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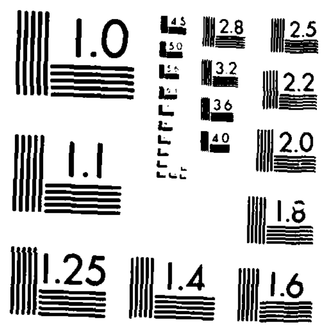

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OSU

The Ohio State University

RADAR TARGET CLASSIFICATION STUDIES - SOFTWARE DEVELOPMENT AND DOCUMENTATION

by

A. Kamis, F. Garber and E. Walton

The Ohio State University

ElectroScience Laboratory

Department of Electrical Engineering
Columbus, Ohio 43212

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A. Kamis, F. Garber and E. Waton

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Ohio State University
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1320 Kinnear Road
Columbus, Ohio 43212

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This report documents the software developed for Technical Report No. 716559-1, generated under Contract No. N00014-84-K-0705. Three computer programs were developed to process and analyze calibrated radar returns. The first program, called DATABASE, was developed to create and manage a random accessed data base. The second program, called FTRAN DB, was developed to process horizontal and vertical polarizations radar returns into different formats (i.e., time domain, circular polarizations and polarization parameters). The third program, called RSSE, was developed to simulate a variety of radar systems and to evaluate their ability to identify radar returns.

Complete computer listings are included in the appendices.

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716559 SOFTWARE DEVELOPMENT OCT 1984 - JULY 1985

INTRODUCTION

The software development for contract #716559 consisted of three tasks. The first task was to develop a data base managment program designed to reduce the effort to retrive calibrated radar data. The second task was to design a program to process horizontal and vertical polarizations radar returns into circular polarization components. The third task was to develop a expandable modularized program to identify a test set of noise corrupted calibrated data strings against a catalog set of "error free" calibrated data strings. The following sections describe key features and show examples of available outputs of the three computer programs.

SECTION 1

1.1 PROGRAM: DATA BASE MANAGER

The Ohio State University Electro-Science Laboratory (OSU ESL) has literally thousands of data files on various radar targets at many different aspect angles, frequencies, and polarizations. Handling such a large data set is very difficult and cumbersome. The DATA BASE program provides the user with a means to combine many files that describe a target feature into one large single file called a DATA BASE. The data base file can provide a quick, efficient, and reliable way of retrieving target data by simply specifing the file name, an aspect angle, and polarization type instead of numerous file names previously required.

Some advantages of the data base file are:

- Shared access with other system users.
- Summary listings of available data.
- Compact data storage.
- Random data string access.
- Expandable.

The DATA BASE program was developed in a modular programming style with a menu driven format. The main program body consists mainly of subroutine call statements that are qued by requesting items from the menu. The complete program consists of thirty-two subroutines. This modular style of programing enables the programmer to locate, modify, compile, or add a new subroutine in an efficient manner.

A data base file is essentially an DEC VAX-11 FORTRAN V3.0 "indexed" file that contains many data strings describing a certain radar target feature. Each data string stored in the data base file is assigned to a single record, which is denoted by a primary key and a set of secondary keys. Depending on the keys specified, the assigned data file will be either stored in a previous allocated record, or in a new data record that expands the data base file size. These keys can be defined in any format by a declaration in the open file command.

They allow the user to access files in a variety of methods. The indexed data base file then allows users to access a particular data record in the file by designating the primary key or a set of data records by specifing a secondary key [1].

For frequency formatted data strings the primary key is defined through the use of a simple algorithm:

PRIMARY KEY = ASPECT ANGLE * 3 + POLARIZATION TYPE (eq. 1.1)

where ASPECT ANGLE is an integer value from 0 to 360 degrees.
POLARIZATION TYPE is an integer value of ethier 1, 2, or 3.

Therefore, allowing the primary key to have a unique value for each frequency formatted data string assigned to a data base record.

When a data base is created, the zero primary key record is allocated for bookkeeping. Its function is to keep a map of the data records, allowing a user to see exactly what data exists in the data base for processing. This record also contains four character strings that allow the user to enter a title and additional comments pertaining to the data to be assigned to the data base file.

For future development of the DATA BASE program, additional unused variables were also allocated in each data record

Currently, only frequency formatted data strings can be entered into a data base file. A frequency formatted data string is one where the data is versus frequency and is uniquely described by a target name, polarization type, and an aspect angle. In later versions of the DATA BASE program, the capability to handle angle and time formatted file will be included.

The frequency formatted data strings encountered at OSU ESL facility contain three polarization types and usally aspect angle intervals of no less then five degrees. The three polarization types are: transmit vertical receive vertical (VV), transmit horizontal receive horizontal (HH), and transmit vertical and receive horizontal (VH). The polarizations VV, and HH are called co-polarized components and VH is called a cross-polarized component.

The data base file has been limited to the three polarization types described above and aspects angles from zero to three hundred sixty degrees by one degree increments. Thus allowing the data base to expand to one thousand eighty three data records.

A physical visualization a data base file might be a large box with keyed storage bins. For a frequency formatted file, the data base may be set up as shown in Figure 1.1-1. This figure represents a data base file that would describe a single target at azimuth angles from zero to three hundred sixty degress by one degree increments for the three polarization types HH, HV, and VH, at one elevation angle.

****

EACH KEY SPECIFIES A RECORD IN THE DATA DASE DEFINED BY
A ASPECT ANGLE AND A POLARIZATION TYPE.

```
                          360  /          .           .          key  1083
               7              /
              /          .   /        .          .             .
             /              /
                        .  /        .          .            .
  AZIMUTH ANGLES           /
                      3  /     key 10         .            .
                        /
                    2  /     key 7        key 8        key 9
                      /
                  1  /     key 4        key 5        key 6
                    /
                 0 /   / key 1 /|    key 2        key 3
                  /   |-------| |
               -------- HH -------- HV --------- VV ------
            1  |      |       | |
DATA POINTS    |      |       | |      POLARIZATION TYPE ->
            2  |      |       | |
     |         |      |       | |
     V      .  |      |       | |<- 1 record
               |      |       | |
            .  |      |       | |
               |      |       | |
            .  |      |       | |
               |      |       | |
            .  |      |       | |
               |      |       | |
            N  |      |_______|/
```

Figure 1.1-1 Frequency formatted data base

****

1.2 MENU LISTING

The menu, driven by a loop routine in the main program body, consists of nine commands. These commands called top level commands are displayed in the following manner:

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

 MENU FEATURES

      TOP LEVEL COMMANDS :

         ASSIGN a data file to the data base.
         CREATE a new data base.
         DELETE files from the data base.
         EXAMINE the contents of a file.
         EXIT from program.
         HELP messages.
         MAP the data base.
         MODIFY a file in the data base.
         PHASE adjust an assignment.
         $ " any VAX/VMS DCL command ".

      Type YES or NO for all " ? "   default value -> YES
      All commands may be abbreviated to three characters
      Press CTRL C to abort any command

  ENTER COMMAND ->

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

1.2.1 MENU SUMMARY

A brief introduction to the top level commands are as follows:

ASSIGN : Assigns a data file to a record in the data base according to a indexed file record KEY. The assignment can either add a new data record or replace/append an existing data record.

CREATE : Opens a data base as an indexed file on a user specifed or default disk drive.

DELETE : Deletes a record from the data base based on the KEY the user specifies.

EXAMINE : Lets the user examine individual ESL data files, DBM header files, or DATA BASE records.

EXIT : Exits the program and returns the user to VAX/VMS operation.

HELP : Helps the user develope proper execution procedures and corrective measures for program error messages.

