna inputs, are already known, and the measurement begins on operator command.

The second mode of program execution allows an operator to specify the various characteristics of a measurement for general applications. Parameters, such as measurement frequencies, beam positions, and number of antenna input ports, are input through the console keyboard using an English language dialog with the operator. The program will then automatically begin the measurement. Controls are available to the operator to perform spot check during a measurement or he may allow a complete measurement sequence to run unattended.

Measurement intervals are normally determined by the measurement frequencies. Data for each beam position and antenna input port should be measured at about half-wavelength intervals at the highest frequency. A table of locations is constructed in the program that is compared to the laser interferometer location data. At each point of coincidence during a vertical scan of the positioner a measurement of phase and amplitude is initiated and then a frequency, beam position or port parameter may be changed to be ready for data to be taken at the next coincidence. This pattern is repeated for each half wavelength segment of travel. At the end of the pass, the vertical drive is set back to the start position, the horizontal drive moved approximately one-half wavelength, and another vertical pass started. Optimum positioner speed is determined from the measurement parameters to allow data to be taken in the shortest possible time while still allowing adequate time for changes to occur between data points.

After the entire data set has been acquired and stored on the disc, the analysis programs are initiated to produce the required output data. The analysis may be performed in a fully automatic manner using predetermined formats, etc., for production tests or in an interactive mode with all selections under operator control. All conventional antenna parameters may be calculated with patterns plotted in conventional formats, as contour plots or as three-dimensional isometrics.

3. HARDWARE DEVELOPMENT

a. Introduction

This section describes the individual hardware elements of the system, discusses problems encountered during the development and comments on the applicability of the items for future systems. In general, the hardware does not deviate significantly from what was originally proposed, no significant problems were encountered, and the primary differences that would be recommended for a new system are those arising from improvements to the state of the art rather than changes in concepts or techniques. Figure 3-1 is a detailed block diagram of the system; for discussion purposes this equipment is divided into these groups:

- Computer system
- Microwave equipment
- Laser system
- Positioner structure
- Positioner drive and control equipment
- Antenna mount structure
- Microwave absorber and housings
- Interface and cabling

b. Computer System

As originally planned, a Hewlett-Packard 1000 computer system and peripherals have been used for the program. With the exception of minor hardware failures normally encountered in this type of equipment and quickly repaired under maintenance contract, no difficulties have been observed in the use of this segment of the system. In addition to hardware maintenance, a software service contract has also been in effect and the computer system software has been kept to the latest HP configuration at all times. During the course of the program a number of enhancements and additions to the operating system have been made and are fully documented in the manuals provided. When and where appropriate the Hughes-developed software has been modified to take advantage of these improvements.

Except for the special card for beam steering unit control (described in the section on interface and cabling), no hardware associated with the computer system has been developed or modified for the program. The Hughes-created software is discussed separately. The computer system consists of the following hardware items:

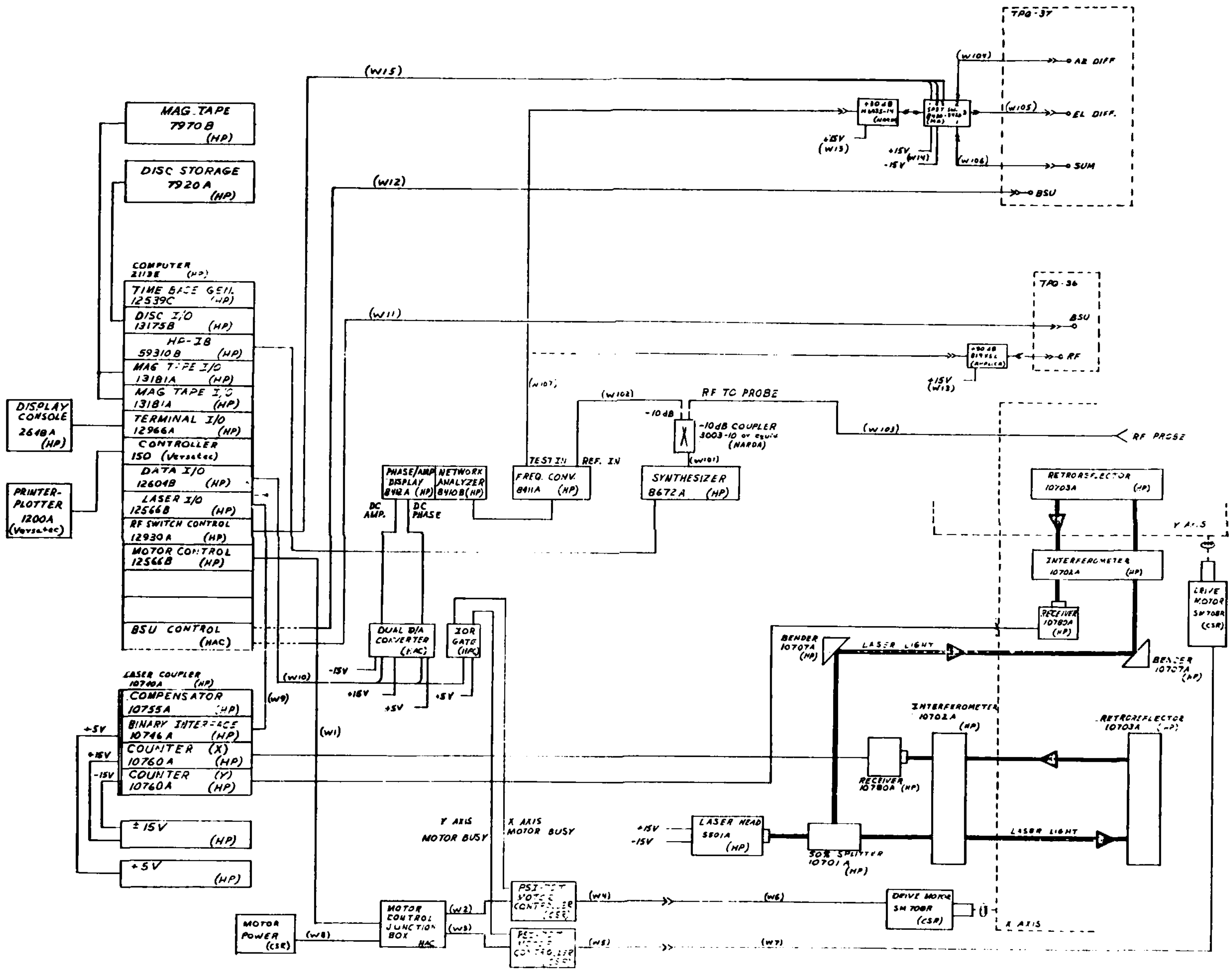

FIGURE 3.1. ARMY NEAR FIELD PROBE--SYSTEM BLOCK DIAGRAM.

A Hewlett-Packard 2172A Computer System containing:

- HP-2113E series computer main frame with 512K byte hi-performance memory
- HP-2648A Graphics Display terminal with dual cassettes used for system console and CRT display.
- HP-7920 50M byte Disc used for normal storage of all software and data files.
- HP-7970 Magnetic Tape Drive.

A Versatec 1200 A Printer/Plotter with a model 150 controller interface provides a high-speed hard copy printer and high resolution graphics output (.005" resolution).

A group of standard Hewlett-Packard interface cards provides communications with other hardware systems.

- 12556B 40-bit Output Register--provides link to the CSR motor controllers.
- 12604B Data Source Interface--provides control and reads data from the A to D converters.
- 12566B Microcircuit Interface--provides the laser subsystem interface.
- 12930 Universal Interface--provides multiplexer control.
- 59310B HPIB Interface--provides control for the synthesizer.

No changes to this group of hardware appear necessary for future system applications. Some improvement in analysis speed would be obtained if the main computer utilized an F series CPU and a larger memory; however, the cost effectiveness of such a change would have to be examined for the specific application. In a new system, the printer plotter should be replaced by Versatec's new model, the VS-80, to obtain a speed improvement and as an insurance against obsolescence. Additions which would be required for system enhancements are discussed in the section on recommendations at the end of the report.

c. <u>Microwave Equipment</u>

This group includes the components of the system associated with the generation, transmission and detection of the RF signals required for operation. Although the general configuration of this equipment is as proposed, some changes to the original approach were made during the program to obtain improved performance. The major components of this group, shown in detail in Figure 3.1, will be described individually.

- Signal Source.

  As proposed, a Hewlett-Packard 8672A Microwave Synthesizer provides the basic RF source. Measurements (described later) have shown that the performance of this unit is more than adequate to meet the control, stability, and switching speed for the program requirements. The unit has proven very reliable and extensive status checks, built into the software, have not shown any operational problems during measurements.

- Receiver

  The RF phase amplitude detector consists of a Hewlett-Packard 8410B Network Analyzer Main Frame, a HP 8412A phase gain display and a HP 8411A harmonic converter. A sample of the synthesizer output is routed, using a Narda 3003-10 or 3004-10 10 dB directional coupler, to the reference channel of the harmonic converter and the signal from the antenna under test is coupled to the test channel of the converter. The analog outputs of the phase gain display provide the simultaneous phase and amplitude information which drives the A to D converter. Most of the measurement errors in the system arise within this hardware. A calibration approach which allows correction of the offsets and nonlinearities has been developed and incorporated in the operating software. Performance tests (described later) show the effectiveness of this correction method. No problem has been encountered in long-term drift, even though measurements may take as long as 18 hours.

  The phase amplitude display provides a phase output within the range of ±180 degrees with a "jump" from -180 to +180 as the actual phase moves past 180 degrees. A small region (typically less than 2 degrees wide) exists where the signal at the analog output is very erratic and not correct. This potential error source is eliminated by detecting (in the computer) the presence of a "noisy" phase signal when the amplitude is not noisy, and setting the phase value for such readings to 180. As described in the section on performance tests, this approach yields excellent phase accuracy. A commonly used alternate approach to obtaining phase data involves a polar display whose analog outputs are the X and Y coordinates of the relative signal. Although no "jump" problem is present, that technique requires an additional A to D channel, automated ranging to obtain adequate dynamic range, and suffers from periodic phase distortions (usually referred to as quadrature error) in any case. The first technique was chosen due to its hardware simplicity, excellent linearity and speed of response. The phase calibration technique allows the system to correct for any offsets and scaling errors in the display. The data for a typical calibration has typically shown only about a two percent deviation from the nominal values of the constants which relate analog voltage and phase.

The analog amplitude signal from the phase amplitude display is the logarithmic ratio of the reference and test signals and is therefore directly related to the dB difference of the two amplitudes. For accurate near field analysis the amplitude data must be relative to a through connection between the system test probe and the output of the antenna under test.

The calibration procedure determines this "absolute" reference and allows setting the network analyzer gain to operate in the region of best linearity. Further improvement in the linearity is obtained by providing software which calibrates each 10 dB segment of the amplitude range.

The useful dynamic range of the network analyzer is on the order of 45 dB. For the planar array antennas that the system was designed for, only about 25 dB of the range is significant since the amplitude falls very rapidly beyond the edges of the aperture. For other uses the dynamic range could be improved to about 50 dB by averaging a number of readings; however, measurement speed would have to be sacrificed. Another approach to a wider dynamic range is discussed under Recommendations.

- Preamplifiers

  Solid state preamplifiers are used to provide adequate signal levels for proper network analyzer operation. They are placed in the line between the antenna under test and the test channel input to the harmonic converter and are included in all calibrations. During the development, one of the original units failed due to a broken connector and was replaced with a newer design. No other problems have been encountered in using these amplifiers. The units currently used are:

  - Amplica 819XSL for the X-band region
  - Narda N62335-14 for the S-band region

- Multiplexer Switch

  A high speed SP3T diode switch is provided to perform port multiplexing between sum, azimuth difference, and elevation difference channels if a multiport antenna is being tested. A Microwave Associates MA-8430-342D is used and is driven directly from the computer via a universal interface card. During the development program this unit has failed once and been replaced. The utility program for the system contains a section which allows control of the switch to check operational performance. The switch loss does vary slightly between ports and since the switch is within the calibrated portion of the RF transmission path the calibration should be performed with the switch set to the port which is most critical for gain accuracy.

- Probes

  The test horns are simple open ended waveguides with narrow wall irises for matching over the operating bands. These horns have been measured at the National Bureau of Standards, Boulder, Colorado and the spherical pattern data stored on tape. This data has also been converted to the format required by the analysis programs and stored as system disc files accessed by the analysis software. Absolute gain of the probes was measured using the NBS extrapolation technique and the gain vs. frequency data is stored as a straight line function in the programs. No problems have been encountered in using these probes. An identical backup unit is available for each band in case of damage.

- Cable Wrap

  The original concept called for RF connections between the moving probe and the signal source to be carried by flexible, coaxial lines using a large drum for each axis to wrap the cable as the probe moved. After purchasing suitable cables, it was found that better stability was obtained by keeping the cable configuration constant (i.e., in a hairpin shape) rather than allowing the varying number of turns on a drum. The drum approach was therefore dropped and simple cable supports used to control the cable shape during motion. The cable selected, Astrolab 71002 series, provides adequate stability with motion, temperature and time. The most critical effect, phase change with motion, is evaluated as part of the system performance checks described later. A combination of semirigid and flexible cables has been used for the remaining RF lines required. All of the RF cabling is included in the calibration so minor variations in loss with frequency, etc., are properly corrected.

d. Laser

A Hewlett-Packard 5500 series measurement laser system provides the high resolution, high precision linear distance measurements required to properly acquire data for the system. As shown in the block diagram, Figure 3.1, a single model 5501A laser transducer provides the dual mode He-Ne beam used for both X and Y axis measurements. This transducer with an output of about 2 milliwatts is more than adequate to provide reliable data over the distances involved in the near field system. The low power level places this unit in safety class II so that special eye protection is not required except when actually adjusting the laser hardware. The beam is split by a HP10701A beamsplitter with the direct portion used for the X axis and the secondary beam directed by two HP10707A 90° beam benders to the Y axis. The splitter and beam benders are on adjustable mounts to permit alignment of the laser beams along the X and Y axis. The measurement sections of the laser system are identical for each axis. An HP10702A interferometer and a 10780A receiver is mounted to the "fixed" part of the structure and the "moving" segment carries a 10703A retroreflector. In this configuration the output from the receiver is a pulse train which measures the change in distance between the interferometer and retroreflector with a resolution of 0.6 microns.

The electronics of the laser subsystem is housed in a 10740A card cage in the system rack and includes two 10760A counters which keep track of the magnitude and direction of the receive pulse outputs; a 10756A manual compensator which provides a mechanism for entering the speed of light correction for humidity, temperature, and atmospheric pressure; and a 10740A coupler which provides the interface to the computer system.

With the exception of some minor difficulties with the computer interface having been designed for a different HP computer system, no problems other than routine maintenance have been encountered with the laser system. This hardware has also been kept on a service contract which covers all parts except the transducer tube.

Operation of the laser system has proven to be simple and reliable. In normal use the system is zeroed at one corner of the scan area and then maintains the distance measurement over a long period of time. Fairly elaborate error checking, reporting, and recovery built into the software has rarely been exercised. The primary problem with this type of system is the loss of a dimensional reference if the beam is broken. Such beam interruption is almost always the result of a physical object such as an arm being in the way and it is relatively easy to train users to be careful to avoid such action. Two problems with beam interruption encountered in normal use were large insects and air currents. Both are minimized by the enclosed chamber; however, with one antenna a plastic film skirt had to be added during testing to direct air from internal blowers in the antenna away from the laser beams.

The laser equipment used is still a standard Hewlett-Packard product and would be recommended for a new system. The nominal resolution and accuracy of the laser exceed any measuring equipment that can be used to test it, so providing the "absolute" accuracy of this equipment is somewhat meaningless. Coarse checks are performed as part of the acceptance procedures described later and, known failure modes result in quickly detected gross errors.

e. Positioner Structure

The positioner structure is essentially identical to the originally planned design except for minor bracket changes and additions to accommodate the drive system. The basic structure shown in the sketch of Figure 2.1 and the photograph in Figure 3.2 consists of six main parts; a lower cross beam, an upper cross beam, two A-frame vertical end sections, a traveling vertical carriage, and a probe mount. These sections are fabricated from standard structural steel shapes and designed to handle the static and dynamic loads with deflections far below system requirements. The traveling carriage and the probe mount ride on steel guide shafts using ball bushing pillow blocks. The lower horizontal shaft is 2" in diameter, the others are 1". The shafts are mounted to the structure with specially-designed adjusters which provide two axes of control for aligning the shafts. Various chain and cable guides, laser component mounts, probe support fixtures and absorber mounting brackets form the balance of the positioner structure.

Except for delivery problems with some of the fabricated components no difficulties were encountered in the construction, erection, and alignment of the positioner structure. Detailed procedures for the assembly, alignment and test of this structure are given in the operating manual and the results of the mechanical evaluation tests are given later in this report.

The primary design limitation found during initial tests of the positioner involved the adjustable mounts for the 2" shaft which supports the traveling carriage. The adjustable mounts do not support the weight of the carriage without measurable deformation--up to .010". This movement could effectively tilt the carriage as it moved along the X axis.

The problem was largely eliminated by providing additional supports under the 2" shaft between the adjustable mounts. The additional supports consisted of 1/2" bolts sitting on flanged nuts to distribute the load. Since the 1/2" bolts are significantly stiffer than the adjustable mounts, the load of the carriage is carried by the bolts. In a new system, a better solution would be the utilization of a 3" lower shaft and heavier duty adjustable mounts.

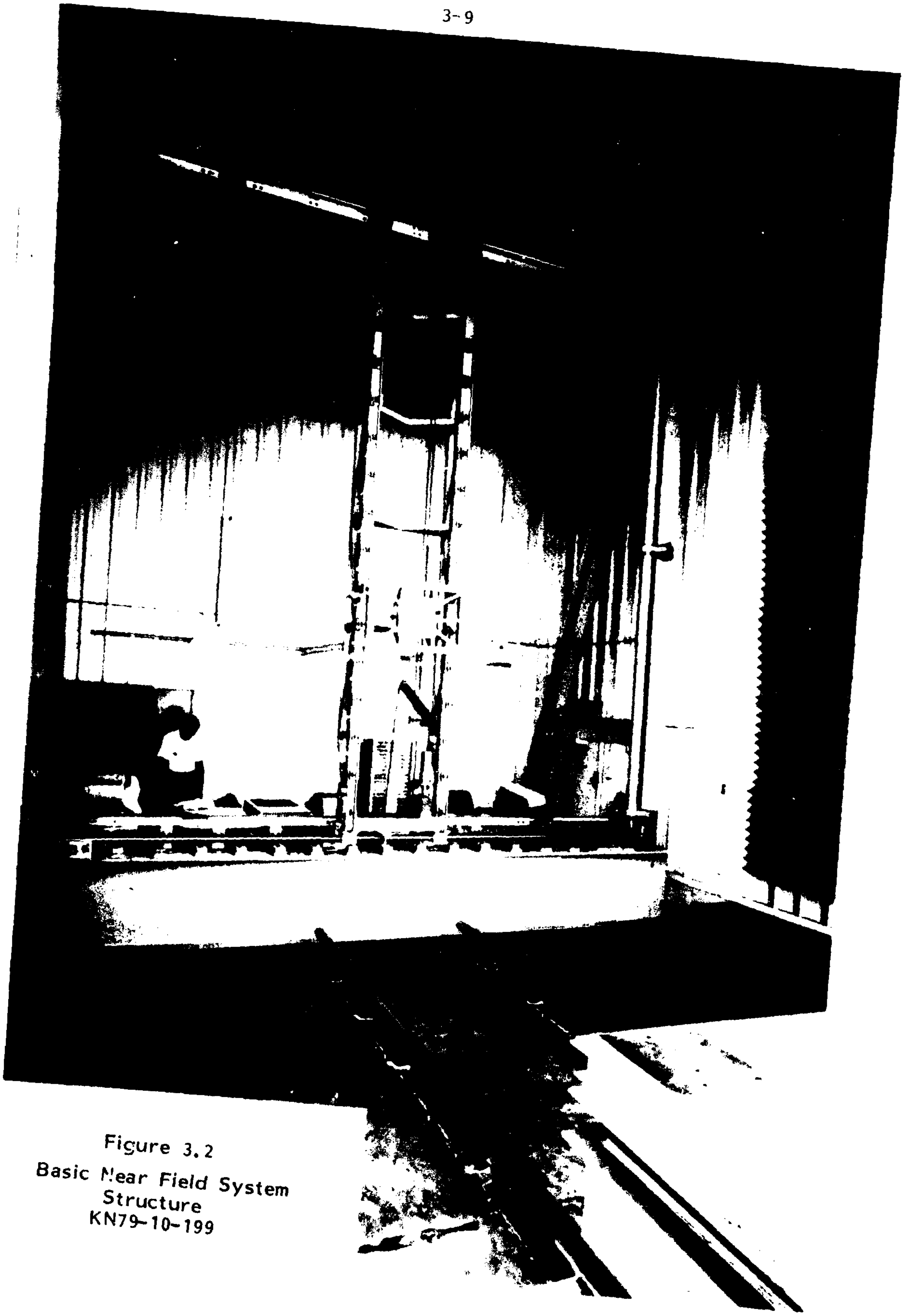

Figure 3.2
Basic Near Field System Structure
KN79-10-199

No problems were encountered using the adjusters on the vertical shafts or in adjusting the lower horizontal shaft in the Z axis. Although the procedure is tedious, adjusting the upper horizontal shaft so that the probe remains within the ±0.010" of plane in the Z direction also presented no problem.

A number of minor design improvements would be incorporated in a new system such as an access ladder and catwalk support to work on the upper rail, raising the A frame cross members above head level, improved adjustments of laser optical components and added diagonal members to improve the system rigidity. None of these are considered critical enough to modify the existing system, however, and there has been no operational problem associated with the positioner structure.

f. Positioner Drive and Control Equipment

It was originally planned to use SCR controlled DC motors to drive both axes. The vertical (Y) axis was to be chain driven and the horizontal axis driven at the bottom and top with a combination of chain and cable. This was basically the NBS approach. Early in the program, it was found that although the chain drive in elevation would be acceptable, the combination of chain and cable for the horizontal drive might result in a dynamic tension unbalance at the top and bottom of the vertical carriage. An alternate system using separate chain drives at the top and bottom coupled with a torque tube was selected to minimize this problem. In addition, the normal operating mode involves data taking only during vertical probe motion so that tilting of the vertical carriage during movement does not affect the accuracy of data locations.

The choice of motor drive and control was also changed early in the program when a supplier was found who provided an entire motor and controller system designed for direct computer interfacing. These units, Control Systems Research PSI 70T-1 controllers with SM 708-R motors appear to the computer interface as stepper motors having as many as 2,000 steps/revolution and allow the computer to independently set speed, number of steps and direction. Control signals to tell the computer the status of a programmed motion are available and the motors may also be controlled manually from a front panel. The controllers automatically provide smooth acceleration and deceleration for the motors.

The drive system has performed very well with little problem with either the chain drives or the controllers. The only significant limitation is in the drive speed; the controllers provide fifteen linearly related speeds and one independent "rapid traverse" setting. The inertia of the vertical carriage and the desire to avoid excessive shock if a limit is encountered at maximum speed have required that the maximum speed be limited to about 6" per second rather than the 10" per second originally planned. This limitation has had no significant effect on system operation. Normal data acquisition is made at one of the linearly programmed speeds which are much slower (about 0.4" per second) in order to allow time for all of the various beam steering, port changes, and frequency changes to occur in each half wave window.

Control of the motor drives involves sending the proper command to the interface card, and once started the motors move the programmed number of steps without further computer control. This capability is necessary to allow computer operations such as laser reading and data acquisition to occur without having to constantly interrogate and control the drive interface. When required, the computer programming provides precise positioning of the probe by a sequence of moving approximately the desired distance, reading the laser, moving any residual amount, reading the laser again, etc. This "closed loop" compensates for backlash in the drives and typically takes only 2 or 3 steps to position the probe within a few thousandths of a desired location. The programming also can sequence the speeds so travel time is minimized in this mode.