MAP : Shows the user the current status of records in the data base. That is whether the record is full, partially full, or empty of data points. Additional information on how a data record was assigned is also available in the map routine.

MODIFY : Allows the user to open an old data base for new assignments.

PHASE : Allows the user to introduce a phase slope offset over a selected range of data points. The phase slope offset is specified in degrees.

$ " DCL COMMAND " : Allows the user to enter a VAX/VMS DCL command for execution while the program is running.

The short description of the top level commands listed previously provided a brief introduction into the capabilities of the DATA BASE program. We will now discuss, in detail, the workings of the DATA BASE commands.

1.2.1.1 ASSIGN

The ASSIGN command operates on ESL range acquired data files only, see ESL report #714190-1. Currently, the files assigned to the data base have only been calibrated target data files but this is not a requirement, uncalibrated ESL files could also be assigned to a data base file as long as the phase reference is centered at the radar target location. Some temporary constraints have been placed on the ESL file type used in assign operation.

These constraints are as follows:

The input ESL file must be a frequency formatted file (ie. the data points must be taken verses frequency).
The frequency formatted file must be taken in increment of less then fifty megahertz.

These constraints will be modified in later versions of DATA BASE program when the need arises.

In assigning an ESL file to a data base, the file is first read into a temporary data buffer. After the user views the file header to ensure the assignment of the correct file, the aspect angle and polarization type is entered. Next, the data string buffer is processed through an interpolation routine that reformats the frequency increment a fifty megahertz step. The fifty megahertz step allows data from targets of approximately twenty feet or less to be processed without any loss of information. A Hamming window with a frequency bandwidth of one-hundred megahertzs centered about the desired fifty megahertz point is used in the interpolation routine [2]. The reformatting saves memory space and standardizes the data strings which have been taken at various frequency increments. After the reformatting, the data string is then stored in a newly created data base record which is referenced to a set of keys. The keys, defined by the aspect angle and polarization type entered, consists of a primary key, defined in equation 1.1, and two secondary keys which are defined as the aspect angle and polarization type. The two secondary keys are not currently used by the data base program, but they do add extra flexibility in other programs that read data from a data base. The unique primary key that defines each data base record is use for all further DATA BASE program input/output operations. After the data record is created, additional assignments to that record will invoke the append/replace routine.

The append/replace routine allows the user to add additional data or replace all or part of the data string contained in the data record. The append/replace routine was created to handle the ESL frequency formatted file types that were band limited by feed horns and software constraints. The append/replace routine can only process the following situation:

The additional data strings must be overlapping or separated by no more than fifty megahertz.

When an overlap of one hundred megahertz or more exists, the merging of data strings takes place at the closet fifty megahertz increment step value within the overlap. When no overlap exist or the overlap is less then one hundred megahertz, a linear interpolation is executed to project the new data string to the respective end point (MERGE POINT) of the DATA BASE record's data string. The merge point is always at a frequency step value of fifty megahertz and the linear interpolation is executed over a one-hundred megahertz bandwidth starting at the merge point value. Once the merge point is established and the linear interpolation is executed, a process of amplitude and phase data adjustment is carried out [3].

Adjusting phase slope, which is equivalent to a postional adjustment in the time domain, a phase offset is calculated at the merge point of the two data strings and is applied to the entire append/replace data string as a phase slope correction by the algorithm shown in equation 1.2.1.1-1.

CORRECTED_PHASE = OLD_PHASE - PHASE OFFSET * (FREQUENCY / MERGE_POINT)

Equation 1.2.1.1-1

The phase correction adjusts the new data string to the same phase reference as the DATA BASE record's data string. The phase offset is chosing by calculating the smallest difference of phase between the two data strings within in a plus or minus one-half cycle of phase (ie. 180 to -180 degrees). This limited range for the phase offset, due to the two pi modulo phase ambiguity, places a constraint on the calibrated targets physical locations. The physical locations of the two calibrated targets must lie within the limits of plus or minus (3E08 / (2 * MERGE_FREQUENCY * 180) meters of each other to achieve the proper phase slope adjustment. If the distance between the calibrated target locations lies outside required limit, an additional phase offset of some multiple of three-hundred-sixty degrees must be added to the append/replace data string through the use of the PHASE command.

Merging the amplitude parts of the data strings is a much easier task. The amplitude part of a calibrated data string is the RCS of the target, which is independent of positional displacements along the line of sight (LOS) for far-field conditions. Therefore the amplitude part of the data strings should match perfectly when an append/replace operation is executed. But slight inaccuracies, due to mis-alignments (not LOS displacements) in repositioning the target between data runs, and the data base's reformatting interpolation routine, cause slight discontinuities between the amplitude data strings to occur. The magnitude of these discontinuities are usally no more than one decibel. To deal with this slight discontinuity, a minimum-squared-error linear interpolation is used to project the append/replace data string to the merge point of the data base record's data string. The final value at the merge point is then calculated by taking the average of projected interpolated value and the data base's merge point value. Also, an additional smoothing around the discontinuity is provided by weighting six additional points around the merge point. These points represent a three-hundred megahertz bandwidth, and are weighted by the following algorithms;

AMP(M + I) = AMP(M + I) + (AMP(M) - AMP(M + I)) * I * .12
& AMP(M - I) = AMP(M - I) + (AMP(M) - AMP(M - I)) * I * .12
for I = 1, 2, 3, and where M is the merge point's array index value.

Figures 1.2.1.1-1 and 1.2.1.1-2 illustrate the merging process of four ESL data files at two, four, and six gigahertz for both phase and amplitude data.

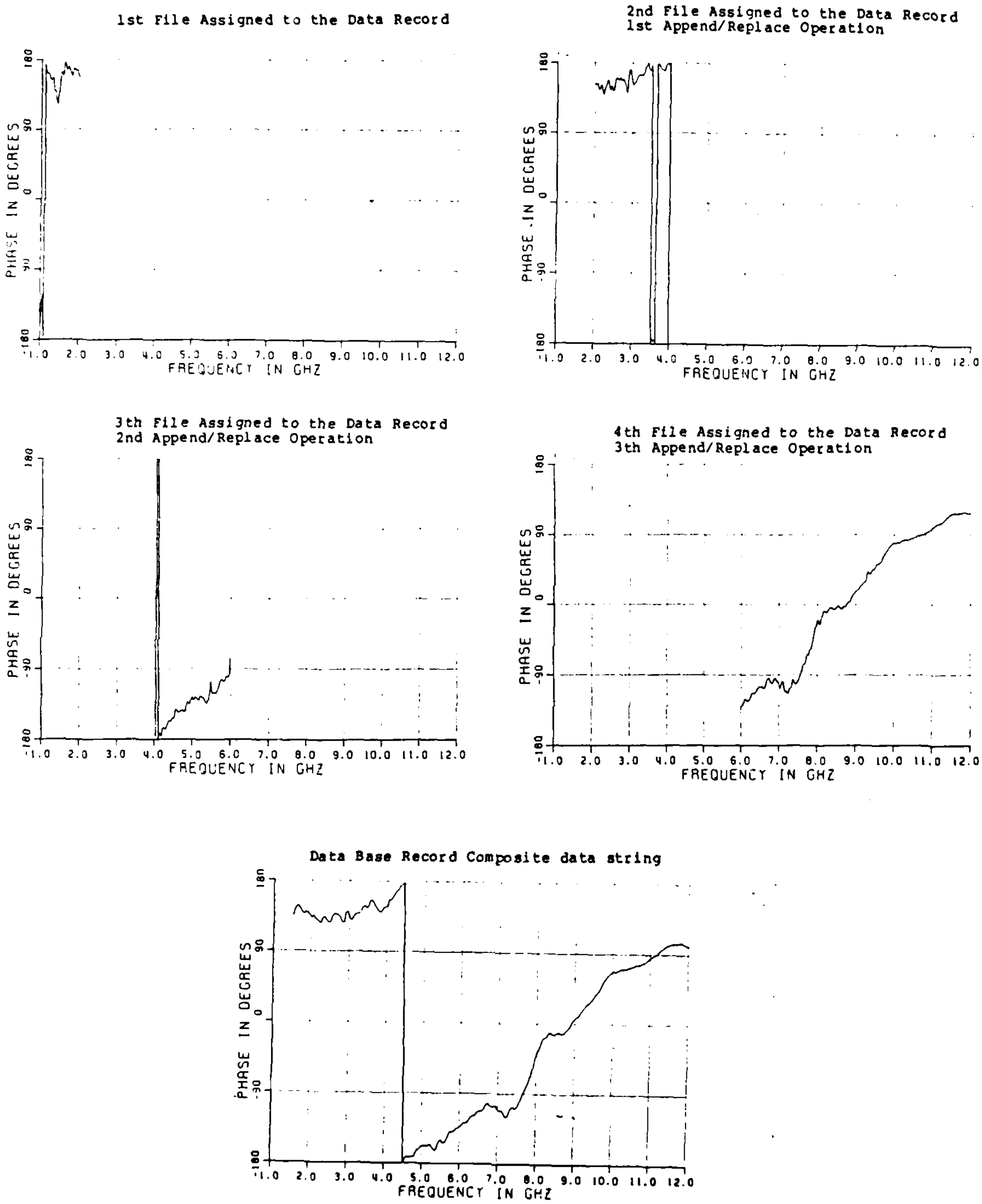


Figure 1.2.1.1-1 Merging of Phase data strings

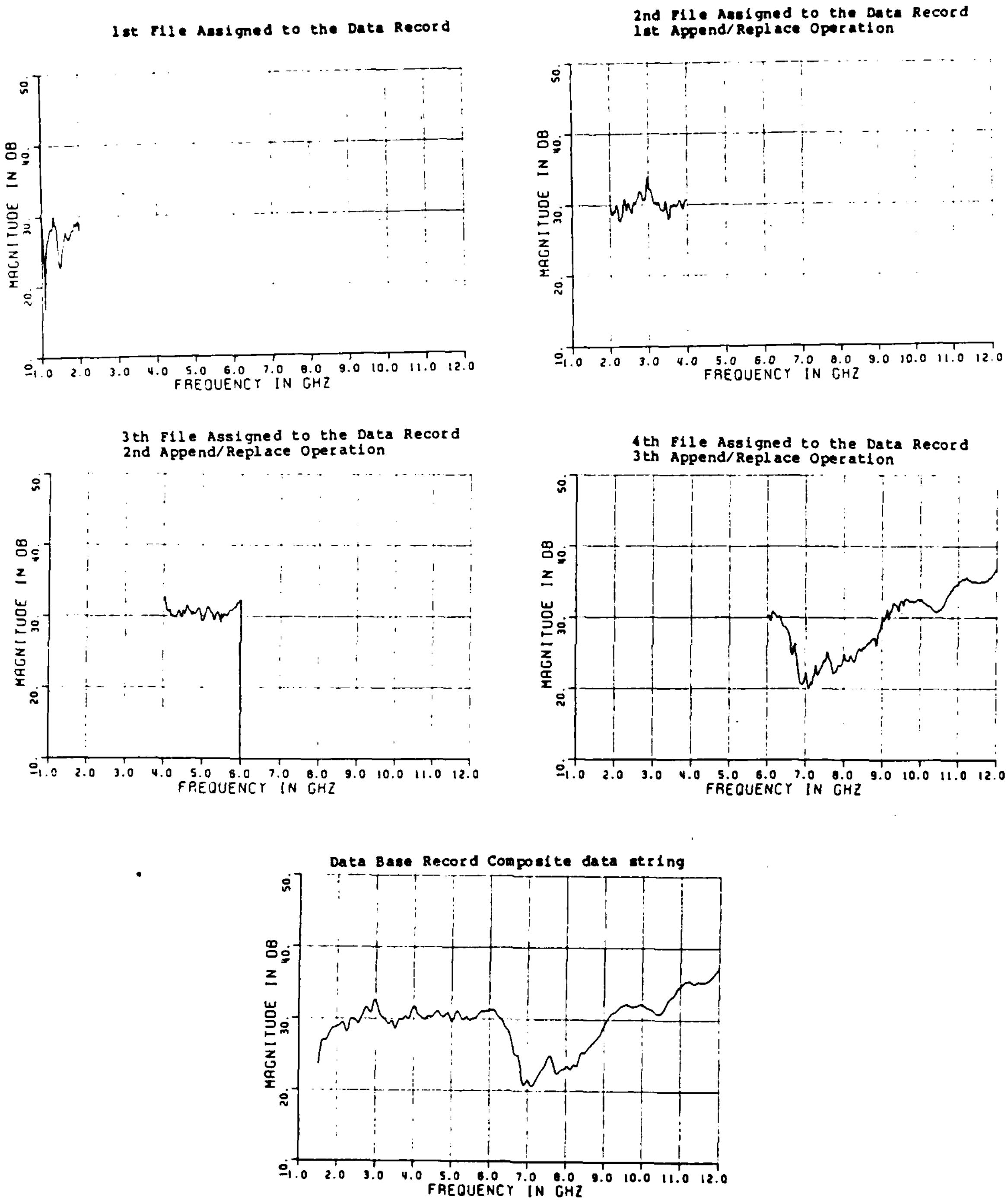


Figure 1.2.1.1-2 Merging of Amplitude data strings

Currently the total composite of any assignments to the a data base record is limited to a lower frequency cutoff of one gigahertz and a upper frequency cutoff of eighteen gigahertz. If a assigned data string goes beyond this range a truncation will occur. Additionally, no more than five assignments can be made to a DATA BASE record (ie. only four append/replace operations to a DATA BASE record are allowed).

On completion of the ASSIGN command operations the data stored in the data base record consists of the reformatted amplitude and phase data, the phase adjustment value, the first header line of the assigned file, and the start and stop frequencies of the assigned data string. The data base record, reference by the primary key, stores the phase and amplitude data as a string of unformatted two byte integers to achieve a more compact file organization. To use the integer format, the floating point amplitude and phase data is multiplied by one-hundred and converted to an integer. The range for a two byte (sixteen bits) integer is approximately plus to minus-thirty-two-thousand-seven-hundred, using one bit as a sign bit. With this format, the floating point data must be in the range of plus to minus three-hundred-twenty-seven with a resolution of one one-thousandth. For ESL data, the phase can be in either a zero to three-hundred-sixty degree format or a plus to minus one-hundred-eighty degree format. If the the phase data is in the zero to three-hundred-sixty degree format, it is automatically converted to the plus to minus one-hundred-eight format when read into the data base program. The amplitude data is calibrated to decibel-square-centi-meter and is usally never greater then one-hundred decibels in un-scaled form. So, with a multiplication factor of one-hundred, both the amplitude and phase data arrays can fit into the two byte integer format without any loss of information. The two data arrays that store the data string are called INT_AMP and INT_PHASE.

Four other arrays, called ST_BASE, STP_BASE, PHA_OFF, and HEAD, are stored in the DATA BASE data record with five elements each. The five elements correspond to the five data record assignments that are allowed. The arrays contain information on the start and stop frequencies of each assigned data string, the phase adjustment values calculated to merge the data strings, and the firs eader line of each of the assigned data files. Two integer variables called STATUS and TIME, also stored in the data record, indicate whether the file is full or partially full, and how many assign operations have been executed on the data record, respectively. Unused variables are allocated in each record for future program modifications.