The very fine resolution of the motor-controller units suggests that for an application which did not require very high positional resolution for data acquisition the laser system might be unnecessary. Such a system could be operated in two modes; the probe could be moved in steps and stopped for each reading or data could be taken at uniformly timed intervals based on the motor speed when running continuously. In the latter case, the mechanical "jitter" in the system would limit the accuracy. Tests have shown that at speeds on the order of 1" per second the jitter is less than .005" and proportionally smaller at slower speeds.

g. Antenna Mounting Structure

The antenna mount provides the system capability for moving antennas under test in the Z direction and rotating about a vertical (Y) axis. These motions, together with internal tilt capability about the X axis built into the test antenna structures, provides the required adjustment to align the plane of the antenna under test with the plane of the probe motion. The mount supplied is a fabricated steel assembly consisting of a lower base which rides on two 3" shafts using Roundway bearings at each corner, an upper base assembly containing a turn table bearing providing Y axis rotation, and two mounting adapters which support a TPQ-36 or a TPQ-37 antenna in the proper orientation.

The 3" shafts mount on sections of rail which are clamped to the concrete floor and aligned perpendicular to the lower horizontal shaft of the positioner structure. The shafts are leveled and the Roundway bearings contains adjustments allowing the entire mounting structure to be set level under the load. Final alignment of antennas is made with references to the probe itself to obtain accurate angular references for calculated patterns.

The accurate alignment of antennas being tested has proven somewhat more difficult than anticipated, partially from the mounting structure. The primary mount related problem is the turntable bearing providing the Y axis rotation. Varying loads require releveling of the antennas each time a change is made. This problem would be minimized in a new system by using a more precision bearing and would not be a problem in a system not requiring angular data accuracies in the 0.01 degree region.

h. System Housing and Absorber

The original concept called for the near field measurement sytem to be located within a major manufacturing facility. This space was not available when required and it was decided to house the system in its own small building. Figure 3.3 shows the housing and Figure 3.4 shows a portion of the absorber used to minimize stray microwave reflections.

The walls and ceiling of the building are covered with a 12" pyramidal absorber made by Plessy Microwave Company while the area behind the positioner uses 18" thick absorber. Various sizes are used where necessary on the positioner structure with full height panels 3' wide on either side of the waveguide probe which travel with the vertical carriage. Additional full length panels 3' wide are provided on movable supports so they may be located immediately adjacent to the antenna under test.

Although Plessy was selected for supplying the absorber due tc price and the availability of 3' x 3' panels rather than the usual 2' x 2' size, they are no longer supplying this material and a new system will require another vendor. This should present no problem since almost all microwave absorber suppliers have similar products and selection should be made based on price and convenience of use. During system use some of the absorber panels tend to suffer random loss of the pyramid tips due to accidental contact; this is not serious unless a large area is damaged at which time the panel should be replaced. Spare panels have been purchased and are available as needed for replacement.

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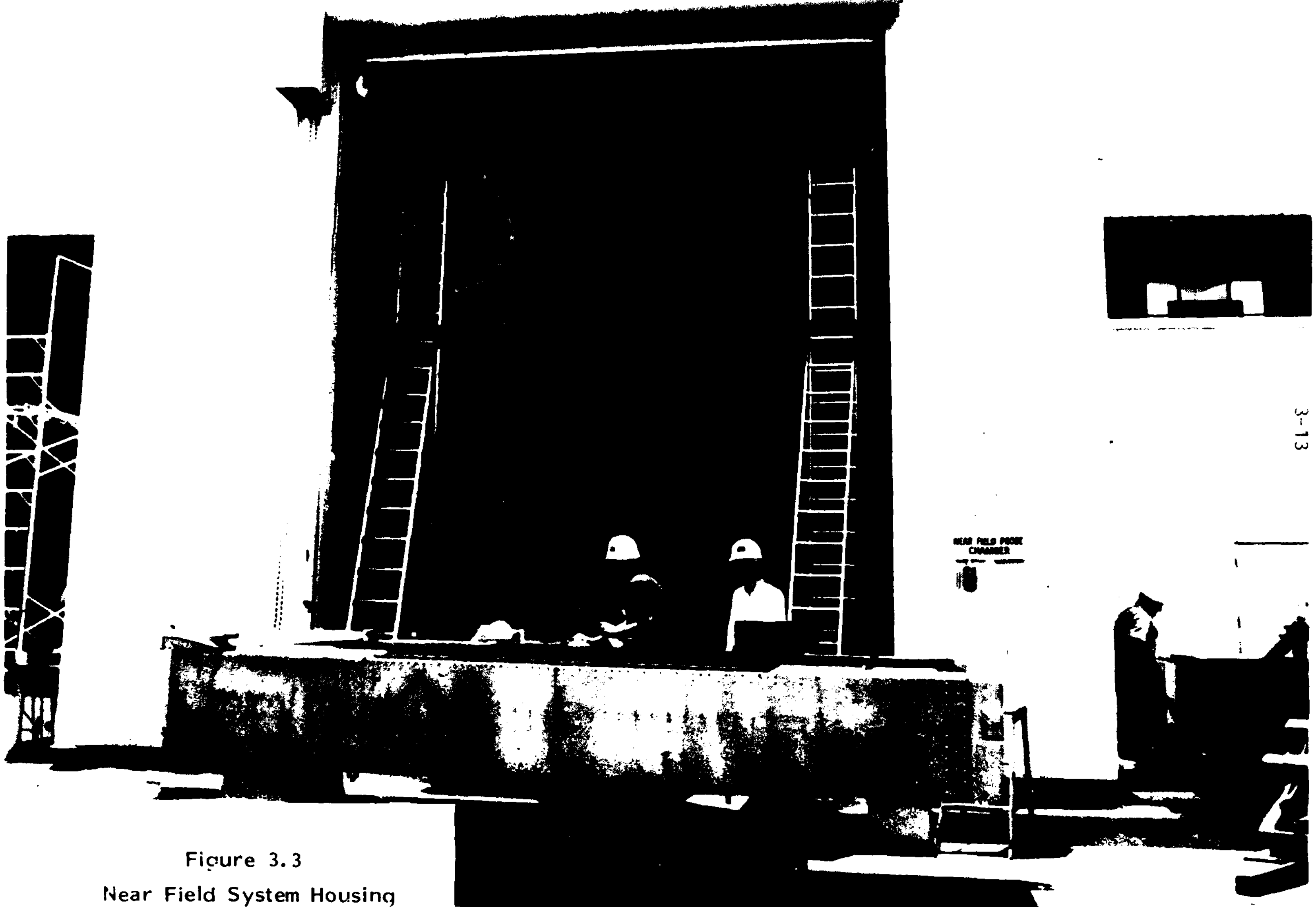


Figure 3.3

Near Field System Housing
KN81-05-413

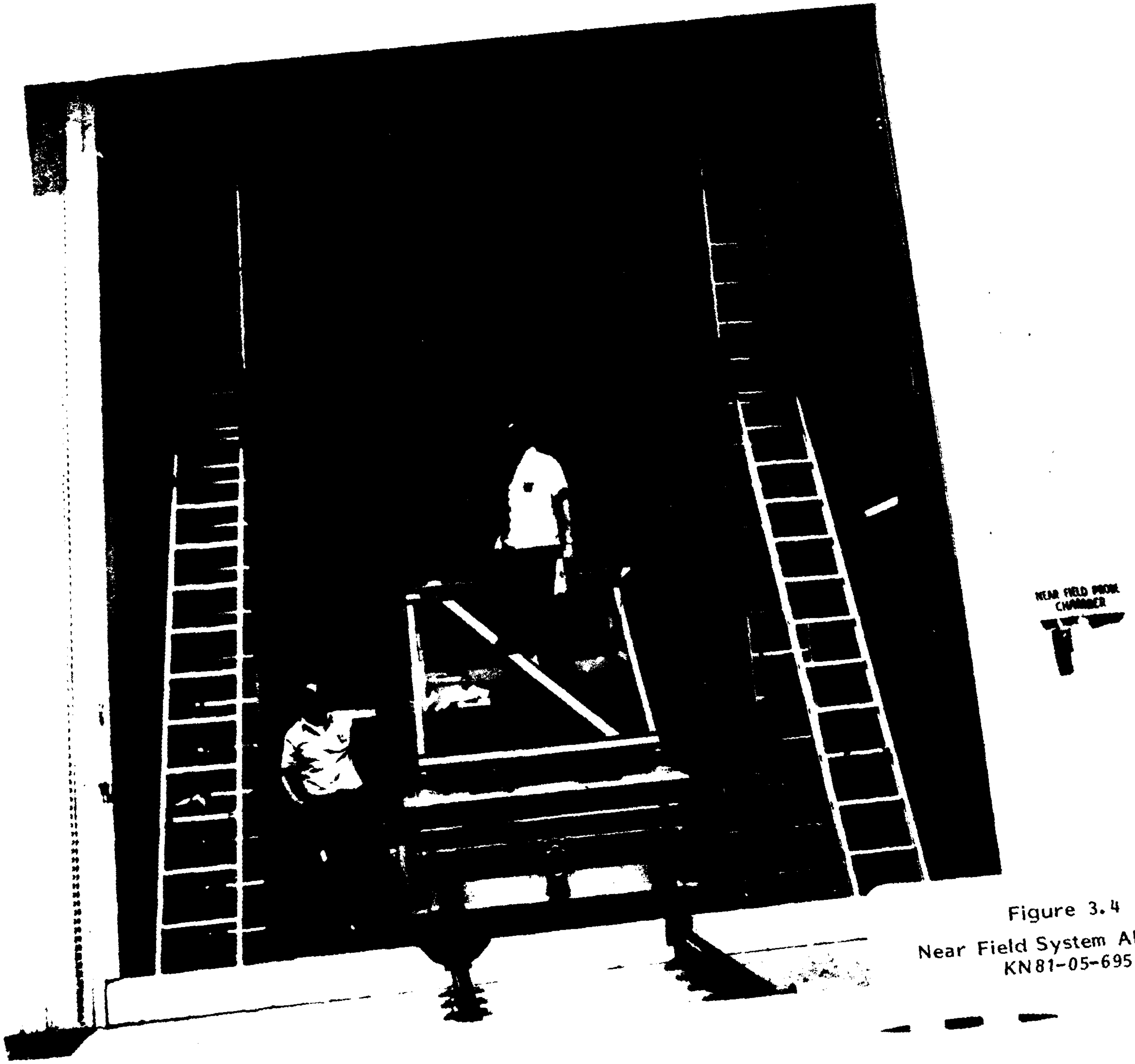


Figure 3.4
Near Field System Absorber
KN81-05-695

Each antenna type to be tested will have its own unique requirements regarding the placement of absorber around the antenna and mounting structure so ample panels have been provided for such use.

i. <u>Interfaces and Cabling</u>

One special purpose interface card was fabricated for the program. This card provides the format conversion and timing control to drive the Beam Steering Units of the FIREFINDER antennas. The card was fabricated using a standard Hewlett-Packard breadboard interface card which plugs into the computer IO cage and comes with the computer interrupt and control circuitry already mounted. The rest of the card contained ample space for the various components and integrated circuits required so that no external equipment is needed. A similar approach could be used for any required antenna control unit if a standard HP card was not suitable. Schematics and a description of this card as well as the cables mentioned below are given in the operating manual.

RF cabling has been discussed under the Microwave Equipment Section. All other fabricated cables are conventional multi-conductor cables using commercially available connectors. During the development no problems were encountered in use of these cables. No noise pickup or ground loop problems were found and the only rework has been associated with replacing connectors damaged by accident.

4. SOFTWARE DEVELOPMENT

a. Introduction

The Near Field System normally operates under control of various programs which perform all of the control, data collection, and analysis functions required for antenna measurement. The amount of operator interaction varies considerably depending on the function being performed; a production test requires virtually no operator control and in fact is usually run in an unattended manner once the measurement is started, while a diagnostic or special measurement may require continuous operator inputs and evaluations.

In all cases the actual use of the system for measurement requires the operator to respond to questions that appear as normal English language queries on the console display with numeric and text responses also in conventional language. For example, questions requiring a yes or no response are responded to with YES or NO (Y or N is normally sufficient) rather than a numeric code. The meaning of all programmed questions and examples of appropriate responses are given in the system operating manual.

Figure 4-1 shows the organizational structure of the software. The system software includes the Hewlett-Packard supplied software, the Hughes-created software, and display library programs obtained from Versatec and the National Center for Atmospheric Research (NCAR).

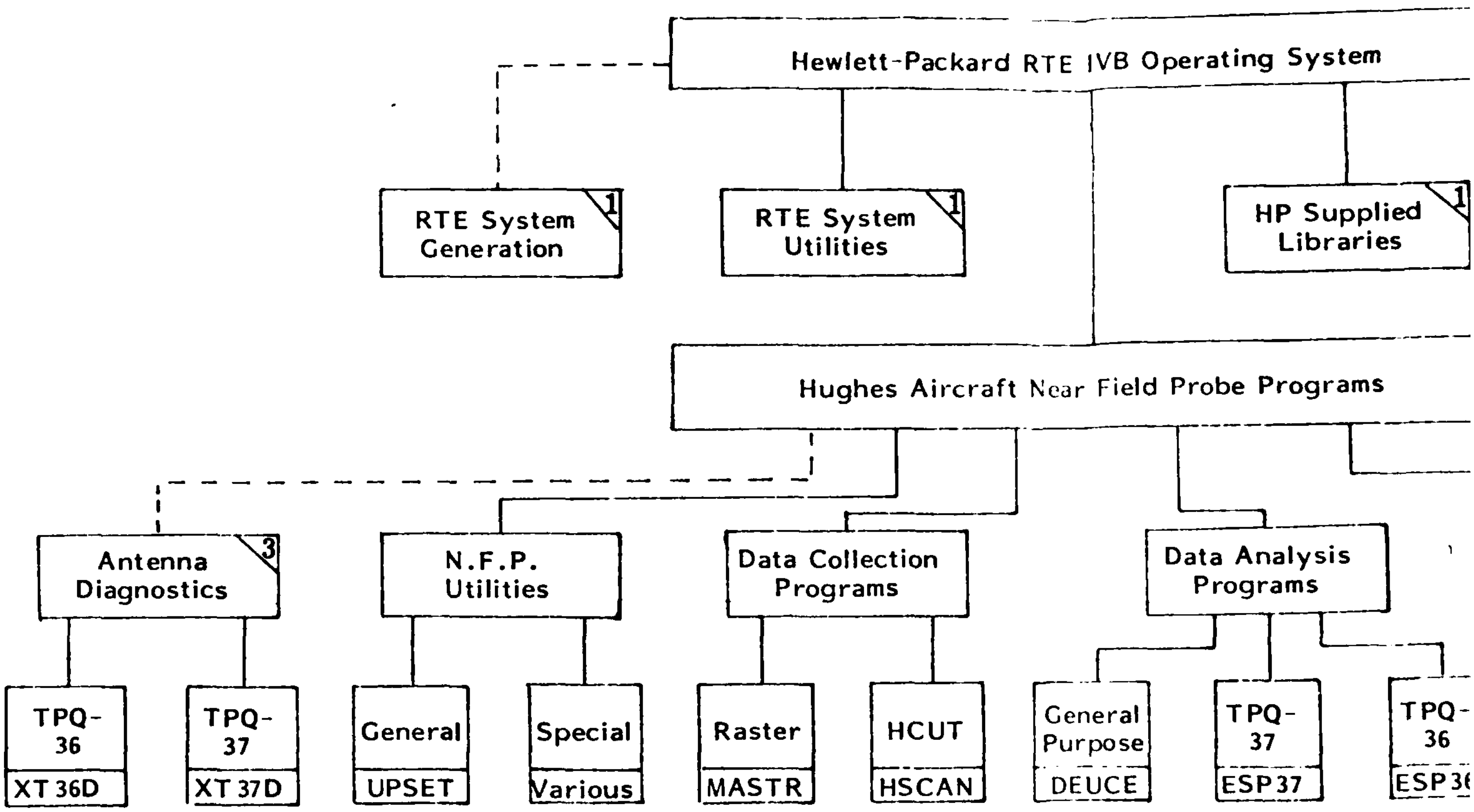
b. Commercial Software

- Hewlett-Packard Sofware

  This group includes all of the software supplied as part of the computer subsystem by Hewlett-Packard. An extensive understanding of this material is not required to operate the measurement system; however, computer system updates, reconfiguration and regeneration should only be performed by an operator who has gone through appropriate Hewlett-Packard training. A software service agreement has been maintained to insure that updates, improvements and problem corrections are current for the NFP system. This material includes:

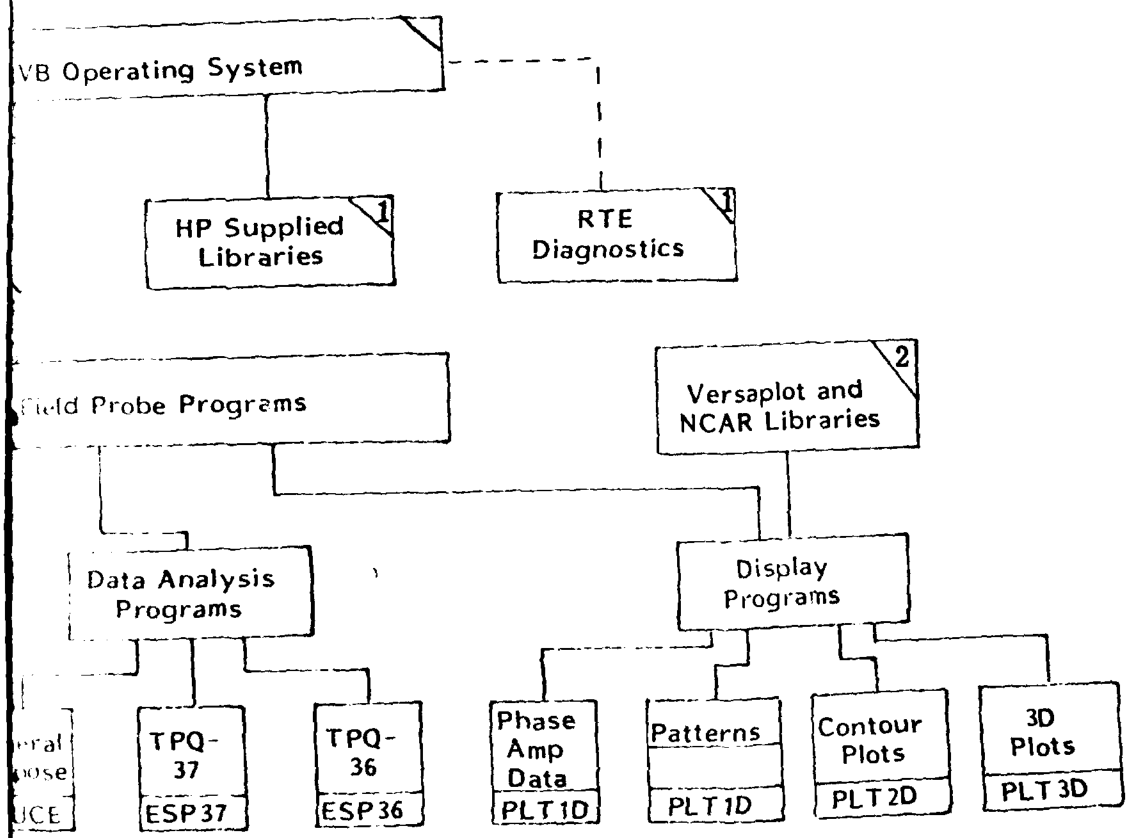
FIGURE 4-1

SOFTWARE ORGANIZATION FOR HUGHES NEAR FIELD ANTENNA MEASU



1) Software supplied by Hewlett-Packard as part of the computer subsystem
2) Software obtained from Versatec and NCAR
3) Software created under other contracts

F 4-1
AR FIELD ANTENNA MEASUREMENT SYSTEM



subsystem

- RTE Operating System consisting of all of the programs involved with the basic operation of the computer system in the real-time environment.

- RTE System utilities which are associated with the creation and modification of new software such as the relocating loader, compilers and assemblers, editor, etc.

- HP-supplied Libraries which include the various subroutines used by the compilers and assembler to handle standard system functions. In addition to the standard relocatable library, special libraries for the FORTRAN 4X compiler and for the HPIB functions are included.

- RTE Diagnostics involving all of the software required for testing of the computer subsystem.

- RTE System generation which is the special software required to recreate or reconfigure the RTE system and is used when a system update is performed.

During the term of this contract, the reliability and support of the Hewlett-Packard software has generally been excellent. A number of system updates have been made which normally involved enhancements to the software since the basic operating system does not appear to contain any known "bugs." The update procedures, while tedious, are straightforward and have not required any unexpected effort. There are no specific recommendations for modifying or improving this portion of the software.

- Versatec and NCAR Software

Two libraries of plotting software were obtained for system operation. The VERSAPLOT library contains the general purpose routines for performing various standard plot procedures and the interface and driver routines for operation of the Versatec printer/plotter in an RTE environment. The NCAR library contains a large group of programs designed to permit various forms of contour and isometric plots to be produced. A selected group of these routines was used in generating a set of plotting programs appropriate to the requirements of the NFP.

The VERSAPLOT package merely required compilation and assembly into a library set to be used with the RTE operating system. No problems were encountered in using this software and, except for inclusion of any future updates obtained from Versatec, no changes can be recommended.

The NCAR material, while designed around and dependent on the VERSAPLOT capabilities, required considerably more effort to create a working library set. The problems were almost totally associated with the conversion of the NCAR's CDC Fortran Code to the HP Fortran format. Once the initial group of software was converted, however, no problems were found in using the programs and additional functions from the NCAR library have been added with little difficulty. These conversions have been done with little regard to program efficiency and no attempt has been made to document the converted material beyond the brief descriptions in the NCAR user's guide. In the future, other sources of graphics programs may become available and the effort required to utilize such programs will have to be weighed against their potential advantage to the use of the system.

c. Hughes Aircraft Created Programs

The programming created by Hughes for operation of the Near Field System may be logically grouped in five categories:

- Antenna Diagnostics. These are special routines created to permit diagnostic tests of TPQ-36 and -37 antennas. The programs were not created under this contract and are supplied for reference purposes only.

- Near Field Probe Utilities. The principal utility program UPSET is a collection of various routines for checkout, test and maintenance of the Near Field System. Selections from a display menu allow the operator to perform tests and setups of the various hardware subsystems and interfaces. In addition, a number of special utilities have been written to implement unique applications during the course of the contract.

- Data Collection Programs. Two programs called MASTR and HSCAN are the routines which perform all of the data gathering for the Near Field System. MASTR is the primary oprating program. It operates with a menu display for data entry and includes all subroutines necessary to set up, calibrate, and specify a multiplexed data gathering application. HSCAN is a program which, while similar to MASTR in terms of operator interface, is limited to performing a single horizontal line measurement under specified conditions. This program was created to allow quick checks of antenna operations.

- Data Analysis Programs. Analysis of the data collected by the MASTR program is performed by either a general-purpose, operator interactive program called DEUCE or special purpose analysis programs which provide production test data on the TPQ-36 or TPQ-37 antennas. These special programs, ESP36 and ESP37, provide operation instructions, schedule MASTR and the appropriate data analysis program.

  DEUCE allows the operator to define what data files are to be used and to select what output data will be produced. The programs scheduled by ESP are optimized for speed of analysis and are designed to automatically generate only that data actually required for production evaluation of the antennas.

- Display Programs. This group includes all of the various programs created to display or print graphic data. These programs utilize the autoplot capabilities of the system computer console for CRT displays. The VERSAPLOT programs supplied with the system printer, and modifications of portions of the NCAR graphics software library provide hardcopy graphics.

A specialfile named ?FILES resides on the system and contains a summary description of the programs and subroutines created by Hughes for the Near Field System. The current listing of this file is given as an appendix to this report. The software manual for the system contains individual program descriptions, flow charts and listings for all of the software written for the system.