The main routines called when a ASSIGN command is executed are the ASSIGN, ASPPOL, READFILE, OPEN, STOREF, and APPEND subroutines. The FORTRAN write statement for the allocation of the data base data records are shown in Figure 1.2.1.1-3.

Figure 1.2.1.1-4 represents a typical display the user will receive after the completion of an assignment to the data base.

****

```
      CHARACTER      HEAD( 5 ) * 60, CDUMMY * 5
      REAL * 4       RDUMMY, ST_BASE( 5 ), STP_BASE( 5 ), PHA_OFF( 5 )
      INTEGER * 2    INT_AMP( 350 ), INT_PHASE( 350 )
      INTEGER * 4    PRIMARY_KEY, KEY_TWO, KEY_THREE, IDUMMY, STATUS, TIMES
C
C                write statement for data records
C
      WRITE( UNIT = DB_UNIT, ERR = 995 )
     $       PRIMARY_KEY, KEY_TWO, KEY_THREE,    ! keys
     $       CDUMMY, CDUMMY, RDUMMY, RDUMMY,     ! unused variables
     $       IDUMMY, IDUMMY, STATUS, TIMES,      ! unused & status variables
     $       ( ST_BASE( I ), I = 1, 5 ),         ! start freq for 5 assignments
     $       ( STP_BASE( I ), I = 1, 5 ),        ! stop freq for 5 assignments
     $       ( PHA_OFF( I ), I = 1, 5 ),         ! phase adjustment values
     $       ( HEAD( I ), I = 1 , 5 ),           ! headers from original files
     $       ( INT_AMP( I ), I = 1, 341 ),       ! reformatted amplitude data
     $       ( INT_PHASE( I ), I = 1, 341 )      ! reformatted phase data
C
C
```

Figure 1.2.1.1-3   FORTRAN data record write statement

****

```
ASPECT ANGLE =  45
POLARIZATION =  VV

ASSIGNMENT IS A PARTIAL RECORD
  CONSISTING OF :

FIRST INPUT OPERATION -
     JL09C0 1:27 45 ASP LARGE 747
     WITH FREQUENCIES : 6.00 to 12.00 GHz
     AND WITH A PHASE CORRECTION OF    0.00 DEGREES
FIRST APPEND/REPLACE OPERATION -
     JL09H5 2:49 45 ASP LARGE 747
     WITH FREQUENCIES : 4.00 to  6.00 GHz
     AND WITH A PHASE CORRECTION OF  157.09 DEGREES
SECOND APPEND/REPLACE OPERATION -
     JL09F8 1:15 45 ASP LARGE 747
     WITH FREQUENCIES : 2.00 to  4.00 GHz
     AND WITH A PHASE CORRECTION OF   98.80 DEGREES
THIRD APPEND/REPLACE OPERATION -
     JL09E1 11:35 45 ASP LARGE 747
     WITH FREQUENCIES : 1.00 to  2.00 GHz
     AND WITH A PHASE CORRECTION OF   55.60 DEGREES
```

Figure 1.2.1.1-4   Display after fourth assignment to record # 135

****

1.2.1.2 CREATE

The CREATE command intially opens and creates a new data base as an "indexed" FORTRAN file [1]. The file can expand to an approximate length of three mega bytes.

When the file is first created the first record is allocated for a bookkeeping function. The first record contains three key variables, one file type varaible, five unused variables, four character strings of sixty bytes each, and an integer array of one-thousand-eighty-six elements. The first key variable, required to be unique by indexed organization of the data base file, is set to zero and designated as the "primary key" in the open statment. The second and third keys, which are not required to be unique, are also set to zero. The file type variable called KIND is either set to "FRE", "ANG", or "TIM", depending on the first file type assigned to the newly created data base. Currently the DATA BASE program can handle only frequency formatted ESL data files on the ASSIGN command, thus the KIND variable is presently set to "FRE" to designate a frequency formatted data base file. Future developement of the data base program will enable time and angle formmated ESL file types to be stored in a data base file format. The five unused variables, which are also allocated for future growth, consists of two character string variables of five bytes each, two four byte real variable, and one four byte integer variable. The four sixty byte character strings contain the title and additional comments pertaining to the data base. The actual bookkeeping function of the first record is done by the one-thousand-eighty-six element integer array called REC_STATUS. The REC_STATUS array, which is an array of two byte integers, creates a map of the status of the records in the data base. Each element of the REC_STATUS array represents a record in the data base which in turn represents a particular aspect angle at one of the three polarization types. The array stores a value of either one, two, or three to indicate the status of a data record. A value of one in an array element position is defined as a null data record; a value of two is defined as a partially filled data record; a value of three indicates the the data record is full. For example, a value of three in the REC_STATUS array element number two for a frequency formmated data base informs the user when a MAP command is executed that the aspect angle of zero degrees and cross-polarization "VH" data record is completely full of data (ie. the record contains amplitude and phase data from one to eighteen gigahertz by fifty megahertz steps). Whenever an ASSIGN or a DELETE command is executed the REC_STATUS array is updated accordingly and rewritten into the first record.

The main routines called when a CREATE command is executed are the CREATE and OPEN subroutines. The FORTRAN open file statement and the FORTRAN write statements for the allocation of the first record for a data base file are shown in Figure 1.2.1.2-1. An explantion of the qualifiers inside the open statement can be found in the VAX FORTRAN software manual [1].

```
      CHARACTER       TITLE * 60, COMMENT * 60, KIND * 3, CDUMMY * 5
      REAL * 4        RDUMMY
      INTEGER * 2     REC_STATUS ( 1086 )
      INTEGER * 4     PRIMARY_KEY, KEY_TWO, KEY_THREE, IDUMMY
C
C               open statement for a data base
C
      OPEN( UNIT = DB_UNIT, NAME = DATA_BASE, ACCESS = 'KEYED',
     $     KEY = ( 1:4:INTEGER, 5:8:INTEGER, 9:12:INTEGER ),
     $     TYPE = 'NEW', FORM ='UNFORMATTED',
     $     RECORDTYPE = 'VARIABLE', RECORDSIZE = 2500, SHARED,
     $     ORGANIZATION = 'INDEXED', ERR = 999 )
C
C               write statement for first "bookkeeping" record
C
      WRITE( UNIT = DB_UNIT, ERR = 995 )
     $      PRIMARY_KEY, KEY_TWO, KEY_THREE, KIND,    ! keys
     $      CDUMMY, CDUMMY, RDUMMY, RDUMMY, IDUMMY,   ! unused variables
     $      TITLE, ( COMMENT( I ), I = 1, 3 ),        ! DB title & comments
     $      ( REC_STATUS ( I ), I = 1, 1086 )         ! DB bookkeeping array
C
C
      CLOSE( UNIT = DB_UNIT, ERR = 988 )
```

Figure 1.2.1.2-1 FORTRAN output statements

1.2.1.3 DELETE

The DELETE command enables the user to delete any data record from the data base by entering the primary key value. For a frequency formatted, file the user is prompted for the aspect angle and the polarization type so the primary key can be calculated. After the data record is deleted from the data base, th bookkeeping array element of the first record, REC_STATUS(PRIMARY_KEY), is reset to one and a response is displayed to the user verifying the operation. The main routine called when a DELETE command is executed is the delete subroutine.