During the program the software has been constantly modified to correct problems, add capabilities, allow for hardware changes and take advantage of operating system improvements. Although this dynamic process would normally continue indefinitely, a point was reached where a fully operational software package for production tests was established and placed under configuration control. This "production" package provides a complete, error-free, system for acceptance testing. The developmental software continues to be modified to meet new requirements and capabilities.

5. EVALUATION PROCEDURES AND RESULTS

a. Introduction

Evaluation procedures have been established to demonstrate that the near field measurement system can perform the necessary measurements and computations with sufficient accuracy to provide performance equivalent to a far field antenna range. These procedures relate to the specific technical goals of the program and may be logically divided into five main areas:

- System configuration and function
- Mechanical performance
- Electronic performance
- Software functions
- Near field-far field comparison

The approach to each evaluation area, the results of the evaluation, and any discrepancies between actual performance and original goals are detailed below. Examples of measured and calculated antenna patterns are given in the appendix.

b. System Configuration and Function

A number of specifications relate to the physical and operational configuration of the near field probe system. Evaluation of most of these requirements involved determination that the specification was met either by reference to data sheets or by direct observation of the system during operation. Requirements for shielding, signal source and receiver frequency range, the use of a 16-bit word minicomputer, paint color, safety requirements and similar items were covered by such examinations and the performance was acceptable.

One area in which the system deviates from the original requirement is in the system safety specification. The proposal called for RF radiation warnings and emergency shutoffs. Since the system RF source has a maximum output of less than 10 milliwatts the radiated signal level will always be significantly less than the 10 mW/cm^2 level which would constitute a potential hazard; therefore the need for warnings, etc., has been eliminated.

c. Mechanical Performance

Conformance with the various mechanical specifications has been evaluated by direct measurement or observation of the parameters involved. In general the system meets or exceeds expectations for all parameters which affect system accuracy. At no time during operation of the system has any mechanical problem been encountered which required a design change although some modifications are recommended (see Section 6) for any new construction.

As described earlier, the probe is driven by the equivalent of high resolution stepper motors with a precision distance measuring laser used for position measurement during actual data acquisition. During the mechanical performance evaluations described below, both manual indexing of the motor drives and closed loop operation with the laser was used in performing the tests. Closed loop positioning with the laser positions the probe to within .002" of the desired X,Y location while manual positioning (currently set to require 64,000 steps per foot) locates the probe to within about .02" of the expected position. The manual mode was most convenient for performing the series of tests which establish the planarity (Z axis) accuracy, etc., but is not used during any actual antenna measurements.

- Scan Area. The probe may be moved in a rectangle 154.5 by 179.5 inches. This is slight less than the design limits of 156" by 180" due to setting of electrical limit switches slightly inside the mechanical limits. The system design may be readily modified to scan areas about 50% larger or smaller than this system. Beyond those limits there would be advantages or requirements for significant design changes.

- Scan Speed. The motor controllers provide 16 speeds for system operation. These speeds are established by internal controller settings and jumpers and have been set equal for the X and Y travel (although they could be independently established). The 16 speeds include 15 in a linear sequence between .03 in./sec. and .9 in./sec. and one rapid traverse speed of 6 in./sec. Normal system operation when multiplexing many data sets uses speeds around .2 in./sec. with the rapid traverse primarily used in nondata acquisition operations. This higher speed can be used, however, when measuring an antenna where individual data points are more than a few tenths of an inch apart. The 6 in./sec. is less than the planned 10 in./sec. value due to torque limitations of the drive motors and a need to reduce vibration when the motors start and stop at the high speed. This limitation has no effect on system performance and only increases the time for a normal production measurement by a few percent.

- Resolution and Accuracy. The resolution requirement (.005 in.) is more than easily met by the laser system with its basic resolution of 6 microinches. The computer processing of the laser data is always carried out in double precision (≈12 significant places) to avoid a significant loss of resolution which would arise if standard precision math (≈6 significant places) was used. The laser resolution is determined by the frequencies present in the dual mode laser source and is not significantly affected by the operating environment. To a large degree the laser system is "failsafe" in that any problem tends to give a catastrophic error which is detected by the software rather than an erroneous reading.

  The mechanical accuracy of the system creates a lower limit on the accuracy with which RF measurements can be made. For electronically scanned antennas at X band, mechanical position errors may result in phase errors of the order of one third degree for each .001 displacement error. There are two specifications relating to the positional accuracy; one for the ability to position (or determine the position of) the probe in the XY, i.e. scan plane, and one relating to the allowable displacement in the Z direction. Evaluation of these displacements involved two independent measurements of the basic static mechanical alignment; to which must be added the positional accuracy of the motor control and readout system and, for the Y axis, dynamic errors in the data acquisition system. Various combinations of effects create the overall errors in the three axial directions and are discussed separately below. The absolute accuracy of the laser system, which is on the order of .0001 inch in 200 inches, does not contribute significantly to the overall error in the XY plane. The reference plane is considered to have a vertical Y axis determined by the local gravitational field and an X axis along an average fit to the probe travel at the horizontal center line of the system.

  - X-axis -- Specified accuracy of ±.05 inches. The X-axis position is measured by the laser with a retroreflector located at the bottom of the vertical carriage. Static displacement errors therefore arise from tilting and nonlinear alignment of the rails on the vertical carriage. Since, in normal use, the carriage is not moving in the X direction during data acquisition, no dynamic errors are involved. These static displacements are measured by the following procedure:

A plumb bob (utilizing a small stranded stainless steel wire and a heavy weight suspended in oil) is hung from the top of the carriage with the wire passing through the nominal centerline of the probe. Utilizing a special fixture with two micrometers at right angles to each other (one positioned parallel to the X axis and the other parallel to the Z axis) measurements are made every 12 inches along the Y axis in both the XY plane and the YZ plane. The measurement uses a battery and ammeter connected in series with the micrometer and plumb bob. When either micrometer contacts the plumb bob wire, a current will flow through the meter indicating the point to read the micrometer. Accuracy and repeatability of .001 inch are easily obtained in this measurement.

- Y-axis -- Specified Accuracy of ±.05 inches. Static error in the Y direction arises entirely from the leveling and linearity of the lower guide shaft. The combination of adjusters every 12 inches with intermediate stud supports results in very small errors in this direction. Two different techniques were used to measure this shaft; first, with a precision level having a resolution and accuracy of one arcsecond, and second with a laser straightness measuring system. The laser only can measure the deviation from an arbitrary line whereas the level gives both absolute level and deviations so that the laser measurement is mainly used to verify the non-linear errors.

The results of these measurements are shown graphically in Figure 5.1 where the X and Y static displacements are shown as resultant vectors at each point on the one foot measurement grid. There is an evident systematic component to these displacements which has been found to arise from a "rotation" of the entire system about the Z axis. Although the system, when erected, was aligned to a true level, it appears that the entire building has settled (by about .005 deg.) to give this effect. If the linear offset created by the rotation of the XY plane is removed, the static position errors then appear as shown in Figure 5.2. Even without realignment to correct for the rotation and the addition of a random .002 in. error to the account for the programmed drive system setting, the performance is well within the requirement.

The technique of having the system take data during uniform continuous motion in the Y direction almost completely eliminates any dynamic errors from the measurement. A small offset occurs since a finite time is required for the software to command an A to D reading after a

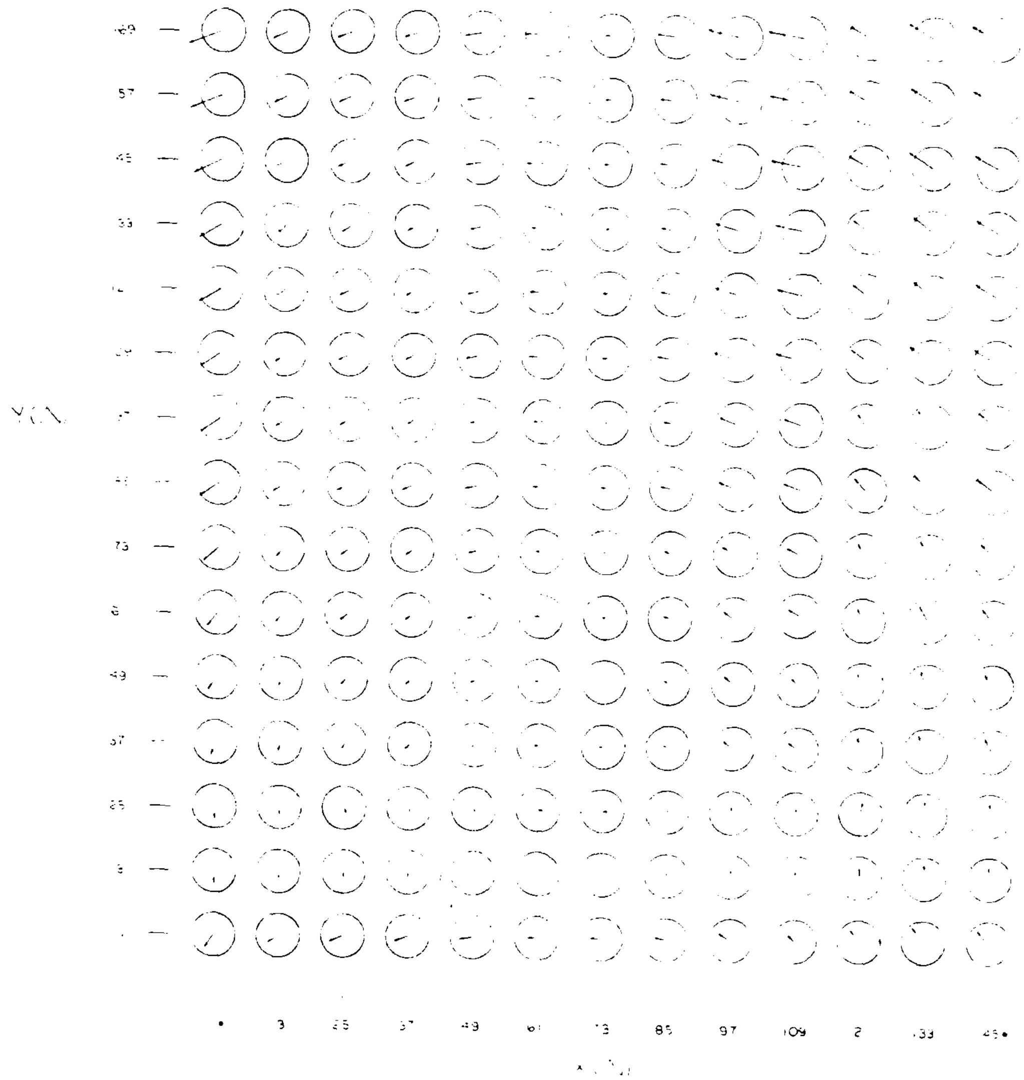


Figure 5.1

Near Field Static XY Displacements from Expected Values.

Circle radius is .01 inch

*Y axis data at 1" and 145" locations measured only using precision level.

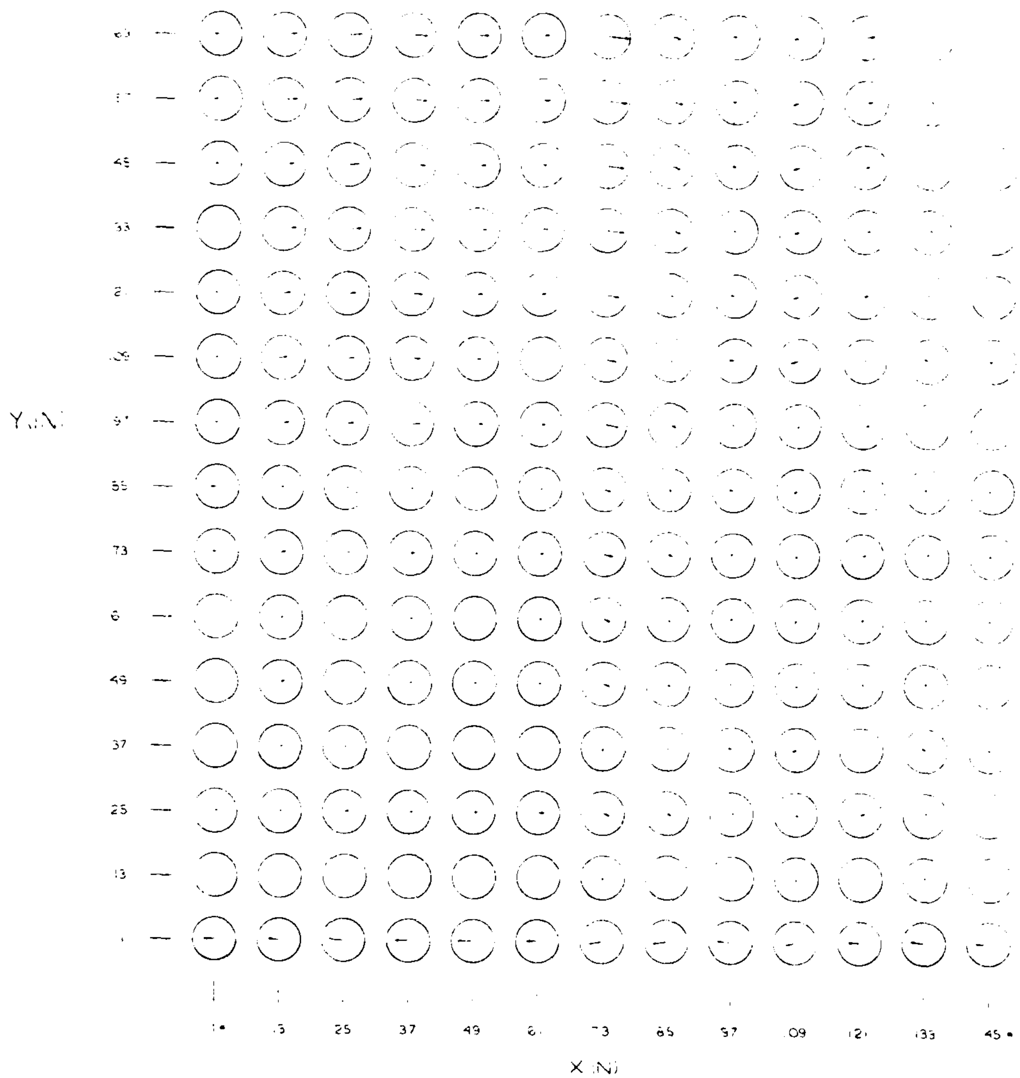


Figure 5.2

Near Field Static XY Displacements after Correcting for System Rotation

Circle Radius is .01 inch

coincidence between the desired location and the laser reading; however, this offset is virtually constant for all readings and in any case is only a few microinches at normal data acquisition speeds.

- Z-axis -- Specified accuracy ±.01 inch. Errors in the Z direction arise from three sources; the nonlinearity in the Z plane of the lower guide rail, lack of parallelism and lack of true vertical alignment of the upper guide rail, and nonlinearity of the vertical carriage rails. The straightness of the lower guide rail was measured with the laser straightness measurement system while the net effect of all other errors was measured using the plumb bob system described for the X axis. The results of these measurements are combined and shown in Figures 5.3 through 5.5. First, numeric data representing the net error from a true vertical plane is listed, then the same data plotted as an isometric plot and then as smoothed contours. As for the XYplane, a small average tilt was found. If the data is corrected for this, a better feel for the capability of the system may be obtained and Figure 5.6 shows the contours for this case. There are no dynamic errors associated with the Z axis performance.

The overall mechanical alignment even without correcting for the linear rotations and tilts is better than required. If the system were realigned and trimmed the maximum alignment error could be reduced to about ±.003 inch.

d. Electrical Performance

The electrical performance evaluations involve tests of the various measurement parameters which affect the ability to properly compute antenna parameters. These tests, carried out independently of an actual antenna under test, establish the limits on the accuracy of the phase and amplitude data recorded during data acquisition. Most of these evaluations are statistical, however, and do not directly determine how closely a near-field measurement will match a far field measurement for a particular set of conditions on a specific antenna. Such comparisons are given in Section 5f.

Certain of the electrical measurements involve evaluating errors by resolving them into linear, quadratic, and random components. This has been done in order to compare results to the work done in reference 4. While this type of error modeling is simple, it is not clear that error effects on real antenna data can be directly related to this model. The appendix contains examples

Y Coordinate	13"	25"	37"	49"	61"	73"	85"	97"	109"	121"	133"
169"	2	4	6	7	7	5	7	4	6	6	7
157"	-1	1	2	4	3	2	3	1	3	3	5
145"	-2	0	2	4	2	1	2	0	2	2	4
133"	-3	-1	0	2	1	-1	1	-2	1	0	3
121"	-3	-1	0	2	1	0	0	-1	1	1	3
109"	-4	-3	-1	0	-1	-1	-1	-2	0	0	2
97"	2	4	5	7	7	5	7	3	5	6	8
85"	1	3	4	6	5	4	5	2	5	5	6
73"	0	1	3	4	4	3	4	1	2	1	4
61"	0	1	2	4	4	3	4	2	2	2	3
49"	-1	1	1	4	3	2	3	1	3	2	2
37"	-3	-2	-1	1	0	-1	-2	-5	-3	-3	-2
25"	-5	-2	-2	0	-1	-2	-2	-5	-4	-4	-2
13"	-5	-4	-3	0	0	0	-1	-5	-3	-4	-1
1"	-1	0	1	2	0	-1	0	-2	-1	0	1

X Coordinate

Figure 5.3

NFP Z-axis Displacements in Thousandths--no tilt correction.

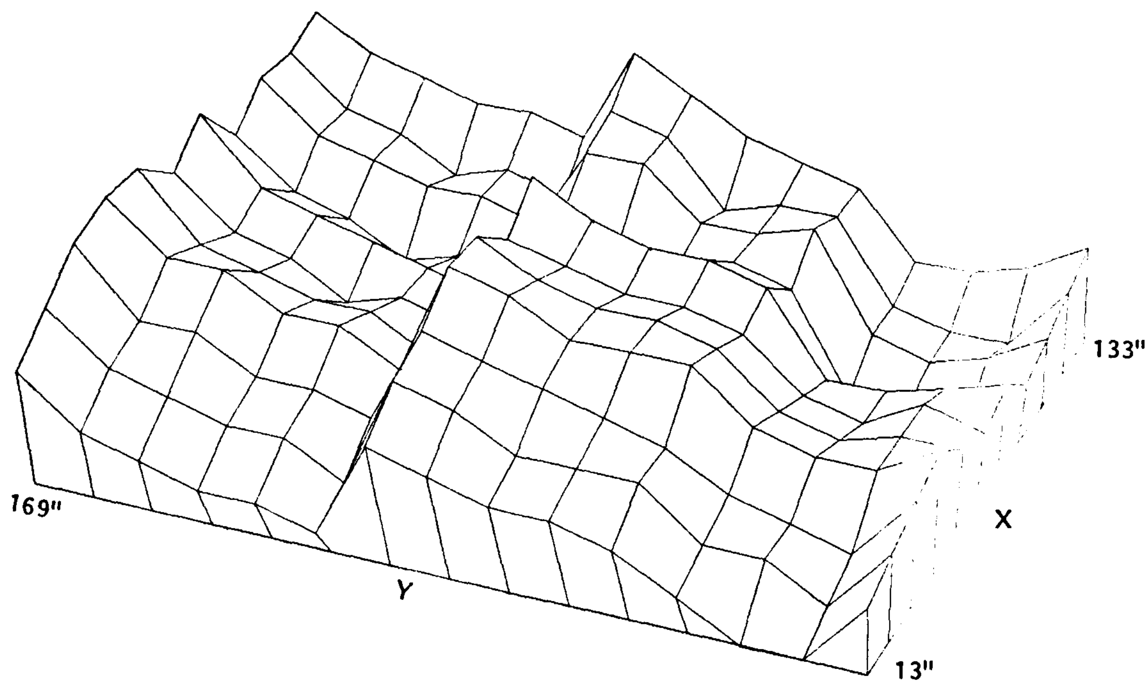


Figure 5.4

NFP Z-axis Displacements
Isometric View

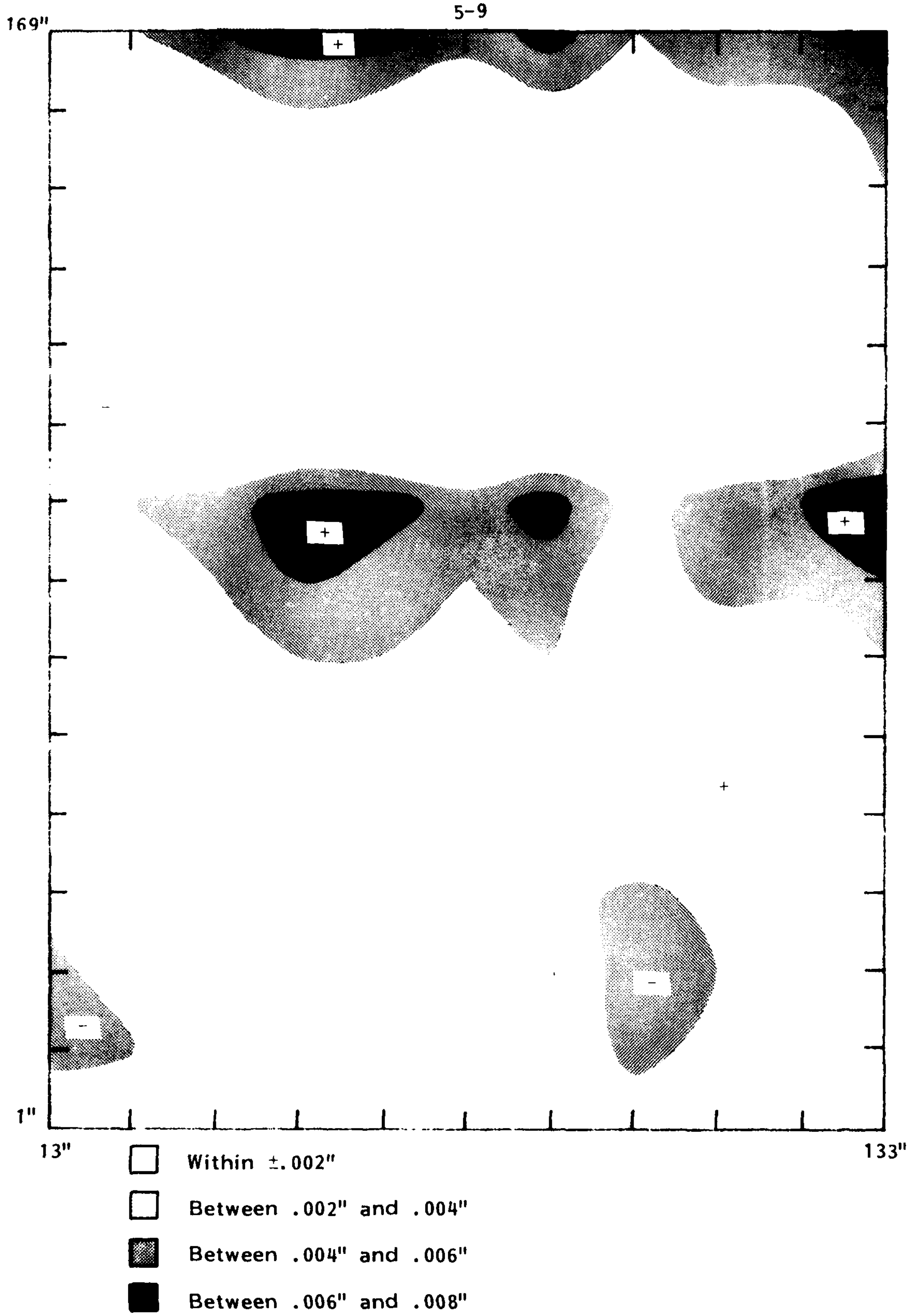


Figure 5.5

NFP Z-axis Deviations from True Vertical Plane.