1.2.1.4 EXAMINE

The EXAMINE command allows the user to display three types of data files. The three files types are; ESL data files (ESL report #714190-1), DBM header files, and the DATA BASE files described in this section. After the EXAMINE command is executed, the following sub menu will appear.

```
EXAMINE MODE
ENTER ONE OF THE FOLLOWING FILE TYPES:

  DBM header file
  ESL single data file
  DATA BASE file

ENTER FILE TYPE ->
```

After selecting one of the three sub commands, either the EX_DBM, EX_ESL, or EX_BASE, subroutine will be executed.

1.2.1.4.1 EX_BASE

The EX_BASE subroutine displays information contained in a data record of the data base requested. The data base currently under assignment is the default data base if no data base name is entered. If the data base is frequency formatted type, the user is prompted for the aspect angle and the polarization type so the primary key can be formulated. Once the primary key is calculated, the corresponding data record is displayed. The display contains information on how the data record was constructed and the values of the data strings contained in the record. The data values for a frequency formatted data base are displayed in amplitude and phase versus frequency in gigahertzs, where the amplitude values are displayed in decibels and the phase in degrees. The user can also request a selected range of data point or default to the entire data string. An example of a display from the EX_BASE subroutine is shown in Figure 1.2.1.4-1.

****

ASPECT ANGLE = 45
POLARIZATION = VV

ASSIGNMENT IS A PARTIAL RECORD
CONSISTING OF :

FIRST INPUT OPERATION -
JL09C0 1:27 45 ASP LARGE 747
WITH FREQUENCIES : 6.00 to 12.00 GHz
AND WITH A PHASE CORRECTION OF 0.00 DEGREES
FIRST APPEND/REPLACE OPERATION -
JL09H5 2:49 45 ASP LARGE 747
WITH FREQUENCIES : 4.00 to 6.00 GHz
AND WITH A PHASE CORRECTION OF 157.09 DEGREES
SECOND APPEND/REPLACE OPERATION -
JL09F8 1:15 45 ASP LARGE 747
WITH FREQUENCIES : 2.00 to 4.00 GHz
AND WITH A PHASE CORRECTION OF 98.80 DEGREES
THIRD APPEND/REPLACE OPERATION -
JL09E1 11:35 45 ASP LARGE 747
WITH FREQUENCIES : 1.00 to 2.00 GHz
AND WITH A PHASE CORRECTION OF 55.60 DEGREES

SELECTED FREQUENCY RANGE 11300 MHz to 12222 MHz

FREQUENCY (GHZ)	AMPLITUDE (DB)	PHASE (DEG)
11.300	4.140	-80.440
11.350	1.760	-60.050
11.400	2.640	-32.620
11.450	4.270	-21.550
11.500	5.380	-13.980
11.550	6.780	-4.810
11.600	8.320	-2.220
11.650	8.790	-6.010
11.700	8.690	-8.850
11.750	8.900	-11.680
11.800	9.050	-16.740
11.850	8.760	-23.850
11.900	7.530	-29.250
11.950	6.810	-33.560
12.000	6.970	-37.290
12.050	0.000	0.000
12.100	0.000	0.000
12.150	0.000	0.000
12.200	0.000	0.000

Figure 1.2.1.4-1 EX_BASE output

****

1.2.1.4.2 EX_ESL

The EX_ESL subroutine allows the user to display the header and data information contained in an ESL file type. The user is first prompted for a ESL file name. The data file can either be formatted as a frequency, angle, or time, file type. Once the header is displayed the user can select a part of the data string, or default to the entire data string for display. For frequency formatted files the values of data are displayed in amplitude (decibels) and phase (degrees) versus frequency in gigahertz. For angle formatted files the data values are also displayed in amplitude (decibels) and phase (degrees) but the value is versus aspect angle in degrees rather then frequency. For a time file the data values are displayed as the magnitude of an impulse versus time in nanoseconds. An example of a display from the EX_ESL subroutine is shown in Figure 1.2.1.4.2-1.

****

A40481 50 DEG AZ - 727 1.-12.-10 L727-1
A=A/B=40 B=35 BW=4 AV=1 RES=ON SRCH=20 HP FEED=O/U
NL1100 FF= 1000.IN= 10. \ RMM/PB 17-FEB-84

SELECTED FREQUENCY RANGE 1000 MHz to 12200 MHz

FREQUENCY (GHZ)	AMPLITUDE (DB)	PHASE (DEG)
1.0000	1.8600	172.3000
1.0100	-4.1600	142.9000
1.0200	-7.0600	140.5000
1.0300	0.4700	97.9000
1.0400	4.4400	42.5000
1.0500	1.8500	-3.1000
1.0600	-1.6300	-9.9000
1.0700	4.3000	-27.5000
1.0800	6.5900	-82.3000
1.0900	4.8500	-140.0000
1.1000	-3.7700	-175.7000
1.1100	3.6300	-136.8000
1.1200	7.6200	151.2000
1.1300	6.4700	81.2000
1.1400	-3.3700	29.1000
1.1500	1.2100	100.9000
1.1600	6.9800	28.0000
1.1700	6.6600	-42.9000
1.1800	-1.6000	-115.1000
1.1900	-1.5000	-19.4000
1.2000	6.1800	-97.8000
1.2100	5.8300	-166.9000
1.2200	-0.2600	119.7000

Figure 1.2.1.4.2-1 EX_ESL output

****

1.2.1.4.3 EX_DBM

The EX_DBM subroutine allows the user to display information contained in a data base manager (DBM) header file.

The DBM header file is a file that is created when the data taken on the ESL RANGE, is transferred to the DEC VAX11/780 main ESL processing computer. The DBM header file only stores the header from all the data files requested for transfer. The information stored is contained in the first one-hundred-eighty bytes of the ESL data files and contains documentation on the type of file (ie. frequency, angle, of time) on the first line (or first sixty bytes), receiver settings or calibration file names on the second line, and number of points, starting point, increment and intials of the person who took the data on the third line. A search routine imbedded in the EX_DBM subroutine allows the user to search the DBM header file for particular character strings. The search routine allows up to five search strings to be entered and each search string can contain up to sixty characters. An example of a DBM header file display with a three string search is listed in Figure 1.2.1.4.3-1.

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

     SEARCH STRING # 1 :   STRIP
     SEARCH STRING # 2 :   90 DEG
     SEARCH STRING # 3 :   45 DEG

  STRINGS FOUND IN 727:727.DBM       TYPE --> FREQUENCY

A4073B  90 DEG.  STRIP @ 45 DEG.  1.-12.-10 XP
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4
NL1100 FF= 1000.IN=    10. \JDB/ RMM 13-MAR-84

  STRINGS FOUND IN 727:727.DBM       TYPE --> FREQUENCY

A4073N  90 DEG  2X15 CM STRIP @ 45 DEG  1.-12.-10 XP
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4
NL1100 FF= 1000.IN=    10. \JDB/ RMM 13-MAR-84

  STRINGS FOUND IN 727:727.DBM       TYPE --> FREQUENCY

B4073C  90 DEG.  STRIP @ 45 DEG.  1.-12.-10 XP
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4
NL1100 FF= 1000.IN=    10. \JDB/ RMM 13-MAR-84