Within ±.002"

Between .002" and .004"

Between .004" and .006"

Figure 5.6

NFP Z-axis Deviations from Average Tilted (.005°) Plane.

of antenna performance as compared to an ideal case when various errors representing the real system are included. These examples imply that the original specification goals for these errors were too restrictive for antennas of the type for which the system was designed but might be too loose for some other antenna type; i.e., a very low sidelobe system.

In most cases special programs have been provided to assist in evaluation of the electrical performance and are included as part of the main system utility program.

- Signal Source Switching Time. When performing measurements where a number of frequencies are multiplexed, there is a potential error introduced if the signal source has not fully changed frequency when a data point is taken. The magnitude of this error is a function of the sensitivity of the transmission paths to small frequency errors and, since the electrical length in the test and reference channels of the phase detector are considerably different; the primary effect of a frequency shift error will appear as a phase error. This effect is evaluated by setting a frequency, obtaining a reference phase reading, changing to some other frequency then commanding a return to the original frequency. By reading data at a selectable interval after the frequency change command and comparing the new reading to the reference it is possible to determine the errors arising from the "settling speed" of the source. Actually the measured error also includes errors arising from settling speed within the receiver but these are considered to be considerably smaller than those arising from the source. Data taken with this technique for frequency changes of 100 MHz typically shows errors of a few tenths of a degree at 15 millisecond and 5 millisecond delays and rising to several degrees at 1 millisecond. Since the multiplexed data acquisition program allows at least 15 milliseconds for frequency changes, no significant errors are introduced by this effect.

- Gain Accuracy. Evaluation of the NFP performance for most antenna parameters must be accomplished by indirect methods since "absolute" standards do not exist. Good standards do exist however for gain testing in the form of pyramidal horns. Such horns provide a reference gain accurately known (typically better than $\pm.2$ dB) both from theoretical considerations or actual measurement. Although such horns are much smaller than the typical antennas for which the NFP was designed they provide an appropriate measurement problem since the near field amplitude falls very slowly with distance from horn center while the phase changes rapidly. Plots of a typical horn distribution are given in the appendix.

Errors in gain performance arise from a variety of effects; however, two appear to be of primary significance. The accuracy with which the probe gain is known directly relates to the system gain accuracy and the accuracy with which the system through path calibration is performed also directly affects gain accuracy. Other parameters such as probe pattern calibration, amplitude linearity and drift, etc., will also have an effect but appear to be secondary when compared to the two main errors.

The probes used in the system are iris matched open ended waveguides. Gain data for these probes has been measured by a number of techniques and the results are stored in the programs in the form of a linear relationship with frequency. These probe gains, which are of the order of 6 dB, are not considered to be more accurate than ±.2 dB. The through path calibration procedure involves a direct measurement of the through path loss with a known fixed attenuator rerpresenting the antenna to be tested. This measurement and the accuracy of calibration of the fixed attenuator is estimated to add about ±.1 dB to the possible gain error.

Both S- and X-band horns were measured at five frequencies and the results compared to calibrated values for the horn. The maximum differences were .39 dB with an RMS error of .2 dB. This is well within the specified gain accuracy of .6 dB and implies that the various system errors may not be as large as anticipated.

- Measurement Errors. The balance of the electrical performance evaluations are involved in determining the errors introduced in the recorded phase and amplitude data by the imperfections in the system components. The allowable error specification which was derived from reference 4 is shown as Table I. These errors represent variations as a function of amplitude only and do not represent an error model which can be measured on an actual system since reference devices having the required performance are not available.

Table I. Allowable Errors.

	Linear	Quadratic	Random
Amplitude	0.8 dB	0.4 dB	2.0 dB
Phase	0.4 deg.	0.8 deg.	4.0 deg.

In order to provide a better evaluation of the actual performance of the system, three independent error sources were evaluated to obtain an overall error which should be characteristic of the system during a measurement. These errors are:

Drift of various system components during a measurement.
Changes arising from cable movement during a measurement.
Deviations of the receiver from ideal (nonlinearity).

In each case a test procedure was developed to determine the errors by measuring a large number of data points, comparing the measured value to an expected value and using a numeric least squares analysis [6] to resolve the differences into linear, quadratic, and random terms. This error analysis does not allow comparisons with the work done in reference 4 but represents the best available way of evaluating the system. The summary of the performance as measured in accordance with the test procedure is given in Table II.

Table II. Measured Errors.

	Linear		Quadratic		Random	
	S	X	S	X	S	X
Amplitude	.17	.22	.05	.08	.20	.21
Phase	1.08	5.74	.47	.29	.53	1.04

Detailed data on the individual error measurements is contained in the test procedure Section 3.5.5.1.

These results must be interpreted in terms of their effect on system performance. The only result where there is a significant error term is in the linear phase error. This term represents the total linear change in phase over the course of a measurement. Almost all of this error arises from the drift of the system with time and motion over a 12 hour measurement period and for shorter periods is roughly proportional to time. The primary significance of this error term is a shift in the calculated beam position. The worst case measured results correspond to a position error of about .012 degrees which is consistent with the required beam position accuracy capability of the system. In a production measurement linear errors could be measured and compensated for to improve this accuracy if necessary.

All other errors are small enough to not significantly affect the nominal pattern performance requirements. The separation of the amplitude errors into the three components is somewhat misleading since it is not clear how to evaluate the pattern effects of these individual terms. Quadratic phase errors tend to reduce the null depths between sidelobes but at the magnitude of the observed error this effect is almost imperceptible. The appendix gives examples of idealized antenna distributions with errors modeled after the measured system performance. These models show changes in sidelobes due to errors as being barely perceptible at 50 dB down. Examples with much larger errors are also given and show acceptable results even with errors much larger than the measured values.

e. Software Functions

Performance requirements on the system software primarily relate to the data analysis and data output capabilities. Evaluation is performed by observation of the data produced by the system and all system goals have been met. A number of specific features not commonly provided with automated systems are described below.

- Antenna Diagnostics. In addition to normal data acquisition, analysis, and display programs, software and hardware accessories have been developed under other contracts to utilize the NFP system for performing antenna diagnostics. This is an important aspect of near field techniques in that component or wiring errors in a complex array may be readily found by making measurements very close to the aperture and using the system computer to exercise phase shifters, switches, etc. Errors can be found with this technique which literally cannot be isolated with a far field measurement.

- Utilities. A number of special purpose utilities have been provided in addition to the general system utility program described earlier in Section 4. Of particular interest are programs to create a data file having specific amplitude and phase values including various errors; a program to examine a data file and correct any anomalous values such as might occur from a noise spike; and a program to remove the linear phase slope from a data set. This latter program is particularly useful for examining data for scanned beams where the raw phase data changes very rapidly and small nonlinearities are impossible to observe. Details of these programs and many others are given in the system software manual.

- Data Collection and System Control. The data collection and control programming includes various subroutines to permit fully automatic operation and allow multiplexed data to be acquired and properly stored for data analysis. One special feature is an error detection and recovery routine for laser faults which, upon fault detection, automatically returns the system to the zero XY location, resets the laser, returns to the top of the data column where the fault occurred and then continues taking data.

- Data Analysis. The analysis software for the NFP was developed from the programs supplied by NBS. Except for the FFT routine, little of the NBS software remains in recognizable form due to the conversion from terminal oriented CDC language to dedicated HP format. In addition, many changes and additions were made to provide specific analysis functions for production antenna testing.

  A number of the changes were made in the interest of saving time during an analysis. In the original NBS programs the location of beam peaks is found by a two dimensional routine. Since production tests usually only require principal conic plane patterns, an iterative one-dimensional analysis is used to find the principal maximum saving several hours of computer time for a typical production run.

  An example of another modified technique is in the handling of probe data for correcting the NFP measurements. NBS uses a separate data file containing probe data at the frequency and data spacing of each measurement. With many frequencies and large numbers of data points, these files take up considerable memory and time to read and write. The NFP software stores the probe data at three frequencies as originally measured and interpolates in frequency and data interval as required.

- Data Display. The use of programs derived from the Versaplot and NCAR libraries has made possible many data display capabilities to make it easier for a user to evaluate the results of near field measurements. In the automatic mode, the system will produce a set of patterns as specified in a data file without an operator present; thus reducing manpower costs for extensive production runs. In addition to preparing conventional antenna pattern plots which match the sizes of most commercial antenna pattern recorder scales, the operator may also produce arbitrarily sized plots.

Contour plots of two-dimensional data may have operator-specified line labels and patterns and the ability to include contour lines on isometric plots greatly enhances their value for visualizing results.

f. Near Field-Far Field Comparison

The error analysis, modeling, and evaluation is a necessary part of the performance evaluation for the NFP; however, the actual comparison between data taken on typical antennas on near field and far field ranges is the basis for determining the usability of the system. Under this program two antennas, one at S-band and one at X-band, were to be measured and compared. Primary performance goals were; .01 degree beam pointing accuracy and .6 dB gain accuracy. These antennas are both planar arrays with the X-band antenna scanning with ferrite phase shifters in azimuth and frequency in elevation. The S-band system used diode phase shifters for scanning in both planes. Hardware and software for interfacing the beam-steering control units for these antennas to the NFP system computer was developed for the program. During the program a number of each antenna type were actually tested so that considerable experience was gained in performing and evaluating near field measurements.

When comparing data, particularly beam positions, from near and far field measurements, it is necessary to know the accuracy of the far field data, to have "absolute" references for the data, and an understanding of the effects of differing physical measurement conditions. For the X-band antenna, these requirements are largely met; however, the S-band system will require more work to completely evaluate the results. Each of the parameters evaluated is discussed below with emphasis on beam position comparisons since this is the parameter requiring the most effort to obtain a meaningful performance evaluation.

- Sidelobes. Comparison of near and far field sidelobe data gave very similar results for both X- and S-band antennas. Typically, comparisons for sidelobes between 20 and 35 dB below the main beam show very good agreement, with RMS differences of about 1 dB and maximum differences of ±3 dB. Occasionally, a lobe will appear on either near or far field data that deviates by a large amount (≈6 dB), however these lobes never would result in rejection of a production antenna and may be associated with the far field range. This difference cannot be evaluated without measuring the antenna at several far field ranges as well as in the near field. In all cases the agreement of sidelobe angular orientation is excellent with deep nulls matching the far field data very closely (see typical patterns in the appendix).

- Gain. Gain data is also very similar for both X and S-band. RMS differences of .25 dB and peak variations of ±.5 dB are observed. As was discussed earlier in Section 5.d the absolute accuracy of the near field gain measurement for any single measurement is expected to be limited by the initial calibration errors on the order of ±.3 dB so these results are quite reasonable.

- Beamwidth. For the X-band system, beamwidths are calculated using a computer analysis of the beam shape. When compared to far field data, agreement within .03 degrees (on a several degree wide beam) is readily obtained. For the S-band system comparisons were made by reading pattern plots and agreement was not quite as good (peak differences of .1 deg.) however this is not considered significant due to the relatively poor resolution of the comparison.

- Difference Pattern Nulls. Only the S-band system has a difference port, and the null depth calculated from near-field measurements is well below production test requirements (as is true for far field).

- *Beam Positions. Both the X and S band antennas are* normally measured on far field ranges with optical encoders having approximately .01 degree resolution and accuracy. This limitation together with other far field instrumentation limitations places a lower limit on the accuracy of any single far field data point of about .02 to .03 degree (common to both antennas). Absolute position references are obtained for both antennas through the use of optical telescopes for azimuth references and precision tilt sensors for elevation. Transferring these references to the near field facility is estimated to increase the potential error in the elevation data by about .01 degree and a somewhat larger amount for the azimuth offset which also depends on the particular antenna. Beyond these considerations the two systems are different and will be discussed separately.

  The X-band system defines beam locations in terms of the crossover location of adjacent beams (no difference ports). The procedure used to find these crossovers is quite similar for far and near field analysis except that in the near field the computer performs the numeric calculations automatically. The differences between far and near field data typically show average offsets of several hundredths of a degree with a superimposed random error of about .03 degree in azimuth and .006 degree in elevation. For this antenna the far field data for the azimuth beam locations is subject to an error arising from bending of the array when front and rear surfaces are at different temperatures. This effect has not been fully evaluated but could easily account for the observed differences. The calculated NFP results give system beamsteering constants which, when used in full system tests, give radar performance as good or better than the measured far field constants.

The S-band system represents a somewhat different situation. The beam locations are defined by azimuth and elevation difference pattern nulls but, due to the range geometry and alignment procedure differences, transfer of the "absolute" position references from the far field to the near field facility has not yet been accomplished. Near field beam position accuracy can, however, be estimated by comparing the calculated positions with the theoretical positions expected from the beamsteering commands used. This comparison gave results very similar to the X-band data; a few hundredths degree of offset with a smaller superimposed random variation.

6. RECOMMENDATIONS

The near field system, as constructed, provides an operational system for accurate production testing of antennas. A number of observations made during the development of the system, and experiences encountered during its operation, suggest improvements and areas for further investigation. These ideas are briefly described below.

The operating software for the NFP underwent many changes and improvements during the development stage. Due to the inherent dynamics of computer technology, a continued effort in the area of hardware/software enhancements, toward a goal of improving computer efficiency, decreasing measurement and analysis time, and increased measurement accuracies is strongly recommended. In that the computer operating system provides a stable software environment for program development, enhancements may easily be tested and implemented while maintaining the integrity of the production test programs. The system also provides an excellent tool for simulation of antenna performance and studies of error effects on NFP performance which should be a continuing investigative effort.

The electrical calibration and mechanical alignment techniques currently used appear to be the primary limiting factors on system accuracy. Additional development in these areas could provide more accuracy for some antenna parameters. Improvements to the receiver calibration through operation over a narrower dynamic range and calibration of phase nonlinearities is one possible approach. A reduction in the effects of long-term drift by measurement of reference data before and after a data run is another possible improvement. Mechanical realignment and improvements to the chain drives and antenna mount bearing would also reduce the small errors arising from mechanical imperfections.

A number of enhancements could be made which would make it easier to set up and operate the system. These include a drive system to move the antenna mount along the rails in the Z direction; an arrangement to hang absorber panels from ceiling mounted roller slides; a coarse (.02" resolution) readout of the probe XY position that was independent of the laser; and a more accurate and automatic system for setting the mechanical 0,0 reference point.

In addition to the various enhancements which could be made to the existing system, any new construction should also consider the following items which, while desirable, would be impractical to change on the existing hardware.

- The cross member on the end A frame supports is too low and should be raised to avoid a personnel hazard.

- The adjusters supporting the lower guide rail should be redesigned and the lower guide rail diameter should be increased to increase stiffness.

- The system should be laid out so that the area where the operating personnel are housed is forward and at one end of the system to allow the operator to watch the probe moving.

- Diagonal bracing from the A frames to the floor should be added to reduce vibration, particularly during emergency stops.

- Larger motors should be used to allow higher speed motion without stalling.

- The mounts for the opticalelements in the laser system should be more readily adjustable in 3 axes to simplify setup of the laser system.

In summary, the system is recommended for use as a production test facility but a continuing support program to continue development of near field measurement techniques using the current system as a test bed should also be funded.

7. PUBLICATIONS AND REFERENCES

Publications

1. Software Manual, Near Field Antenna Measurement System--Contract No. DAAB07-77-C-0587, 22 July 1981.

2. Test Procedure for Near Field Antenna Measurement System--Contract No. DAAB07-77-C-0587, 10 July 1981.

3. Operating Manual, Near Field Antenna Measurement System--Contract No. DAAB07-77-C-0587, 30 September 1981.

References

[1] D. M. Kerns, "Plane-wave Scattering-matrix Theory of Antennas and Antenna-antenna Interactions: Formulation and Applications," Journal of Research of the National Bureau of Standards, Vol. 80B, No. 1, January-March 1976, pp. 5-51.

[2] P. F. Wacker, "The Analysis of Near Field Measurements: An Introduction and Coordinating Reference," NBS Class Notes, Boulder, Colorado.

[3] A. C. Newell, "Upper Bound Errors in Far-field Antenna Parameters Determined from Planar Near-field Measurements," Lecture Notes for NBS Short Course, July 7-11, 1975, Boulder, Colorado.

[4] G. P. Rodrique, E. B. Joy and C. P. Burns, An Investigation of the Accuracy of Far-field Radiation Patterns Determined from Near Field Measurements," Final Report, Contract No. DAAH01-72-C-0950, August 1973.

[5] G. P. Rodrique, et al, A Study of Phased Array Antenna Patterns Determined by Measurements on a Near Field Range, Georgia Institute of Technology, March 1975.

[6] W. E. Milne, Numerical Calculus, Princeton University Press, 1949.

8. APPENDIX

This section contains a number of examples of the Near Field Measurement System graphic data output. Four groups of plots are included. These are:

1. An ideal antenna distribution
2. The ideal distribution with random and quadratic errors at the system specification levels.
3. The ideal distribution with random and quadratic errors modeled to represent the worst case expected from the internal NFP system errors.
4. Actual data from a standard gain horn.

In addition to the graphic data shown in this section, the system computes and displays to the operator various parameters such as gain, RMS sidelobe levels and beam position. Programs for production testing are readily set up to format such data in tabular form with deviations from system performance limits flagged.

The time required for analysis and data output depends on the size of the data array and the complexity of the plot; however, for a 128 x 128 data point array the following values, which include operator response times, are typical.

Analysis producing 512 data point antenna pattern conic cut through beam peak--both planes with probe correction--two minutes.

Analysis producing a 90 x 90 data point two dimensional pattern data set--no probe correction--five minutes.

Typical plot of antenna pattern--conic cut with 512 data points--90 seconds.

Contour plot--128 x 128 data points--eight contour levels--three minutes.

Isometric plot--90 x 90 data points--three contour levels--four minutes.

The first three groups of plots represent an attempt to evaluate the errors inherent in the NFP system. A system utility program was used to create a raw data set representative of what would be measured with an ideal antenna and system. The program allows the operator to specify independent distributions in the azimuth and elevation planes and to set the various parameters (spacing, number of elements, etc.) necessary for the use of the standard analysis routines. In addition, the operator may include errors in the form of random amplitude, random phase and quadratic phase variations. The random terms are added as independent, random sized errors (within specified limits) at each data point in the two dimensional array while the quadratic phase term is applied systematically, i.e., all elements in a column have the same value of error appropriate to a symmetric function about the centerline in azimuth.

As discussed in Section 5.d, page 5-13, small linear phase errors only create beam position errors and will not affect pattern shape, so this type of error is not included in the simulation. Amplitude errors which were separated into components in the earlier analysis, have been added to give an effective total amplitude error used to set the maximum value of the random error term.

The first group of plots shows the situation when no errors of any kind are included in the simulated data. The distributions used are representative of a typical high performance antenna. The patterns do not show infinitely deep nulls everywhere due to the limited number of data points (512) in the pattern. The scales of the contour and isometric plots are somewhat distorted since the two dimensional analysis program operates in kx, ky space. The numeric value on the plots are only approximate.

In Group 2, the same basic distributions are used; however, random and quadratic phase errors and random amplitude errors corresponding to the measured performance have been added to the ideal distribution. In addition, in the region outside the "antenna" random terms having a peak amplitude 40 dB below the maximum have been included to better represent the actual system. As can be seen by comparing the patterns of Figure 8.2.1 through 8.2.7 to those of Group 1, virtually no effects are noticeable above -45 dB below the peak and in the two dimensional plots error effects appear to be at least 55 dB down.

In order to provide a feeling for how large errors can be without seriously degrading performance, a third data file was created with errors on the order of the maximum observed during system test. These results are given in Group 3. Some principal plane pattern degradation in the -35 to -40 dB region can now be observed and off axis lobes as high as -50 dB can be seen.

In Group 4, plots are shown for actual data measured on a standard gain horn. During this measurement the scan area was set to obtain approximately 30 dB range in the amplitude data. As a result, the phase data goes through about seven cycles and the effects of random errors, reflections, etc., all show on the contour plots of Figure 8.4.1. The isometric plot of the raw amplitude data is typical of that obtained for broad beam antennas and the isometric plot of the pattern clearly shows the sidelobe structure of the gain horn.

These patterns are followed by a listing of the system file while lists all of the currently utilized programs and subroutines.

GROUP 1

IDEAL DISTRIBUTION PATTERNS

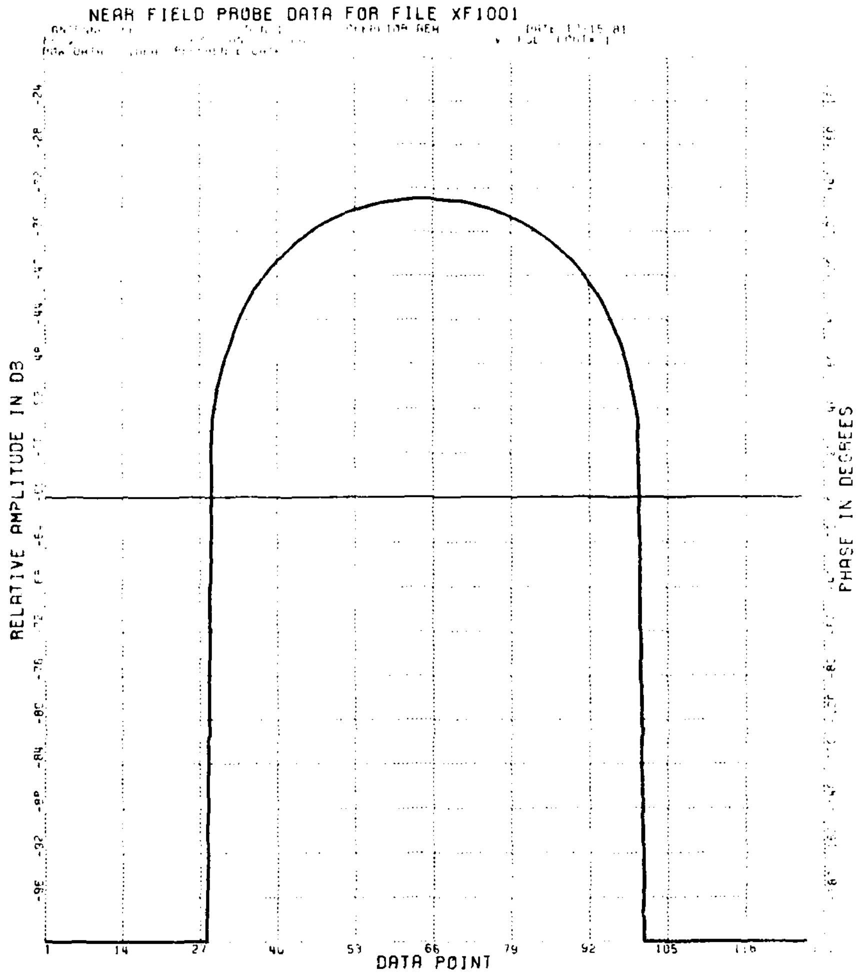


Figure 8.1.1

Idealized Azimuth Distribution.
Amplitude = cosine on a .1 pedestal
Phase = uniform
Active region = 72 out of 128 elements

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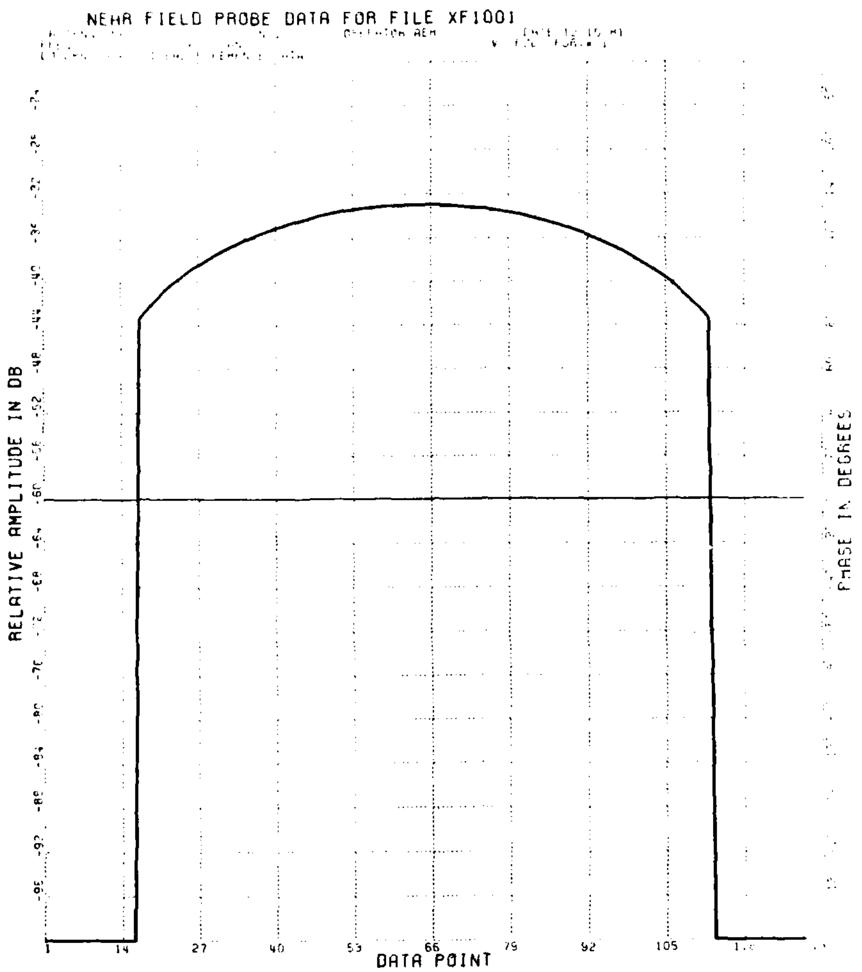

Figure 8.1.2

Idealized Elevation Distribution
Amplitude = cosine on a .3 pedestal
Phase = uniform
Active Region = 96 out of 128 elements

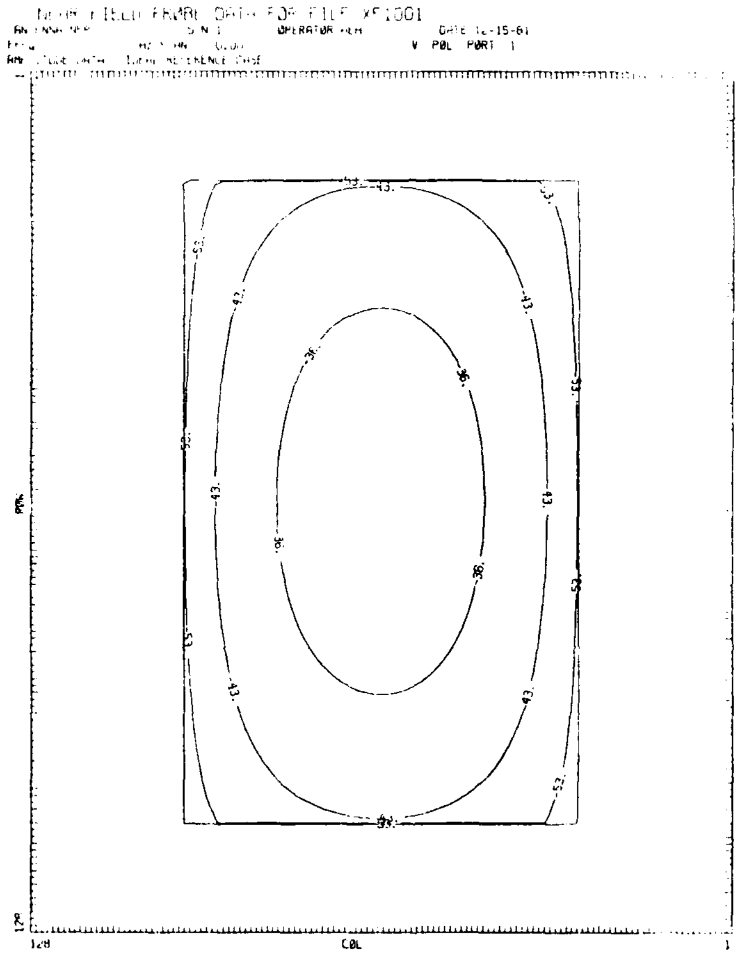

Figure 8.1.3

Contour Plot of Idealized Amplitude Distribution
Peak level is at -33 dB

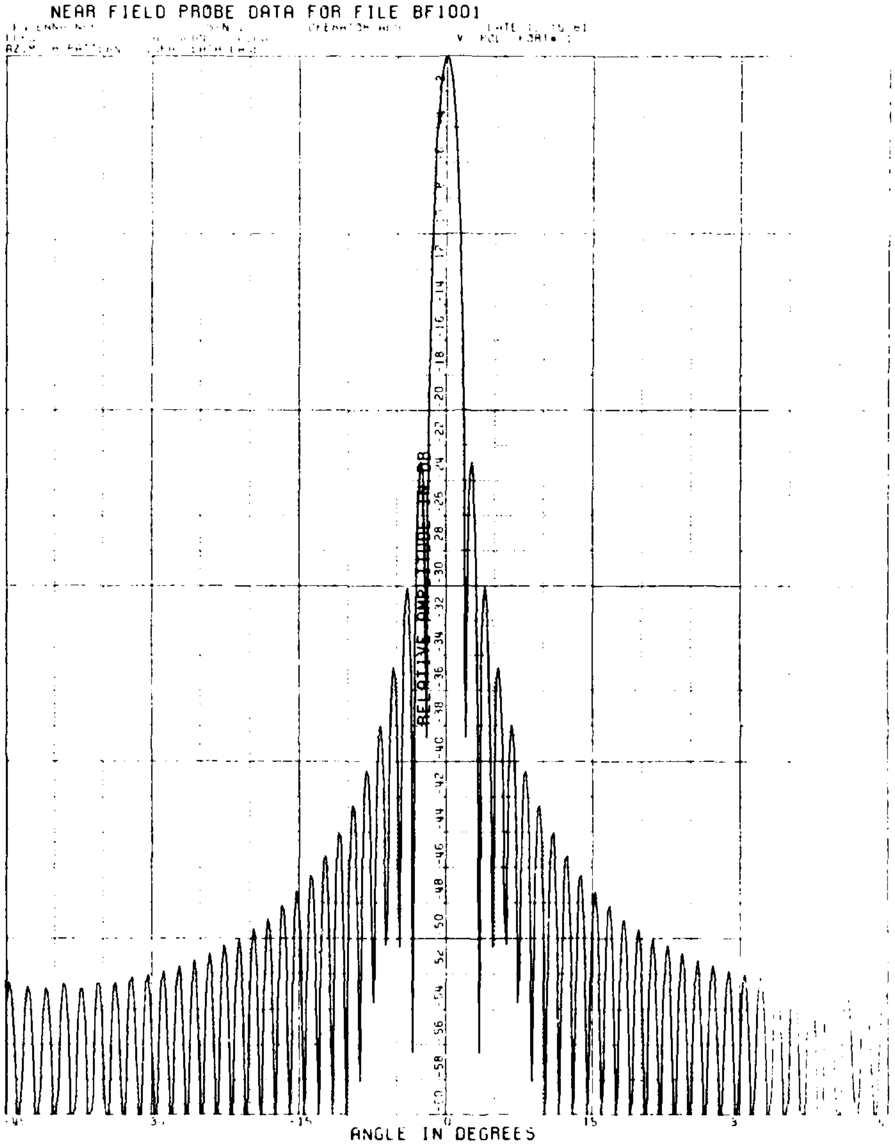

Figure 8.1.4

Computed Azimuth Pattern of Ideal Distribution.

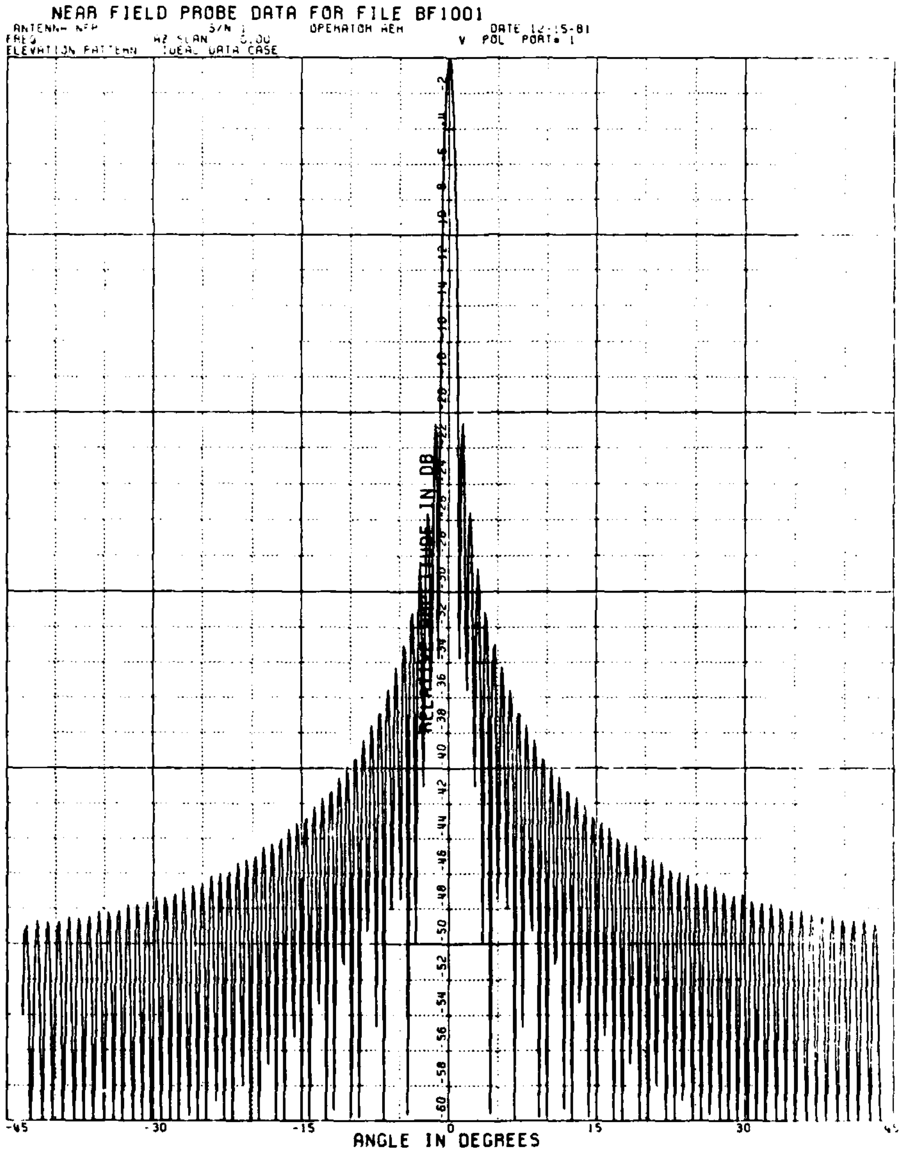

Figure 8.1.5

Computed Elevation Pattern of Ideal Distribution.

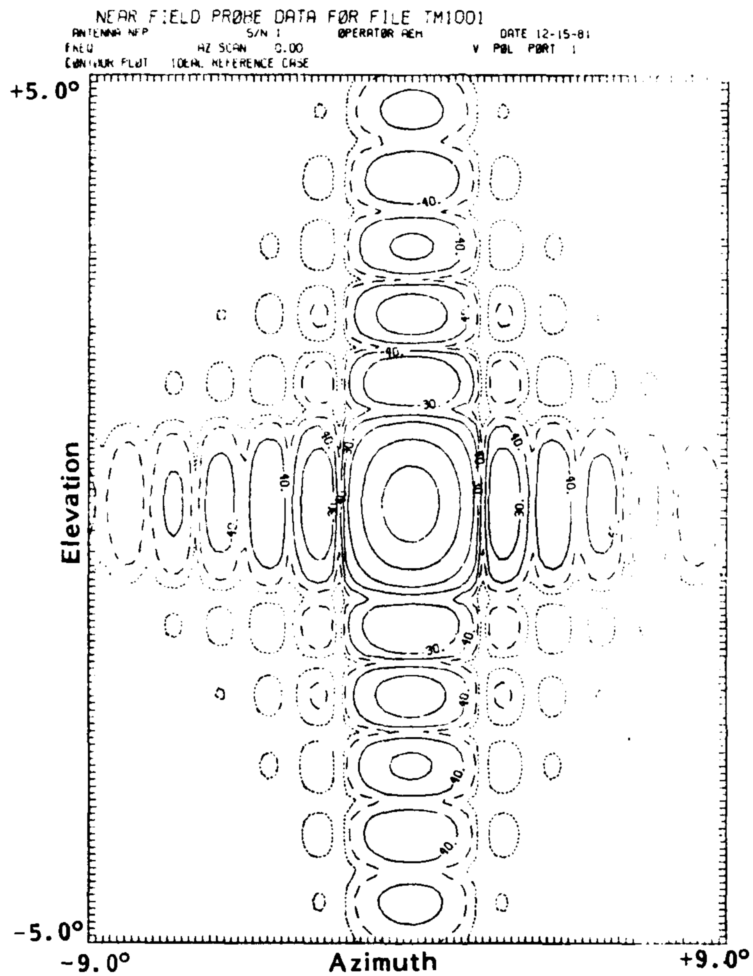

Figure 8.1.6

Contour Plot of Computed Two-dimensional Pattern Using Ideal Distribution.

Dashed contours are -50 dB
Dotted contours are -60 dB

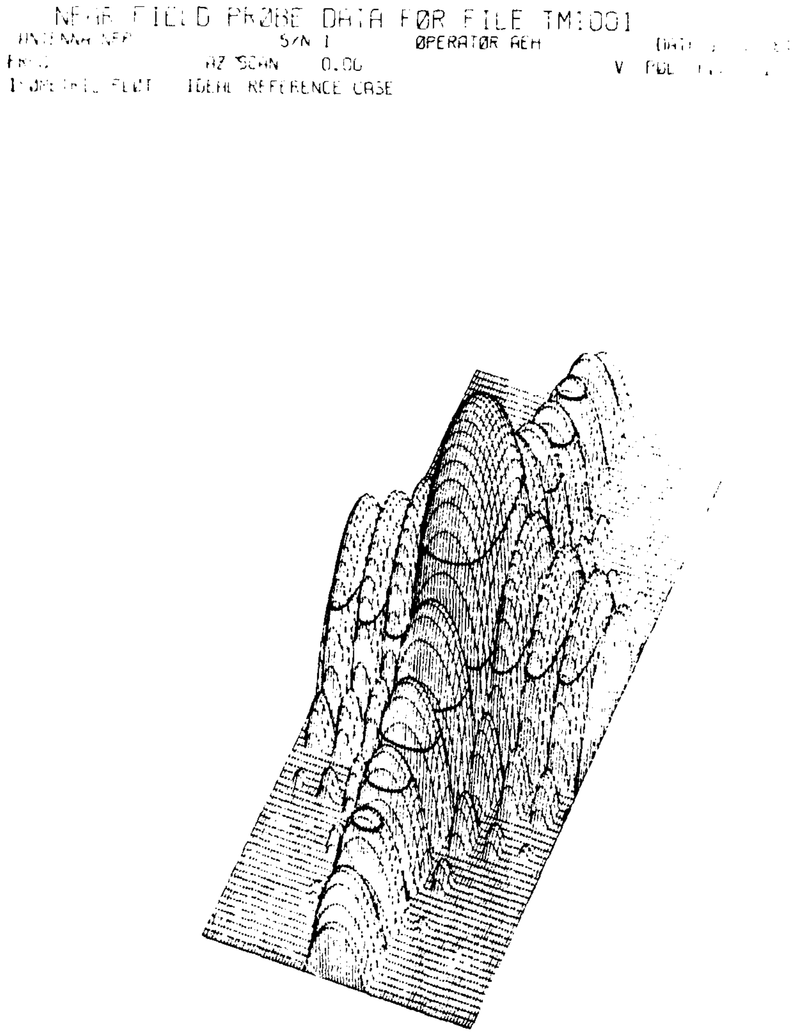

Figure 8.1.7

Isometric Plot of Two-dimensional Pattern
Using Ideal Distribution.

Contours at -20 and -40 dB
Base level is -60 dB
Viewing point is from above and to the right
with reference to Figure 8.1.6
Area mapped is ≈±5.0° in both planes

GROUP 2

IDEAL DISTRIBUTION WITH SPECIFICATION
LEVEL ERRORS

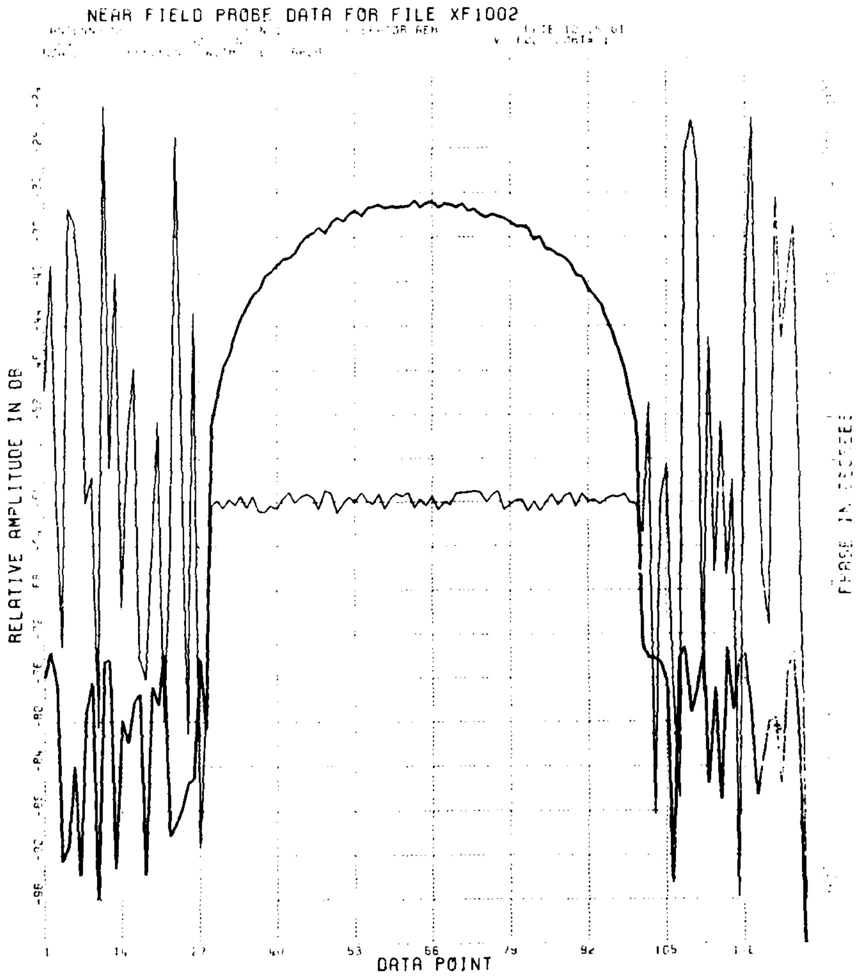

Figure 8.2.1
Azimuth Distribution with Typical Errors.

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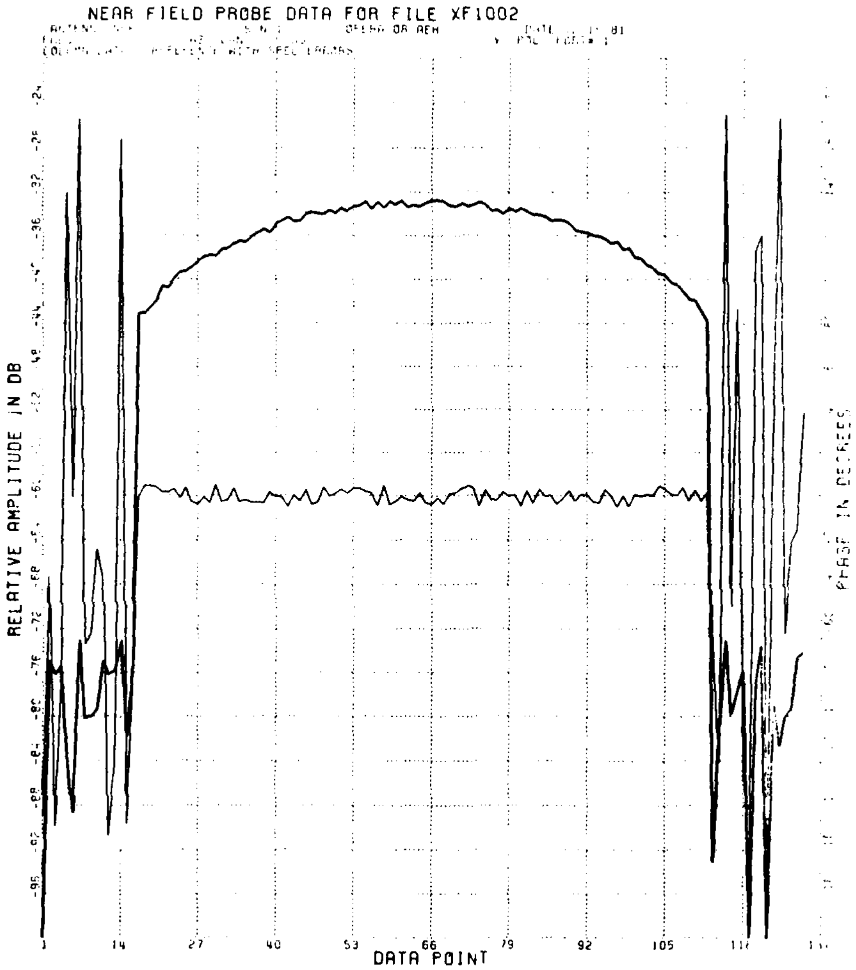

Figure 8.2.2
Elevation Distribution with Typical Errors.

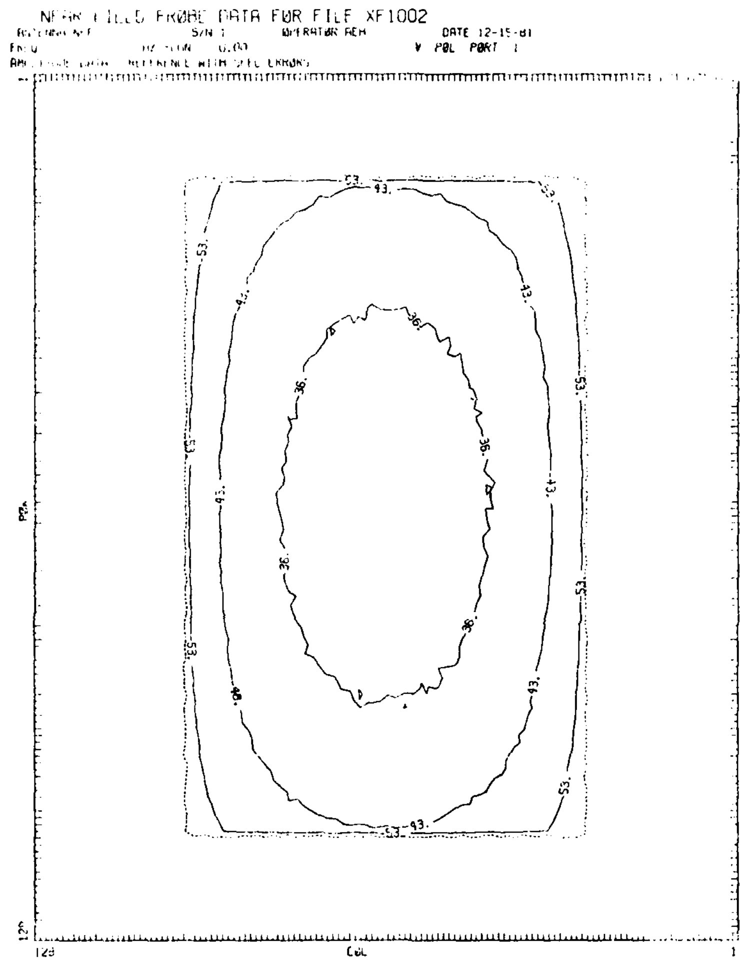

Figure 8.2.3
Contour Plot of Amplitude Distribution with Typical Errors.