  STRINGS FOUND IN 727:727.DBM       TYPE --> FREQUENCY

B4073L  90 DEG.  STRIP @ 45 DEG.  1.-12.-10 XP
A=A/B=40 B=30 BW=4 AV=1 FREQ. RESET=ON SRCH=15 DISK=DC10-4
NL1100 FF= 1000.IN=    10. \JDB/ RMM 13-MAR-84
```

Figure 1.2.1.4.3-1 EX_DBM output

****

The main routines called when a EXAMINE command is executed is the EXAMINE subroutine and either the EX_BASE, EX_ESL, or EX_DBM subroutines. All EX subroutines provide the user with an option to acquire a hard copy of the displayed information.

1.2.1.5 HELP

The HELP command provides the user with information pertaining to the top level commands, error messages, and additional software that uses the data base format. The HELP command is supported by the DEC VAX/VMS V4.0 system software and allows the help routine to be set up in a multi level structure (ie. the help topics branch down to subtopics) [4], [5]. Figure 1.2.1.5-1 shows the major help topics currently available to the user, and an example of a help message display.

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

  Information available:

ASSIGN    AUTHOR    CREATE    DELETE     ERRORS     EXAMINE    MAP
MENU      MODIFY    PHASE     PROGRAMS   START_UP   USER_SUBS


Topic?  ASSIGN

 Assigns a data file to a record in the data base according to a indexed
  file's record KEY. The assignment KEY is based on two specified
  parameters such as the aspect angle and the polarization type for a
  frequency formatted data base.

            KEY = ASPECT ANGLE * 3 + POLARIZATION TYPE


  Additional information available:

APPEND/REPLACE     EXAMPLE

Sub Topic?
```

Figure 1.2.1.5-1 HELP routine displays

****

1.2.1.6 MAP

The MAP commands allows the user to list the current status of records in a data base file. The mapping shows the user whether the data records in the data base are full, partially full, or empty of data points. Also, information on record assignments, as shown in Figure 1.2.1.1-4, is available. For a frequency formatted data base, the mapping lists only aspect angles that have records allocated (ie. contains data in at least one of the polarization types). A record is defined as full when the data string starts at one gigahertz and ends at eighteen gigahertz.

The Figure 1.2.1.6-1 shows the output of the map routine for an example data base illustrated in Figure 1.2.1.6-2. The example data base only contains data in six records, three are completely full and the other three are partially full. The mapping also reveals that data only exists at four aspect angles and two polarization types. Later versions of the DATA BASE program will incorporate the start and stop values of the data string instead of the words PART and FULL as shown in Figure 1.2.1.6-3.

****

```
EXAMPLE :  OUTPUT OF MAP ROUTINE  ( FREQUENCY FORMATTED DATA BASE )


                    360  /     NULL          NULL          PART
          7             /
         /            . /    NULL          NULL          NULL
        /            . /
                    . /    NULL          NULL          NULL
  ASPECT ANGLES      /
                  3 /    FULL          NULL          NULL
                   /
                2 /    FULL          NULL          PART
                 /
              1 /    NULL          NULL          NULL
               /
            0 /    PART          NULL          FULL
             /
            ------- HH -------- HV --------- VV ------
         1 |
           |          POLARIZATION TYPE --->
         2 |
           |
         3 |       DATA POINTS
           |
         . |             |
           |             |
       341 |
```

Figure 1.2.1.6.3-1   Example DATA BASE

****

****

MAP OUTPUT FOR DATA BASE AS SHOWN ABOVE

DATA BASE NAME

TITLE: ***********
COMMENTS: **********

ASPECT ANGLE (Deg)	POLARIZATION TYPE HH	HV	VV
0	PART	NULL	FULL
2	FULL	NULL	PART
3	FULL	NULL	NULL
360	NULL	NULL	PART

ADDITIONAL INFORMATION ?

Figure 1.2.1.6.3-2 MAP output of example DATA BASE

****

****

ASPECT ANGLE (Deg)	POLARIZATION TYPE HH	HV	VV
0	1-6	NULL	1-18
2	1-18	NULL	1-12
3	1-18	NULL	NULL
360	NULL	NULL	12-18

Figure 1.2.1.6.3-3 Version II MAP output

****

1.2.1.7 MODIFY

The MODIFY command allows the user to open an existing data base for further assignments, deletions, or phase adjustments of data records. The MODIFY command can also changes the default data base to the data base under modification.

1.2.1.8 PHASE

For a frequency formatted data base, the phase offset, in degrees, is referenced to the starting point of the selected string and causes a postional displacement in the data string according to the algorithm ;

POSTIONAL_DISPLACMENT = (PHASE_OFFSET * 300) / (2 * 360 * FREQ) meters

where FREQ is in MHz and PHASE_OFFSET is in degrees.

The PHASE command allows the user to make fine adjustment to an append/replace string if the ASSIGN command's auto phase adjustment (see Section 1.2.1.1) is in error. This error condition occurs when the LOS positional displacement of the target is greater than one cycle of phase at the merging frequency of the two data strings. The PHASE command is also useful to align the three polarization components HH, HV, and VV at a given aspect angle to a common positional reference. Whenever the PHASE command is executed, the stored phase offset array " PHA_OFF " (see Figure 1.2.1.1-3) is updated.

1.2.1.9 $ DCL COMMAND

The $ DCL command allows the user to execute VAX/VMS command language statements without terminating the program session. DCL commands, such as DIRECTORY, and SEARCH are very complementary to the data base program [4].

1.3 RELATED SOFTWARE

As part of this contract effort, two new programs nave been written to utillize the data base file structure. These two programs are FTRAN_DB, and RSSE. The FTRAN_DB program utillizes the data base for data analysis and the RSSE program uses the data base for target identification analysis. These two programs, also documented in this report, provide powerful analytical tools that take advantage of the ease and efficiency of the data base file format.

A subroutine called DB_READ has been written to furnish the user with a routine to read a data record from a frequency formatted data base. The subroutine statement, as shown in Figure 1.3-1, has fourteen passed parameters, the first four are inputs, the next two are either inputs or outputs, and the last eight are outputs. Detailed documentation on the subroutine pass parameters can be found in Appendix I.

****

```
      SUBROUTINE READ_DB( DATA_BASE, DB_UNIT, INP, OUT,
     $               INT_ASP, POL_TYPE,
     $          AMP, PHASE, STATUS, STF, STPF, TITLE, COMMENT, ERR )
```

Figure 1.3-1 READ_DB subroutine

****

1.4 DATA BASE SUMMARY

DATA FILE INPUTS TYPES:
ESL DATA FILE TYPES REPORT # 714190-1

DATA BASE OUTPUT: INDIVIDUAL DATA FILES ARE ASSIGNED TO INDIVIDUAL RECORDS IN THE DATA BASE ACCORDING TO A SPECIFIED KEY.

DATA STORAGE :
2500 BYTES PER RECORD
682 DATA POINTS PER RECORD
2 BYTES PER DATA POINT
1084 RECORDS

DATA RANGE AND RESOLUTION :
DATA POINT MAX - MIN VALUES : +- 327
DATA POINT RESOLUTION : 0.01

FREQUENCY FORMATTED DATA BASE :
OUTPUT DATA BASE RECORD - 1 to 18 GHz by 50 MHz
341 AMPLITUDE POINTS
341 PHASE POINTS

ANGLE FORMATTED DATA BASE :
OUTPUT DATA BASE RECORD - 0 to 360 degrees by "TBD"
"TBD" AMPLITUDE POINTS
"TBD" PHASE POINTS

DATA RECORD OPERATIONS :
FOUR APPEND/REPLACE

1.5 NESTING OF MAJOR SUBROUTINES

```
                                  DATABASE

ASSIGN        CREATE     DELETE     EXAMINE       MAP         MODIFY      PHADJ
  ASPPOL        GETNAME    ASPPOL     EX_BASE       GETNAME     GETNAME     OPEN
  READFILE      OPEN       OPEN         ASPPOL      OPEN                    ASPPOL
  OPEN                                  OPEN        ASPPOL                  CORRECT
  STOREF                                SECLIST     READ_DB
    INTHAM                              EX_DBM
    OPEN                                GETRECORD
  APPEND                              EX_ESL
    CORRECT                             READFILE
    INTHAM                              SECLIST
    OPEN
```

SECTION 2

2.1 PROGRAM: FTRAN_DB

The FTRAN_DB program is a modification of existing ESL "FTRAN" software. The FTRAN_DB modifications allow the program user to access a data base formatted file (see Section 1) and to create circular polarization components from the linear polarizations HH, VV, VH.

2.2 BASIC FTRAN COMMANDS

The FTRAN program was originally written to implement calibration, Fourier transforms, filtering, time gating, and plotting for frequency or time formatted ESL data files. A listing of the original FTRAN commands are shown in Figure 2.2-1.

****

ORIGINAL FTRAN COMMANDS

```
REA : READ AN UNFORMATTED FILE
RED : READ A FORXXX.DAT FILE
WRI : CREATE A NEW FILE WITH CURRENT DATA
LAB : WRITE IN OR CHECK CURRENT LABEL
PRI : TYPE OUT CURRENT DATA IN DB
FAS : ADD/SUBTRACT TWO FREQUENCY FILES
PHD : REMOVE POSITIONAL ERROR VIA PHASE ADJUST
SMO : SMOOTH DATA POINTS VIA A HAMMING WINDOW
MDF : MANUALLY MODIFY FILE DATA POINTS
MOV : ASSIGN CONTENTS OF MAIN ARRAY TO A BUFFER
CAL : TARGET CAL. WITH BACKGRD/SPHERE DATA
CRF : CREATE A FREQUENCY FILE TO BE TRANS
SCD : SCALE LOW FREQUENCY DATA
RAY : ADD RAYLEIGH PORTION TO THE SPECTRUM
WIN : WINDOW THE FREQUENCY DOMAIN DATA
GAT : GATES A DESIRED PORTION OF A TIME DOMAIN SIG
TAS : ADD/SUBTRACT TWO TIME FILES
CON : MDF PLOT LABELS AND SCALE FACTORS
FFT : FREQ. TO TIME DOMAIN TRANS
IFT : TIME TO FREQ DOMAIN TRANS
APP : AMPLITUDE AND PHASE PLOT
RPL : RECTANGULAR PLOT CURRENT DATA
POL : VECTOR PLOT OF THE AMPLITUDE AND PHASE DATA
EXI : TERMINATE THIS PROGRAM SESSION
```

Figure 2.2-1 Basic FTRAN commands

****

The basic FTRAN commands provide useful tools in analyzing calibrated radar data. Six of the most useful commands in analyzing the data are ; the IFT, RPL, GAT, WIN, FFT, and APP, commands. The IFT (inverse fast Fourier transform) command, transforms frequency domain data into the time domain. The time domain data is displayed through the use of an RPL (rectangular plot) command and is formatted as the response to an impulse excitation versus time in nanoseconds. Transforming to the time domain allows the target response to be analyzed as a function of distance, which allows the user to discriminate and isolate scattering mechanisms. For example, after the scattering mechanisms have been isolated through the use of the GAT (time gate) command, the data can be transformed back to the frequency domain through the use of the FFT (fast Fourier transform) command and plotted with an APP (amplitude phase plot) command. The WIN (window) command allow the user to pass the frequency domain data through a band pass or low pass filter. The filtering helps reduce the ringing effect (ie. Gibbs phenomenon) caused by the discontinuous frequency data string when the IFT, RPL command sequence is performed. Caution should be used when using the window command if the time domain data is to be transformed back to the frequency domain. Distortion in the RCS of the target is introduced by a bandpass or low pass filter whenever the window command is used.

Figures 2.2-5 and 2.2-6 illustrate these command procedures with data obtained from an ellipsoid body at a tilt angle of zero degrees (see Figure 2.2-3). Plot(a) shows the result of the APP command executed on the amplitude and phase calibrated RCS data for the HH (transmit horizontal receive horizontal) polarization obtained in the ESL compact range. Plot(b) shows the result of the RPL command after the IFT command has been executed on the data contained in plot(a). Plot(b), shows that the major scattering center of the ellipsoid body is at approximately -1.05 nanoseconds, and the creeping wave mechanisms along the top to bottom, and side to side, are at approximately 1.3 nanoseconds. A useful rule of thumb is that one nanosecond of time corresponds to 11.8 inches, or one foot in space. Plot(d) shows the result of the GAT command applied to the energy contained in the major scattering center, and plot(f) shows the time gate command applied to energy spectrum of the other scattering mechanisms. The plots(c & e) show the amplitude results of the FFT command applied to the data in the RPL plots(d & f). In Figure 2.2-6, plot(g) and plot(b) are used to illustrate the effect of the WIN command. Plot(g), the result of the WIN, IFT, RPL command sequence, compared to plot(b) (shown again in Figure 2.2-6 for ease of comparison) shows the reduction in the ringing effect when window command is performed.

In Appendix 3, a user guide for the the basic FTRAN commands is included.