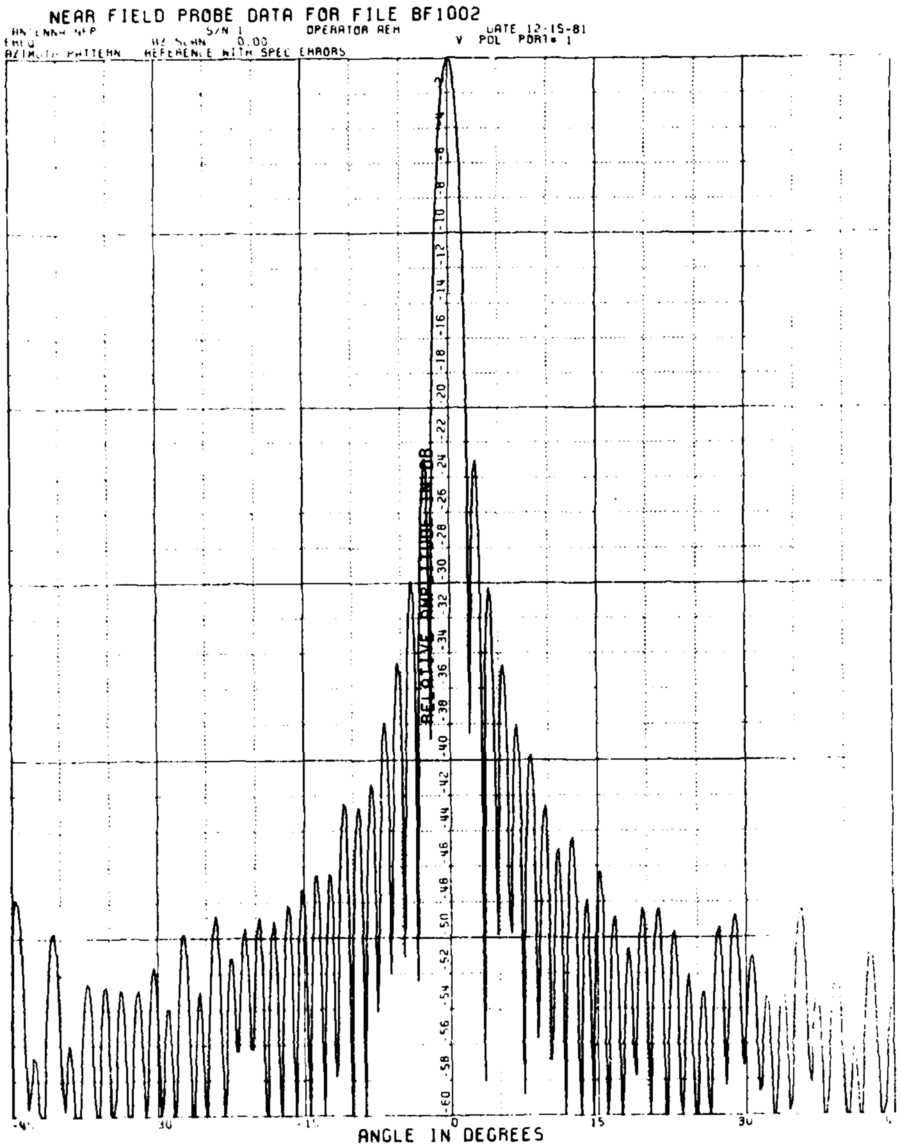

Figure 8.2.4
Azimuth Pattern with Typical Errors.

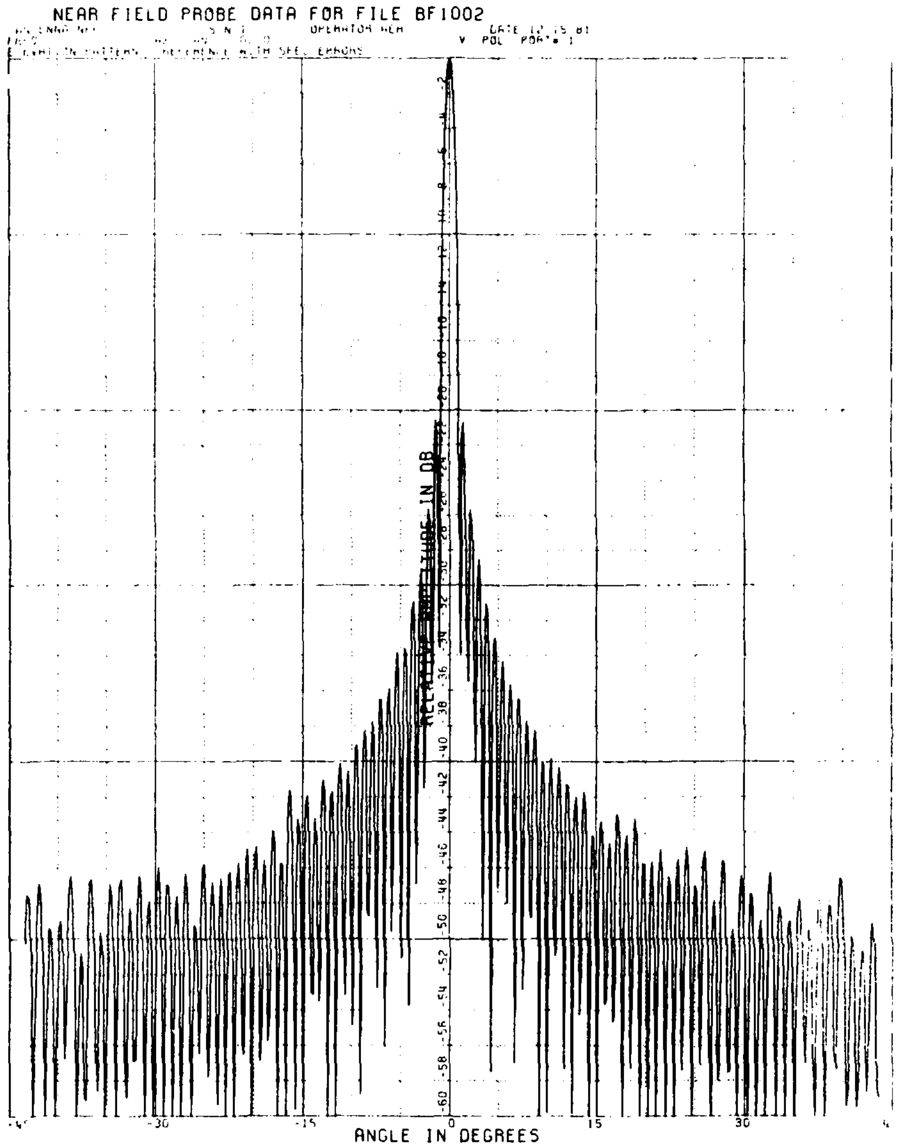

Figure 8.2.5

Elevation Pattern with Typical Errors.

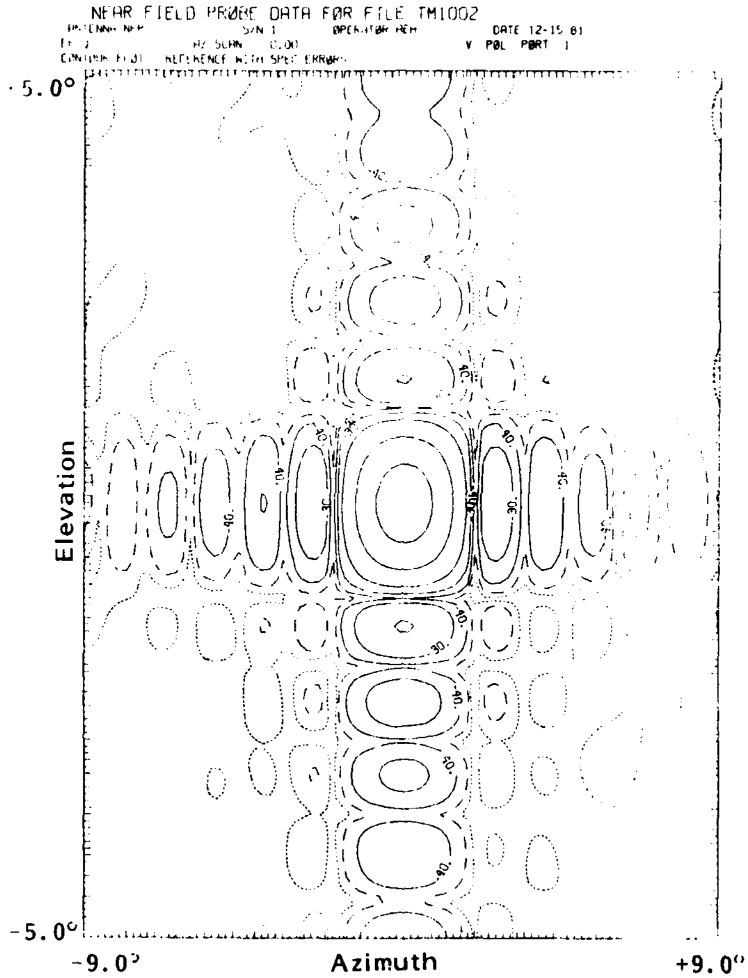

Figure 8.2.6
Contour Plot of Two-dimensional Pattern with Typical Errors.

NEAR FIELD PRØBE DATA FØR FILE TM1002

ANTENNA NFP S/N 1 ØPERATØR AEH DATE

FREQ AZ SCAN 0.00 V PØL

ISØMETRIC PLØT REFERENCE WITH SPEC ERRØRS

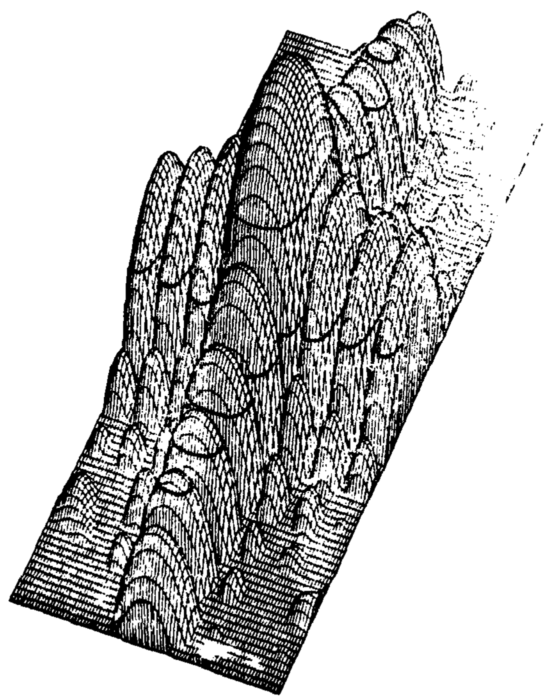

Figure 8.2.7

Isometric Plot of Two-dimensional Pattern with Typical Errors.

Scaling same as Figure 8.1.7

GROUP 3

IDEAL DISTRIBUTION WITH MAXIMUM EXPECTED ERRORS

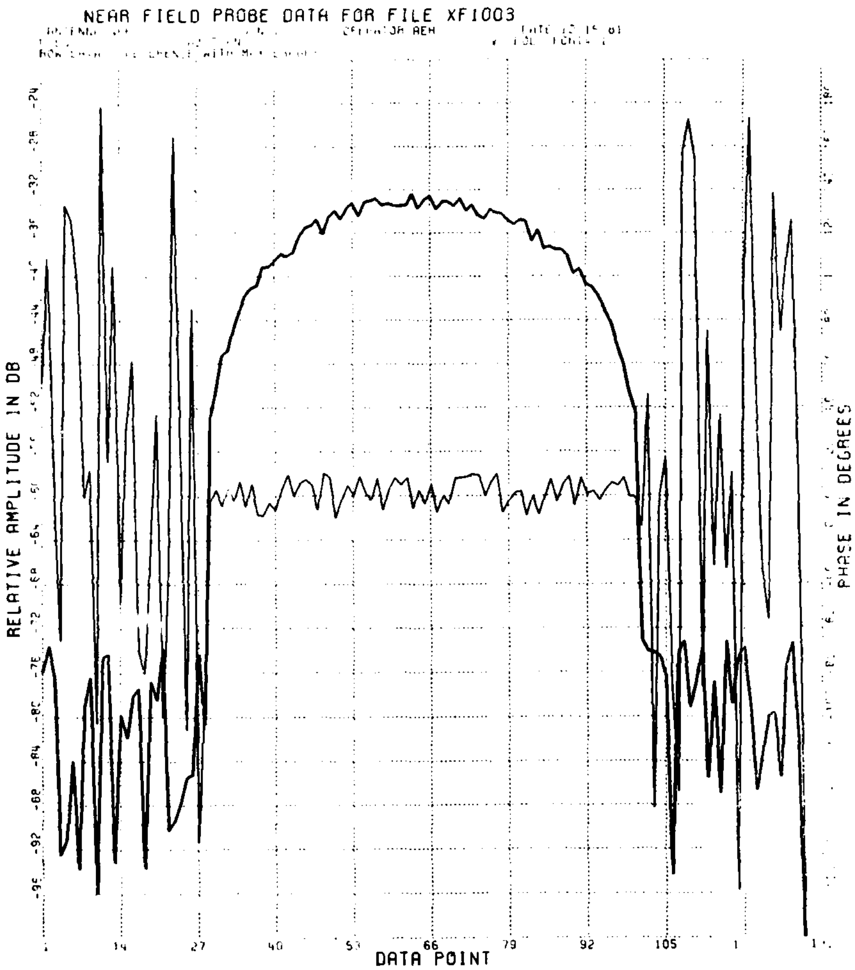

Figure 8.3.1

Azimuth Distribution with Maximum Expected Errors.

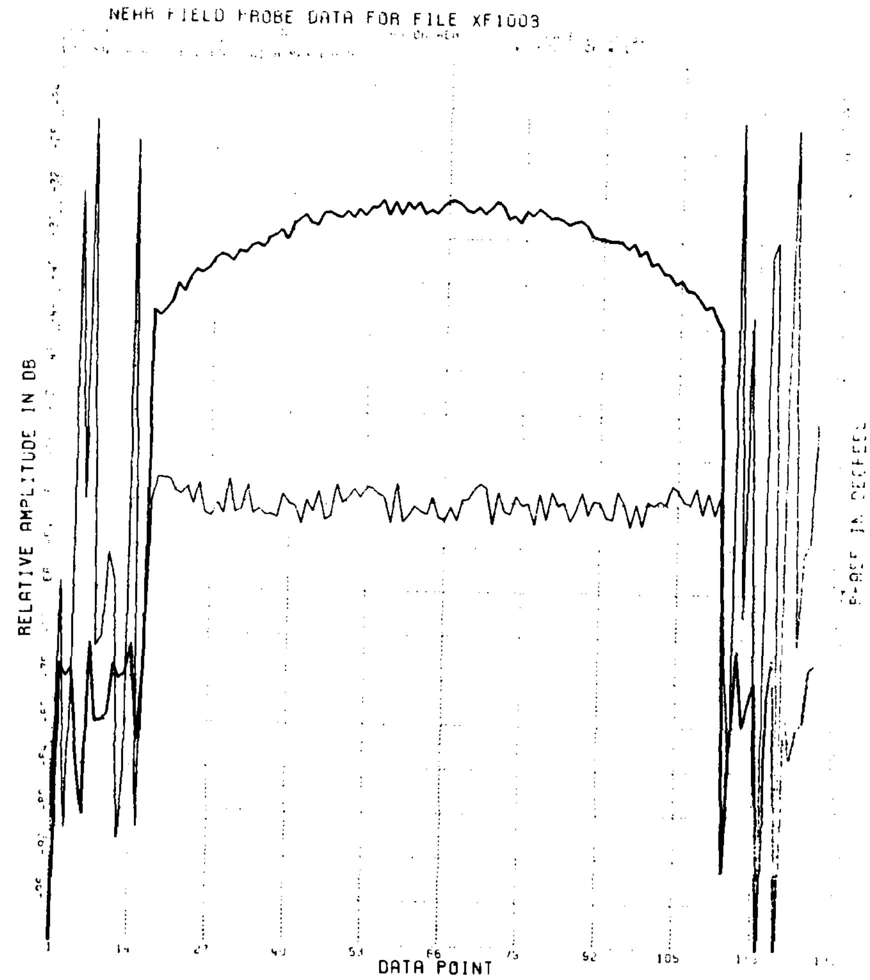

Figure 8.3.2

Elevation Distribution with Maximum Expected Errors.

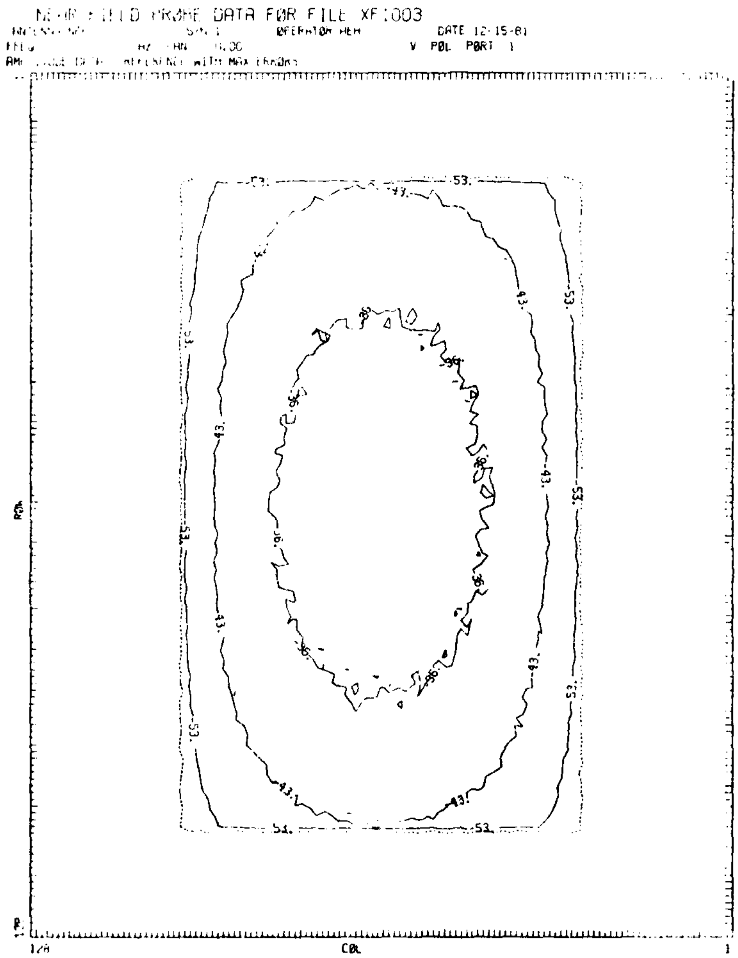

Figure 8.3.3

Contour Plot of Amplitude Distribution with Maximum Expected Errors.

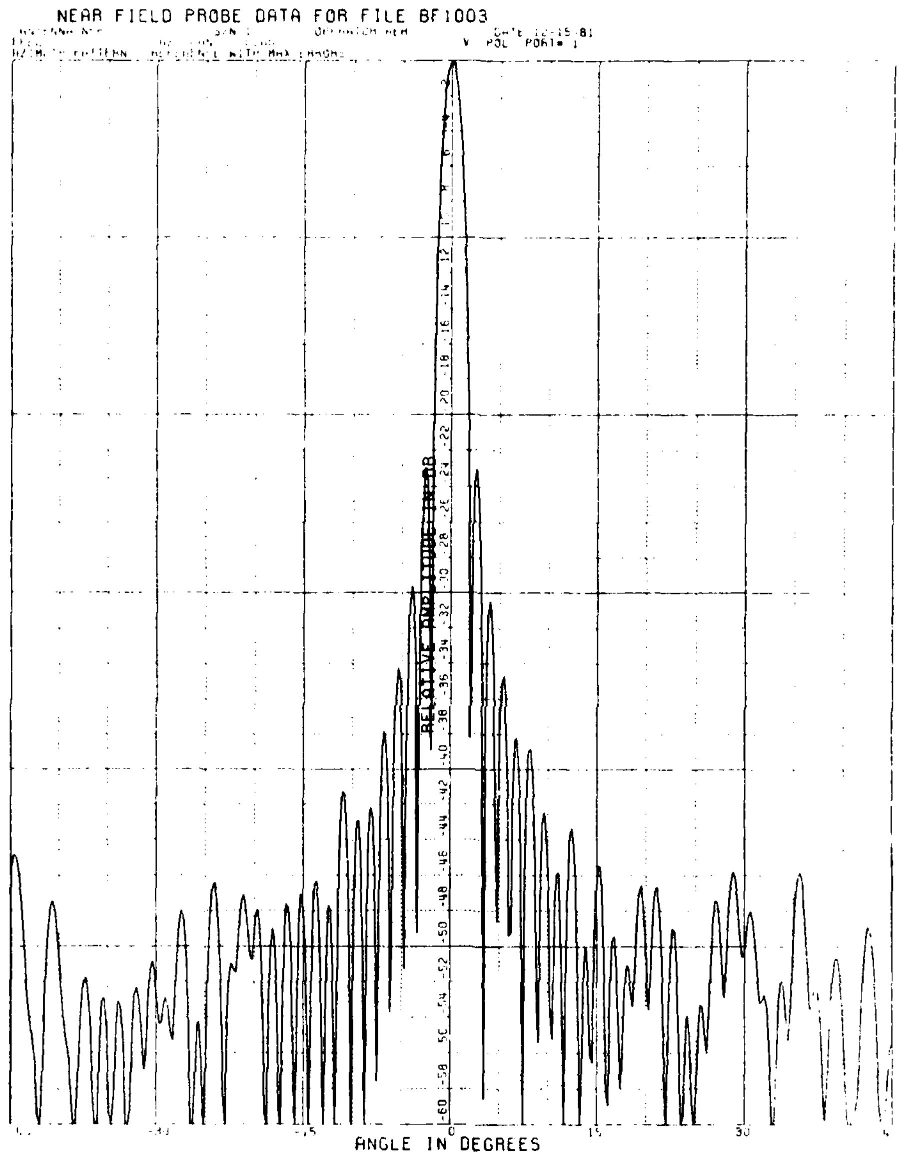

Figure 8.3.4

Azimuth Pattern with Maximum
Expected Errors.

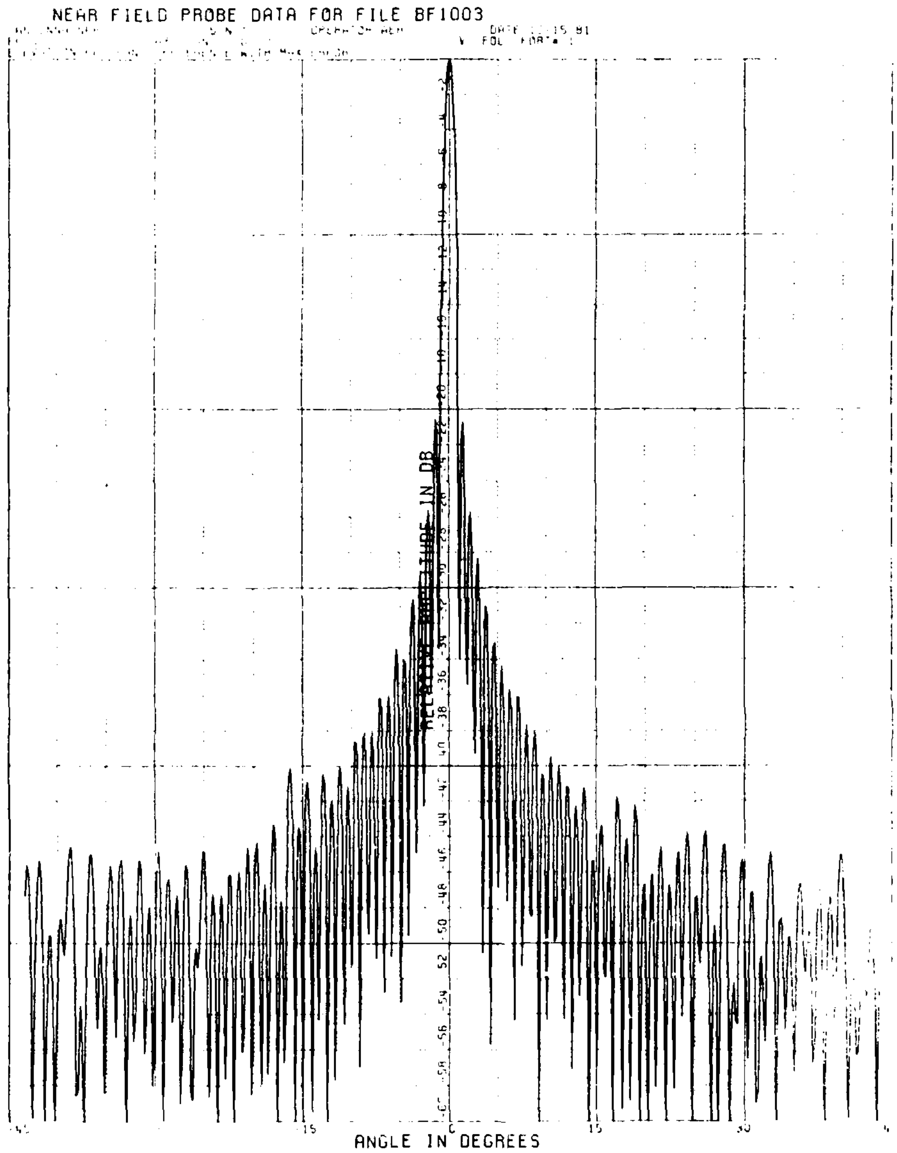

Figure 8.3.5

Elevation Pattern with Maximum
Expected Errors.

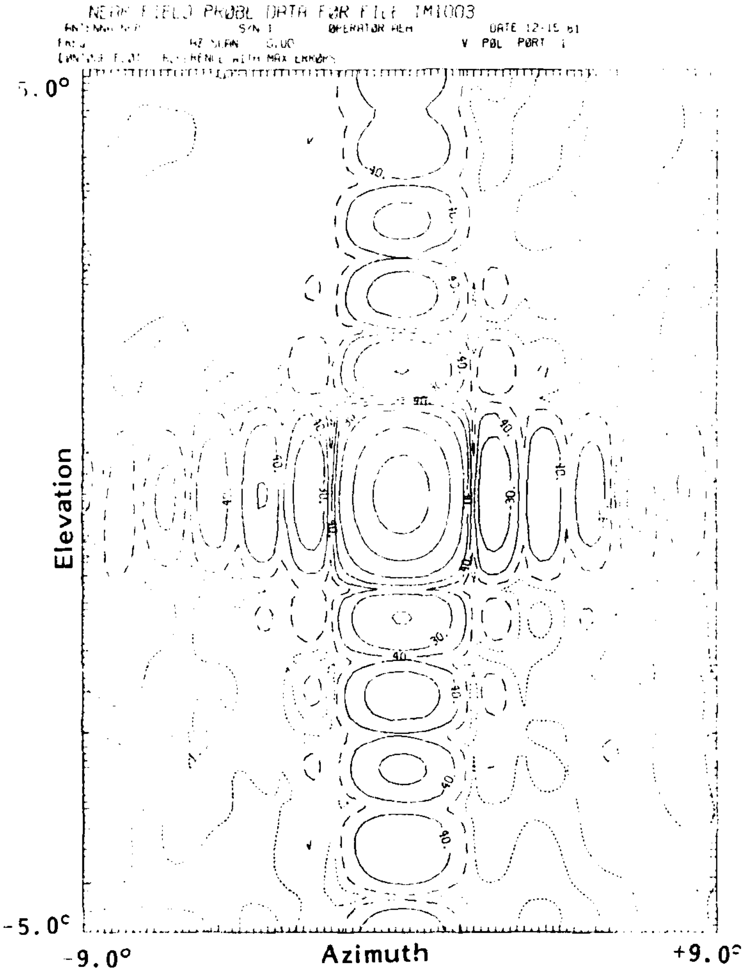

Figure 8.3.6

Contour Plot of Two-dimensional Pattern with Maximum Expected Errors.

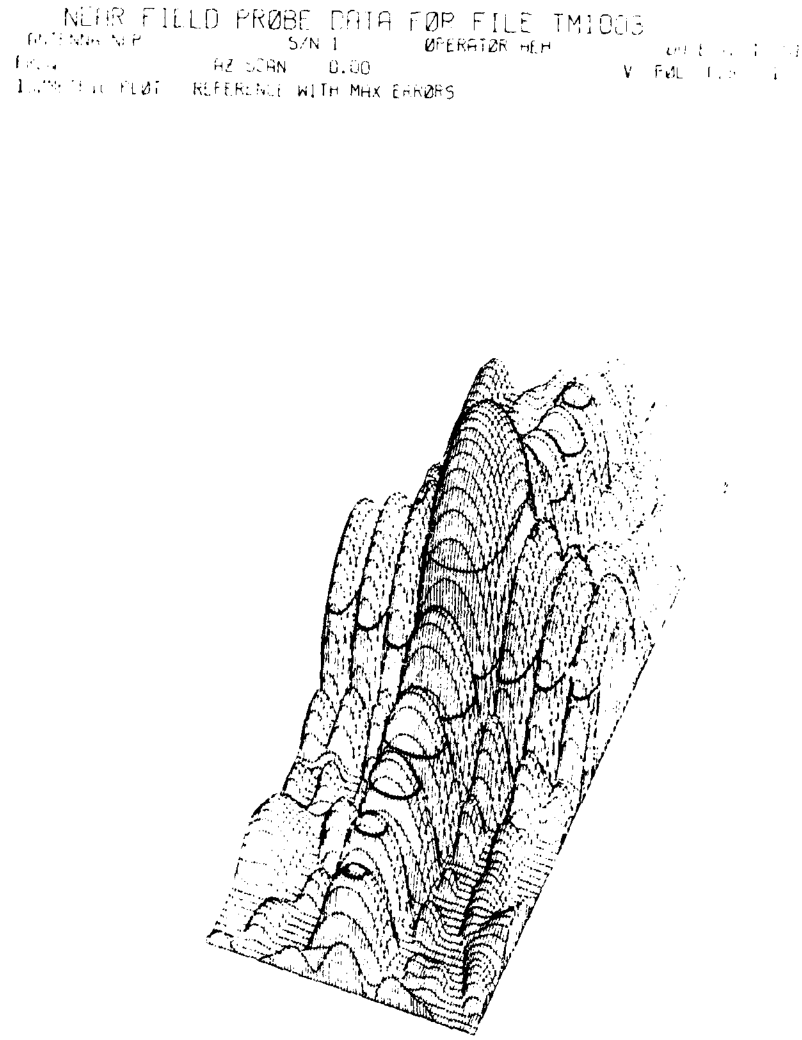

Figure 8.3.7

Isometric Plot of Two-dimensional Pattern with Maximum Expected Errors.

Scaling same as Figure 8.1.7.

GROUP 4

GAIN HORN DISTRIBUTION AND PATTERN

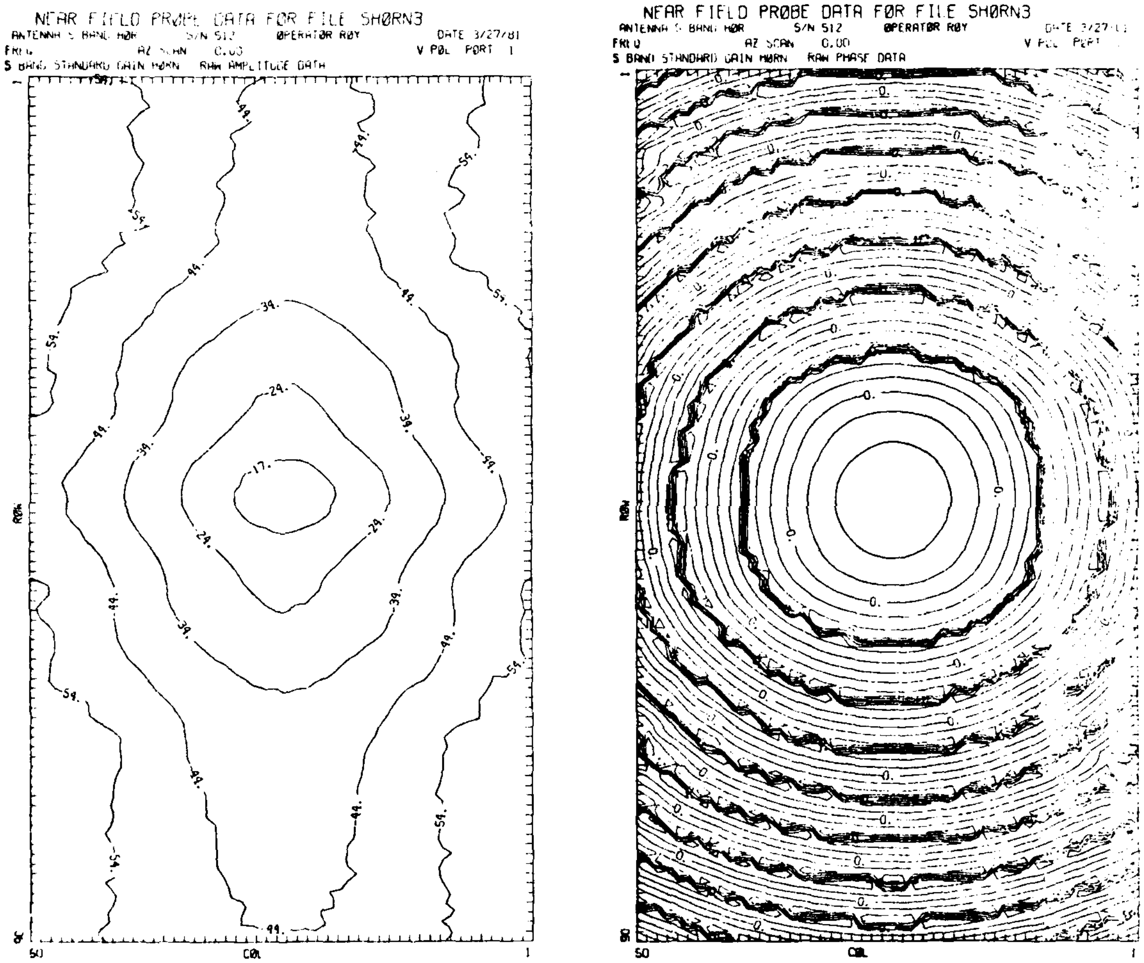

Figure 8.4.1

Gain Horn Amplitude and Phase Data Contours.

Data is taken at 1 inch increments.
Horn is approximately 13 inches wide by 10 inches high.

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NEAR FIELD PRØBE DATA FØR FILE SHØRN3
ANTENNA S BAND HØR   S/N 512   ØPERATØR RØY
FREQ   AZ SCAN 0.00   DATE
S BAND STANDARD GAIN HØRN   RAW AMPLITUDE DATA   V PØL PØRT 1

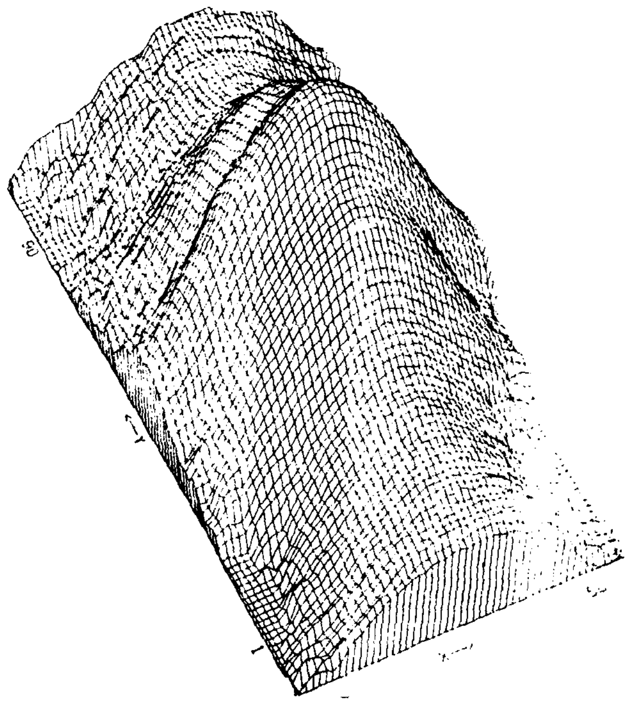

Figure 8.4.2

Isometric Plot of Gain Horn Amplitude Data.

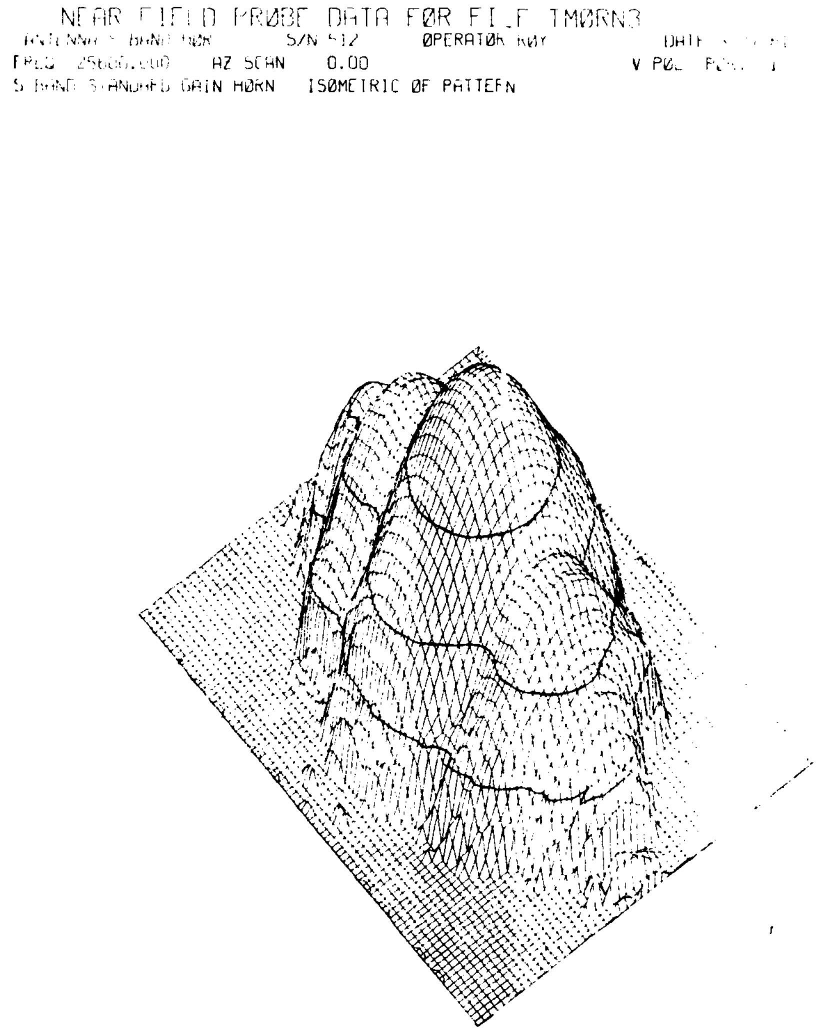

Figure 8.4.3

Isometric Plot of Gain Horn Pattern
Contours at -10, -20, and -30 dB.

SUMMARY LISTING OF NEAR FIELD SYSTEM PROGRAMS

THIS FILE IS A SUMMARY OF THE VARIOUS PROGRAMS THAT ARE USED FOR CONTROL,MEASUREMENT, DISPLAY,AND DATA ANALYSIS FOR THE NEAR FIELD PROBE.

WHEREVER POSSIBLE ROUTINES ARE STORED ON DISK WITH THE ROUTINE NAME USED AS THE FILE NAME WITH THE SPECIAL CHARACTER "&" ADDED SO THAT THE COMPILER CAN DIRECTLY PRODUCE RELOCATABLE OBJECT FILES.

WHERE NEEDED ROUTINES USE COMMON BLOCKS TO TRANSFER DATA AND VARIABLES. THE COMMON BLOCK CONTENTS ARE LISTED BELOW.

VARIABLES WHOSE FIRST CHARACTER IS A "D" ARE USUALLY DOUBLE PRECISION, ALL OTHERS FOLLOW THE NORMAL FORTRAN CONVENTION.

```
************************************************************************

 ******** THE COMMON BLOCK VARIABLES USING SYSTEM COMMON ARE ********

            IR1----------FIRST INTEGER WORD OF LASER READING
            IR2----------SECOND INTEGER WORD OF LASER READING
            DX-----------MOST RECENT LASER READING OF X POSITION
            DY-----------MOST RECENT LASER READING OF Y POSITION
            IFRQ(2)------CURRENT FREQUENCY SETTING

            LOK----------ERROR FLAG AND INDICATOR
            NMAX---------# OF DATA ROWS PER BEAM (Y AXIS DATA)
            MMAX---------# OF DATA COLUMNS PER BEAM (X AXIS DATA)
            NDS----------# OF DATA SETS PER RUN (MULTIPLEXED STEPS)
            MCC----------CURRENT COLUMN # (FOR ERROR RECOVERY)
            IRATE--------SPEED CONTROL VALUE

            DDX----------SPACING OF DATA ON X AXIS
            DDY----------SPACING OF DATA ON Y AXIS
            DXS----------LOCATION IN X OF START OF MEASUREMENT
            DYS----------LOCATION IN Y OF START OF MEASUREMENT
            DSAVE--------CURRENT X POSITION (FOR ERROR RECOVERY)

            ADPAR(3)-----ARRAY CONTAINING THE A TO D CONVERTER
                         CALIBRATION CONSTANTS FOR PHASE DATA.

            ZI(5)--------ARRAY CONTAINING INTERCEPTS FOR THE FIVE
                         LINEAR SLOPE SEGMENTS OF THE A TO D
                         CONVERTER AMPLITUDE SHAPE CALIBRATION.

            IB(4)--------ARRAY CONTAINING THE INTEGER VALUES FOR
                         BREAK POINTS FOR THE A TO D CONVERTER
                         AMPLITUDE SHAPE CALIBRATION.

            SL(5)--------ARRAY CONTAINING THE SLOPE VALUES FOR THE
                         A TO D CONVERTER AMPLITUDE SHAPE CALIBRATION

            IOFF(15Ø)----ARRAY CONTAINING THE SYSTEM OFFSET VALUES
                         FOR AMPLITUDE CALIBRATION. THERE IS ONE
                         VALUE FOR EACH MULTIPLEXED DATA SET.

            IDCB(144)----ARRAY WITH CURRENT FILE DATA CONTROL BLOCK

            DLMP(15Ø)----ARRAY CONTAINING THE RELATIVE POSITIONS IN
                         THE WINDOW AT WHICH DATA POINTS ARE TO BE
                         TAKEN FOR EACH STEP.

            FDAT(15Ø)----ARRAY CONTAINING THE FREQUENCIES FOR EACH
                         DATA SET.

            IANGL(15Ø,2)-ARRAY CONTAINING BEAM STEERING ANGLES FOR
                         EACH DATA SET AS INTEGERS (IANGL=ANGL*1ØØ)

            IPORT(15Ø)---ARRAY CONTAINING THE PORT NUMBER FOR EACH
                         DATA SET.

            INAME(3,15Ø)-ARRAY CONTAINING THE FILE NAME FOR EACH DATA
                         SET.

            DXC----------MOTOR PULSE COUNTER FOR X DRIVE
            DYC----------MOTOR PULSE COUNTER FOR Y DRIVE

            IBSU---------# OF WORDS TO BE SENT BY BEAM STEERING
                         INTERFACE CARD.
```

IN ADDITION TO THIS COMMON BLOCK TWO EMA ARRAYS ARE USED TO

```
          STORE THE INTEGER DATA WHEN USING THE MASTER PROGRAM
          THESE EMA ARRAYS WHICH LIMIT THE DATA ARE REFERENCED
          ONLY IN THE MAIN CALLING PROGRAM, THE VLOOP ROUTINE
          THE TEST ROUTINE AND THE FWRIT ROUTINE.

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

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

        EACH DATA FILE HAS A "PREAMBLE RECORD" AS RECORD #1
        THIS RECORD CONTAINS INFORMATION PERTINENT TO THE
        MEASUREMENT, AND HAS THE FOLLOWING FORMAT:

        IREC(1-9)      System Name    ASCII     Up To 18 Char.   9 Words
        IREC(10-14)    Serial #       ASCII     Up TO 10 Char.   5 Words
        IREC(15-22)    Operator Name  ASCII     Up To 16 Char.   8 Words
        IREC(23-31)    Date           ASCII     Up To 17 Char.   9 Words
        IREC(32-33)    Freq.          Two coded integers         2 Words
        IREC(34)       Spare
        IREC(35-37)    X Spacing      Double Prec. Value         3 Words
        IREC(38-40)    Y    "           "      "     "           3 Words
        IREC(41)       # Of Data Col. Integer                    1 Word
        IREC(42)       # Of Data Rows Integer                    1 Word
        IREC(43)       Port #         Integer                    1 Word
        IREC(44,45)    Beam Angle(Az) Real                       2 Words
        IREC(46)       Polarization   ASCII                      1 Word
        IREC(47,48)    Probe Z Spac.  Real                       2 Words
        IREC(49,50)    Beam Angle(El) Real                       2 Words

        Note: In the event of classified freq. values the 1st word
              of the 2 word freq. block will contain the frequency as
              a negative MHz value and the second word contains the
              code number. If not classified the first word is the
              Mhz freq and the second word is the kHz portion, both
              as integers.

        Additional words are inserted in the preamble record by the
              analysis routines to store the values for the number of
              calculated points in the patterns.

        RECORD #2 CONTAINS THE AMPLITUDE DATA FOR THE FIRST COLUMN
        RECORD #3 CONTAINS THE PHASE DATA FOR THE FIRST COLUMN ETC.

*************************************************************************
*************************************************************************
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

              DATA COLLECTION PROGRAMS

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
*************************************************************************

            TWO DIFFERENT MAIN PROGRAMS ARE USED FOR DATA COLLECTION

            MASTER IS THE NORMALLY USED PROGRAM WITH THE CAPABILITY
               TO TAKE UP TO 16384 DATA POINTS FOR EACH OF UP TO 150
               MULTIPLEXED DATA SETS DURING A SINGLE RASTER SCAN OF
               THE SYSTEM. DATA IS STORED IN AN EMA ARRAY AS IT IS
               TAKEN AND WRITTEN TO DISK FILES DURING THE RETRACE OF
               THE PROBE.

            HSCAN TAKES A HORIZONTAL DATA CUT AS OPPOSED TO THE
               NORMAL VERTICAL CUT OF MASTER. ONLY ONE LINE OF DATA
               IS MEASURED AND NO MULTIPLEXING CAPABILITY IS PROVIDED
               HOWEVER A DISK FILE IS CREATED TO ALLOW STANDARD
               ANALYSIS AND PLOT PROGRAMS TO BE USED.

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

MAIN PROGRAM

            HSCAN    FTN    CALLS POINT, SETUP, PRAMB, CALAD, HRAST

               PROGRAM TO OPERATE THE SYSTEM FOR A SINGLE DATA SET
               TAKING DATA IN THE "X" DIRECTION.

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

MAIN PROGRAM

            MASTR    FTN    CALLS TRANS, DATIN, SETUP, XLATE
                                  CALAD, RASTR
```

PROGRAM TO OPERATE THE SYSTEM FOR MULTIPLEXED DATA SETS
TAKING DATA IN THE "Y" DIRECTION

```
***********************************************************************

SUBROUTINE

            SETUP(I)  FTN   CALLS LASER, MOTRC, MOTR, WHERE, SYNTH,
                                  WAIT, PROBE, RASTR

               INITIALIZES COMPUTER SYSTEM AND TERMINAL.
               SETS LASER TO ZERO LOCATION AND CLEARS ERROR
               FLAGS. INCLUDES ENTRY TO RESET LASER IF
               INTERRUPTED. ALLOWS FOR POSITIONING OF PROBE
               TO AN OPERATOR DEFINED POINT.

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

SUBROUTINES

            RASTR(LNEW,IEND,IDUMP)   FTN    CALLS LASER, TMEAS, PROBE
            HRAST                               MOTR, WHERE, VLOOP,TEST

               PERFORMS RASTER SCAN AND DATA COLLECTION
               CAN BE REENTERED TO CONTINUE AN INTERRUPTED
               SEQUENCE.

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

SUBROUTINE

            LASER   ASMB    CALLS ERMSG

               LASER IO ROUTINE.  ACTUAL ENTRIES ARE:
                   COMP.......READS AND STORES COMPENSATION DATA
                   SET(I).....RESETS ALL OR PART OFINTERFACE
                   READX(DXP).READS X LOCATION
                   READY(DYP).READS Y LOCATION
                   LDIAG(I)...SENDS DIAGNOSTIC WORD TO INTERFACE

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

SUBROUTINE

            PROBE(DREQ,IAXIS)    FTN   CALLS LASER, WHERE, MOTRC, MOTR
                                             WAIT, ERMSG

               MOVES POSITIONER FROM PRESENT LOCATION TO A NEW LOCATION
               WHEN IRATE=-1 THIS ROUTINE WILL SEARCH UNTIL POSITION
               IS WITHIN .ØØ2 IN. OF REQUEST. OTHERWISE MOVEMENT IS
               COMPUTED FROM MOTOR STEP INCREMENT ONLY.

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

SUBROUTINES

            TEST(I,IT)            FTN   CALLS VALAD, FWRIT
            HTEST                       LINKS TO LPTRN

               EVALUATES A COLUMN OF DATA AND IF ACCEPTABLE PUTS THE
               PHASE AND AMPLITUDE DATA INTO THE PROPER DISK FILE.
               OPERATOR REVIEW AND HARDCOPY OPTIONS ARE INCLUDED

               IN ADDITION TO THE ENTRY VALUE I, THE SWITCH REGISTER
               IS TESTED. IF ANY SWITCH IS ON THE DISPLAY IS INHIBITED.

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

SUBROUTINE

            VLOOP              FTN    CALLS LASER, SYNTH, POINT, RELAY
            HLOOP                           WHERE, DA2D, ERMSG

               CONTROLS OPERATIONS AND DATA ACQUISITION DURING MOTION

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

SUBROUTINE

            SYNTH(DFREQ,I1,I2,I3)    FTN   CALLS WAIT, ERMSG

                CONTROL ROUTINE FOR THE 8672 SYNTHESIZER
```

```
***************************************************************************

SUBROUTINE

            POINT(DFREQ,AZ,EL,IBSU)   FTN   CALLS BSTER

               SETS BEAM STEERING UNIT

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

SUBROUTINE

            BSTER(I1,I2)  ASMB    CALLS WAIT

                SENDS INTEGERS COMPUTED BY POINT TO THE
                BEAM STEERING CONTROLLER IN THE ANTENNA.

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

SUBROUTINE

            RELAY(I)  ASMB

               SELECTS RF SWITCH PORT

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

SUBROUTINE

            WAIT(IT)    ASMB

               CAUSES A PROGRAMMED WAIT IN MILLISECONDS

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

SUBROUTINE

            TMEAS          FTN

               COMPUTES TIME REQUIRED USING PROPER OPERATING
               SPEED FOR VERTICAL SCAN FROM TASK DATA AND ASKS
               FOR OPERATOR VERIFICATION AND SELECTION.

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

SUBROUTINE

            DA2D(IA,IP,IC,NAVG)        ASMB

               PERFORMS IO TO DUAL ADC INTERFACE CARD. RETURNS
               INTEGER RESULTS OF ADC READ IN IA(1ST CONVERSION),
               AND IP(2ND CONVERSION). SETS PHASE DATA TO GIVE A
               +180 DEG VALUE IF AT A "JUMP" POINT.

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

SUBROUTINE

            MOTRC(DMOVE,IAXIS,ISPEED,IDIR)   FTN   CALLS MOTR, WAIT

                CONVERTS MOTOR CONTROL COMMANDS TO INTEGER WORDS FOR
                CONTROLLER.

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

SUBROUTINE

            MOTR(I1,I2,I3,I4,I5)   ASMB   CALLS WAIT

                OUTPUTS THE 5 INTEGERS TO THE 40 BIT REGISTER WHICH
                DRIVES THE TWO MOTOR CONTROLLERS

                OTHER ENTRY POINTS ARE:

                  MBUSY..  WAITS FOR MOTOR TO STOP RUNNING
                  MHOLD..  HOLDS THE OPERATING MOTOR.
                  MTRGO..  RELEASES A PREVIOUSLY HELD MOTOR

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

SUBROUTINE

            WHER   FTN   CALLS OUT40
```

SENDS LASER POSITION DATA TO EXTERNAL DISPLAY
(CALLING NAME IS WHERE)

****

SUBROUTINE

OUT4Ø(IDATA,LU) ASMB

OUTPUTS 5 WORDS OF IDATA ARRAY TO 4Ø BIT CARD
AT ADDRESS LU

****

SUBROUTINE

ERMSG FTN CALLS MOTRC, MOTR, WAIT, SETUP

PROVIDES OPERATOR WITH INFORMATION ABOUT ERROR
CONDITIONS. IN THE CASE OF LASER ERRORS THE SYSTEM
IS RESET TO THE ZERO ZERO LOCATION. THE OPERATOR
MAY CONTINUE THE MEASUREMENT OR ABORT.

****

SUBROUTINE

CALAD FTN CALLS PVAL, SYNTH, WAIT, DA2D

PROVIDES A CAPABILITY TO CALIBRATE THE SYSTEM
NETWORK ANALYZER AND A TO D CONVERTER. PHASE
CALIBRATION USES THE RESPONSE OF A LONG CABLE TO
GIVE MULTIPLE PHASE CYCLES WHICH SHOULD BE
+18Ø TO -18Ø DEGREES. AMPLITUDE IS CALIBRATED
USING A SWITCHED ATTENUATOR IN THE SIGNAL LINE.

****

SUBROUTINE

PVAL(PH,IDEL,DFR) FTN CALLS SYNTH, WAIT, DA2D

SETS SYNTHESIZER, READS A TO D, AND RETURNS
PHASE READING TO THE CALAD ROUTINE.

****

SUBROUTINE

VALAD(IA,IP,ID,IN) FTN

CONVERTS A TO D READINGS INTO PHASE AND AMPLITUDE
VALUES USING CALIBRATION CONSTANTS ESTABLISHED BY
CALAD. DATA IS THEN CONVERTED BACK TO INTEGER FORM
FOR STORAGE. (IPHAS=1Ø*PHAS) (IAMP=5Ø*AMP)

****

SUBROUTINE

TRANS(IBUF,INDEX) FTN

HANDLES BLOCK MODE TRANSFER FROM CRT MENU DISPLAY
TO MEMORY.

****

SUBROUTINE

DATIN(INPT) FTN

ENTERS CONTROL DATA FOR MULTIPLEXRD DATA SETS.
KEYBO/RD, DISK, OR CASETTE MAY BE SPECIFIED AS
THE DATA SOURCE AND RESULT MAY BE COPIED TO
DISK OR CASETTE. INPT SPECIFIES THE DATA SOURCE
WITH A DEFAULT TO THE KEBOARD UNLESS INPT=D OR C.

****

SUBROUTINE

INIT(INFO) FTN CALLS FCRE8

```
          INITIALIZES CONTROL PARAMETERS FOR PRODUCTION MEASUREMENT

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

SUBROUTINE

          XLATE(INFO)    FTN    CALLS FCRE8

              TRANSLATES PREAMBLE DATA INTO FORM FOR DISK FILE

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

SUBROUTINE

          FCRE8(IREC)   FTN     CALLS FWRIT

              CREATES AND OPENS THE SET OF FILES REQUIRED TO STORE
              THE MULTIPLEXED DATA SETS. IREC IS THE PREAMBLE DATA
              THAT IS COMMON TO ALL FILES FOR A RUN. FILES ARE
              INDIVIDUALLY NAMED, CREATED, COMPLETE PREAMBLES
              WRITTEN, THEN CLOSED.

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

SUBROUTINE

          FWRIT   FTN

              TRANSFERS DATA FROM EMA ARRAY TO THE PROPER DISK FILES.

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

SUBROUTINE

            DCODE  FTN

               CONVERTS STRINGS OF ASCII CODED DATA TO THE PROPER
               NUMERIC FORMATS.

************************************************************************
************************************************************************
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

          ANTENNA DIAGNOSTIC PROGRAMS   (FOR REFERENCE ONLY)

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
************************************************************************
************************************************************************

MAIN PROGRAM

          XT36D   FTN

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

SUBROUTINE

          XT36U   FTN

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

MAIN PROGRAM

          XT37D   FTN

************************************************************************
************************************************************************
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP

         PLOTTING PROGRAMS

PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
************************************************************************
************************************************************************

MAIN PROGRAM

           PLT1D   FTN     CALLS CRTPT  LINPT
                           LINKS PLTPT
```

PROGRAM TO COMPUTE AND PLOT "LINE SOURCE" PATTERNS FROM SINGLE LINES OF PROBE DATA. THE PROGRAM CAN ACCESS EITHER THE CURRENT COLUMN OF DATA OR REFER BACK TO A RECORD STORED IN A USER SELECTED DISK FILE. THE PROGRAM LOOPS UNTIL INSTRUCTED TO RETURN TO A CALLING "FATHER" I.E. TEST2 OR EXITS. PLOTS OF THE PHASE AND AMPLITUDE DATA AS WELL AS LISTINGS MAY ALSO BE REQUESTED.

****

SUBROUTINE

LINPT FTN CALLS FOURT

THIS SUBROUTINE IS CALLED BY PLT1D TO COMPUTE THE PATTERN OF A LINE SOURCE.

****

MAIN PROGRAM

PLTPT FTN CALLS TITLE

CONVENTIONAL ANTENNA PATTERNS ARE PLOTTED WITH THIS PROGRAM. THE DATA TO BE PLOTTED MUST BE IN A FILE NAMED "LINDAT" AND CONTROL PARAMETERS MAY BE ENTERED AS PART OF THE SCHEDULING OF PLTPT OR ENTERED DURING PROGRAM EXECUTION. THE PROGRAM CONTAINS THE DATA TO ALLOW PATTERNS TO BE PLOTTED WITH SCALING TO DIRECTLY OVERLAY ANY OF THE COMMONLY USED SCIENTIFIC ATLANTA PATTERN FORMS. A FORMAT FOR PRODUCING RAW DATA PLOTS OF PHASE AND AMPLITUDE OF A ROW OR COLUMN IS ALSO INCLUDED. SPECIAL FORMATS CAN BE SET UP FOR OTHER APPLICATIONS. AUTO MODE OPERATION WITH NO OPERATOR ENTRIES ARE HANDLED BY PROPERLY SETTING ENTRY VALUES.

****

MAIN PROGRAM

PLT2D FTN CALLS TITLE

THIS PROGRAM PLOTS DATA IN THE FORM OF A TWO DIMENSIONAL CONTOUR MAP. DATA IS EXPECTED TO BE IN A DISK FILE IN THE FORMAT OF THE SYSTEM DATA AS DESCRIBED ABOVE. THE OPERATOR CAN SPECIFY THE PORTION OF THE DATA TO BE PLOTTED AND MUST SELECT THE CONTOUR LEVELS. THIS PROGRAM UTILIZES THE PROGRAMS FROM THE CONTOUR LIBRARY OBTAINED FROM NBS BOULDER AS WELL AS VERSAPLOT ROUTINES. PREAMBLE INFORMATION AND ONE LINE OF COMMENTS ARE ALSO PRINTED IF DESIRED. THE PLOTS MAY BE SIZED TO MEET ANY REQUIRED SCALING.

****

MAIN PROGRAM

PLT3D FTN CALLS TITLE

THIS PROGRAM PLOTS DATA IN THE FORM OF THREE DIMENSIONAL PERSPECTIVE PICTURES. DATA IS AS ABOVE AND THE OPERATOR MUST SPECIFY THE PLOT LIMITS, CONTOUR LEVELS (IF USED), THE VIEWING POINT ETC. THIS PROGRAM USES ROUTINES FROM THE SURFACE LIBRARY OBTAINED FROM NBS BOULDER AS WELL AS VERSAPLOT ROUTINES.

****

SUBROUTINE

XAPLT FTN

THIS IS A SPECIAL PURPOSE PLOTTING ROUTINE USED PRIMARILY WITH THE DIAGNOSTIC PROGRAMS. IT PROVIDES FOR BOTH CRT (USING AUTOPLOT) AND HARDCOPY OUTPUT OF A NUMBER OF PRESET PHASE AND AMPLITUDE SCALES.

****

MAIN PROGRAM

HCPYA

VERSATEC OUTPUT ROUTINE USED FOR XAPLT HARDCOPY

****
SUBROUTINE

CRTPT FTN

PRODUCES CRT PLOTS OF RAW DATA USING HP AUTOPLOT.

****

SUBROUTINE

TWOD FTN

MODIFIED VERSION OF THE NCAR ROUTINE CONREC USED WITH PLT2D.

****

SUBROUTINE

SURF FTN

MODIFIED VERSION OF THE NCAR ROUTINE SRFCE USED WITH PLT3D.

****

SUBROUTINE

TITLE FTN

CONVERTS PREAMBLE DATA INTO ASCII ARRAYS FOR LABELLING PLOTS. OPTIONALLY, A COMMENT LINE MAY BE REQUESTED.

****
****
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU

UTILITY PROGRAMS

UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
****
****

MAIN PROGRAM

UPSET FTN

GENERAL PURPOSE UTILITY. INCLUDES MOST OF THE ROUTINES NEEDED FOR THE NFP SYSTEM CHECKOUT AS WELL AS A NUMBER OF EVALUATION TEST PROGRAMS. MENU SELECTION OF FUNCTION IS PROVIDED.

****

MAIN PROGRAM

BKLSH FTN

A SPECIAL PURPOSE UTILITY FOR CHECKING THE DRIVE SYSTEM GEARBOXES FOR BACKLASH.

****
MAIN PROGRAM

CLEAN FTN

THIS UTILITY PROGRAM ALLOWS THE OPERATOR TO SEARCH A STANDARD DATA FILE AND FIND VALUES WHICH DIFFER FROM A RUNNING 5 POINT AVERAGE. LIMITS FOR THE ALLOWABLE DIFFERENCE ARE OPERATOR SPECIFIED. IF REQUESTED A NEW FILE WILL BE CREATED WITH EACH BAD DATA POINT CHANGED TO THE VALUE ENTERED BY THE OPERATOR.

****

MAIN PROGRAM

SERCH FTN

AD-A114 125 HUGHES AIRCRAFT CO FULLERTON CA F/G 17/9

NEAR FIELD ANTENNA MEASUREMENT SYSTEM.(U)

MAR 82 A E HOLLEY DAAB07-77-C-0587

UNCLASSIFIED NL

2 of 2

AD A114125

END

DATE FILMED

6 82

DTIC

ALLOWS THE OPERATOR TO PRINT THE LINES IN A PROGRAM
WHERE A SPECIFIED STRING OCCURS. LINE NUMBERS ARE
PRINTED TOGEATHER WITH THE ENTIRE LINE.

****

MAIN PROGRAM

FLATN FTN

TESTS A DATA FILE FOR PHASE SLOPE IN BOTH COORDINATES
AND ALLOWS CREATION OF A NEW FILE WITH OPERATOR ENTERED
SLOPES REMOVED.

****

MAIN PROGRAM

PPCON FTN

CONVERTS PROBE DATA FILES INTO DATA SETS IN THE
PROPER FORMAT TO BE PLOTTED BY THE STANDARD PLOT
ROUTINES.

****

MAIN PROGRAM

PRLST FTN

LISTS THE DATA IN THE PREAMBLE RECORD FOR A FILE.

****

MAIN PROGRAM

FAKIT FTN

CREATES A DATA SET CONTAINING OPERATOR SPECIFIED
PHASE AND AMPLITUDE VALUES. LINEAR PHASE SLOPES
EACH PLANE MAY BE SET AND COEFFICIENTS FOR COSINE
ON A PEDESTAL AMPLITUDE TAPERS MAY BE SET FOR EACH
PLANE. RANDOM ERRORS MAY ALSO BE INCLUDED.

****

MAIN PROGRAM

FRSEQ FTN

RESEQUENCES A FTN PROGRAM SO THAT LABELS ARE IN A
UNIFORM ASCENDING SEQUENCE. FROM HP 1000 USERS GROUP
LIBRARY. REQUIRES CARE THAT NO NUMERIC VALUES ARE IN
COLUMN 7.

****

SUBROUTINE

FITQ FTN

PERFORMS A LEAST SQUARES FIT OF A LARGE DATA SET TO
A GENERAL QUADRATIC FUNCTION AND LISTS RESULTS AND
RESIDUALS.

****
****
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

ANALYSIS PROGRAMS

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
****
****

MAIN PROGRAM

ESP36 FTN

PROGRAM TO RUN COMPLETE MEASUREMENT AND ANALYSIS OF A
TPQ/36 ANTENNA. SCHEDULES ALL OF THE REQUIRED PROGRAMS

IN SEQUENCE AFTER INSTRUCTING THE OPERATOR IN THE CORRE
SET UP OF THE PROBE SYSTEM.

****

MAIN PROGRAM

ESP37 FTN

SIMILIAR TO ESP36 FOR A TPQ/37 ANTENNA

****

MAIN PROGRAM

DEUCE FTN

ANALYSIS OF A SINGLE DATA SET WITH NO RESTRICTIONS.
ALL POSSIBLE OUTPUT FUNCTIONS ARE AVAILABLE WHEN
REQUESTED BY THE OPERATOR.

****

PROGRAM

FAR39 FTN

COMPUTES 2 DIMENSIONAL PATTERNS OF USER SPECIFIED AREAS
AROUND THE MAIN BEAM. PROVIDES HIGH RESOLUTION DATA BUT
DOES NOT INCLUDE PROBE CORRECTIONS.

****

PROGRAM

SING4 FTN

COMPUTES CONIC PATTERNS AT USER SPECIFIED ANGLES. FULL
PROBE CORRECTIONS ARE INCLUDED AND DATA IS OUTPUT IN
STANDARD PATTERN FORMAT.

****

PROGRAM

FFT FTN

PROGRAM VERSION OF FAST FOURIER TRANSFORM ROUTINE. USES
EMA ARRAY FOR DATA HANDELING.

****

SUBROUTINE

FOURT FTN

MODIFIED VERSION OF THE NBS FAST FOURIER ROUTINE.

****

SUBROUTINE

FFFFF FTN

SIMPLIFIED VERSION OF FOURT TO MINIMIZE RUN TIME AND
PROGRAM SPACE FOR PRODUCTION PROGRAMS.

****

SUBROUTINE

BEAM FTN

ROUTINE TO COLLAPSE 2D DATA TO LINE SOURCES, PERFORM
FFT AND LOCATE BEAM PEAKS.

****

SUBROUTINE

FARPR FTN

ROUTINE TO MAKE PROBE CORRECTIONS TO DATA FROM BEAM,
COMPUTE GAIN, AND PUT DATA INTO FORMAT FOR PLOTTING.

****

SUBROUTINE

REWR FTN

ROUTINE TO HANDLE THE DATA WHEN USING THE PROGRAM VERSION OF THE FFT ROUTINE.

****

SUBROUTINE

REARG FTN

REARRANGES, NORMALIZES, AND CORRECTS TWO DIMENSIONAL FFT DATA SO IT CAN BE USED TO PROVIDE ANTENNA PATTERN VALUES FOR DATA OUTPUT.

****

SUBROUTINE

RE1D FTN

ROUTINE TO REARRANGE AND NORMALIZE DATA FROM A ONE DIMENSIONAL FFT CALCULATION.

****

SUBROUTINE

BMPK FTN

FINDS THE PEAK LOCATION FOR A 2D DATA SET.

****

SUBROUTINE

PHSC2 FTN

CORRECTS PATTERN PHASE FOR A 2D DATA SET.

****

SUBROUTINES

PROW FTN
PCOL

INTERPOLATES PROBE DATA TO OBTAIN VALUES AT LOCATIONS MATCHING PATTERN DATA POINTS.

****

SUBROUTINE

RALAN FTN

COMPUTES REAL ANGLE ARRAY FOR PATTERN DATA.

****

SUBROUTINE

LOK1D FTN

COMPUTES AMPLITUDE IN DB FOR PATTERN DATA.

****

SUBROUTINE

DSLOP FTN

COMPUTES DIFFERENCE BEAM PARAMETERS FROM PATTERN DATA.

****

SUBROUTINES

ARTP FTN

APTR
ARTAH

ROUTINES TO CONVERT BETWEEN RECTANGULAR AND POLAR COORDINATES FOR ARRAYS OF COMPLEX DATA.

****

PROGRAMS

XBLUR FTN
SBLUR

PROGRAMS TO HANDLE ANALYSIS OF TPQ36 AND 37 DATA. THESE ARE GREATLY SIMPLIFIED VERSIONS OF DEUCE AND ARE LIMITED TO AUTOMATICALLY PRODUCE THE DATA REQUIRED FOR SYSTEM PRODUCTION TESTING.

****

PROGRAM

BMPOS FTN

COMPUTES BEAM CROSSOVER LOCATIONS FROM PATTERN DATA FILES FOR TPQ 36 ANTENNA TESTS.

****

PROGRAM

ROPAT FTN

COMPUTES AND TABULATES ANTENNA PARAMETERS FROM PATTERN DATA FOR THE TPQ 37 ANTENNA.

****

PROGRAMS

REDUC FTN
SEDUC

PRODUCE PATTERN PLOTS FOR THE PRODUCTION TESTS OF THE TPQ 36 & 37 ANTENNAS. REDUC ALSO PRINTS A DATA SUMMARY FOR THE TPQ 36.

****

SUBROUTINES

XPAPA FTN
SPAPA

SIMPLIFIED VERSIONS OF BEAM USED WITH THE BLUR PROGRAMS. THESE VERSIONS RUN MUCH FASTER AND REQUIRE NO OPERATOR INTERACTION.

****

SUBROUTINES

XGAPP FTN
SGAPP

SIMPLIFIED VERSIONS OF FARPR USED WITH THE BLUR PROGRAMS THESE VERSIONS RUN FASTER AND REQUIRE NO OPERATOR INTERACTION.

****

SUBROUTINE

AZOCT FTN

COMPUTES INTERELEMENT PHASE DATA FOR TPQ 36 ANALYSIS.

****

SUBROUTINES

FIT FTN
FITWN

PERFORMS SECOND ORDER POLYNOMIAL FITS FOR BEAMWIDTH AND BEAM SHAPE CALCULATIONS.

****

SUBROUTINES

ELEV FTN
EL2
AZIM

COMPUTE ANTENNA SCAN CONSTANTS FOR THE TPQ 36.

****

SUBROUTINES

INV FTN
MULT
TRAMP

HANDLE DOUBLE PRECISION MATRIX MANIPULATIONS.

****

SUBROUTINE

PATRN FTN

HANDLE LINKAGE TO PLTPT FOR PRODUCTION TEST PROGRAMS.

****

SUBROUTINE

SLOBE FTN

COMPUTES BEAMWIDTHS AND LOCATES SIDELOBES.

****

SUBROUTINE

NULL FTN

FINDS EXACT LOCATION OF DIFFERENCE PATTERN NULL.

****

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