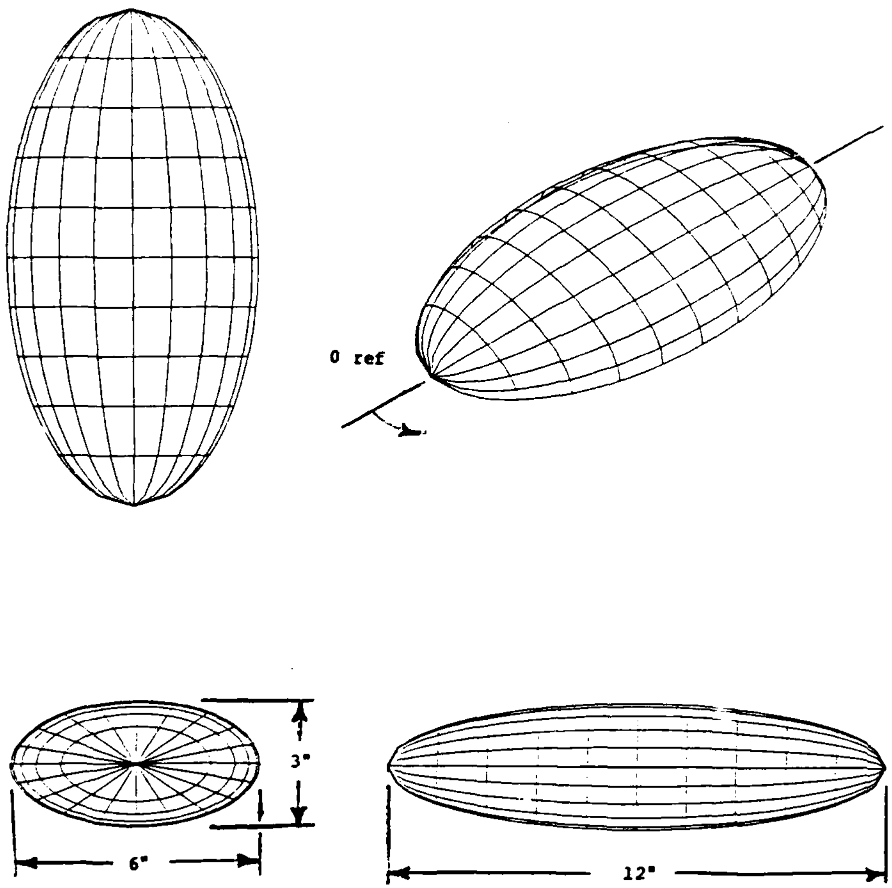


Figure 2.2-2 Ellipsoid Body dimensions

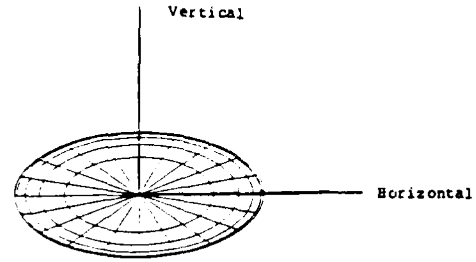


Figure 2.2-3 0° radar view with 0° tilt angle

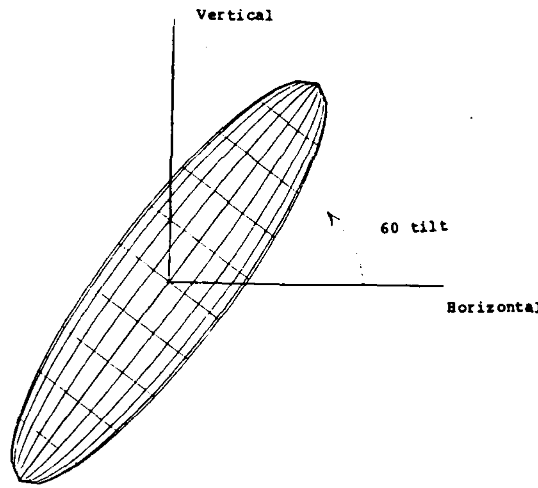


Figure 2.2-4 90° radar view with 60° tilt angle

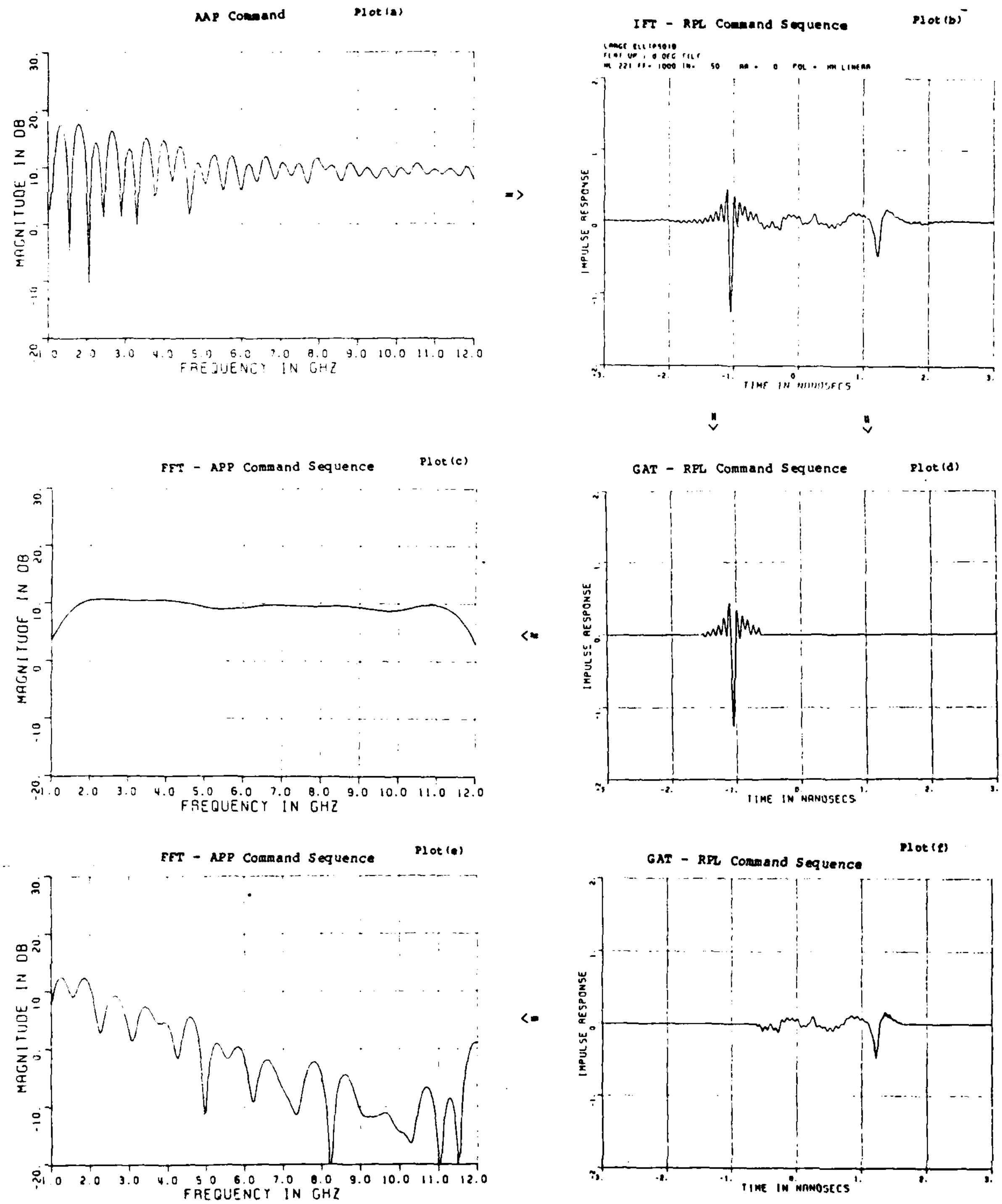
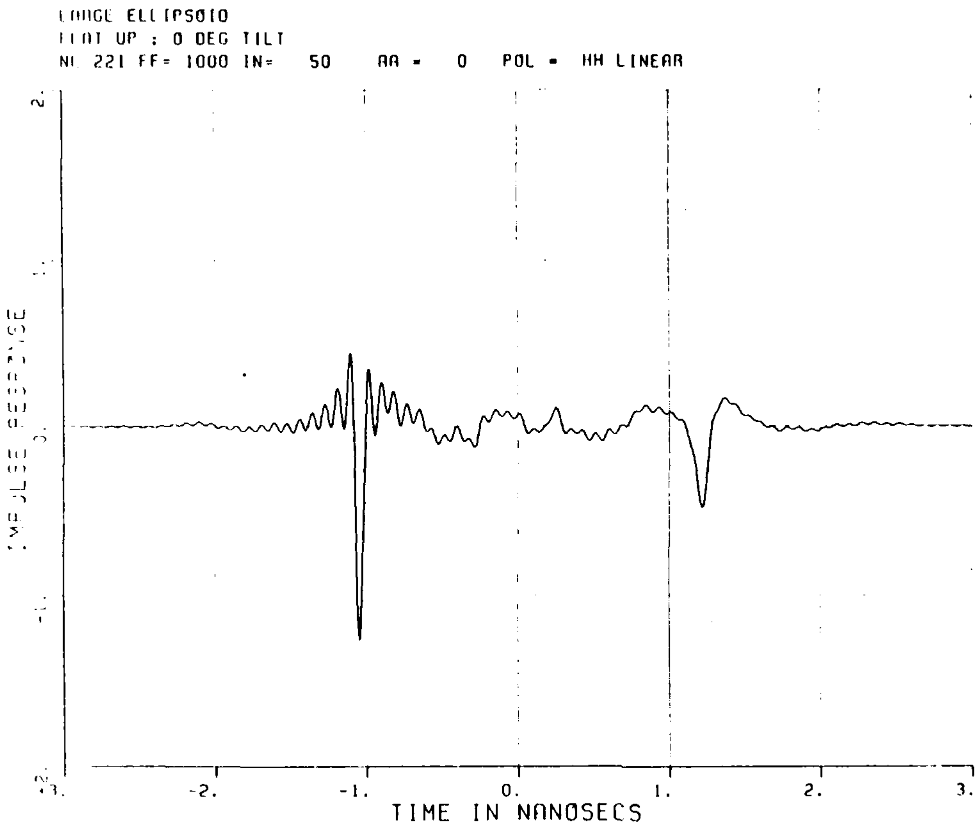
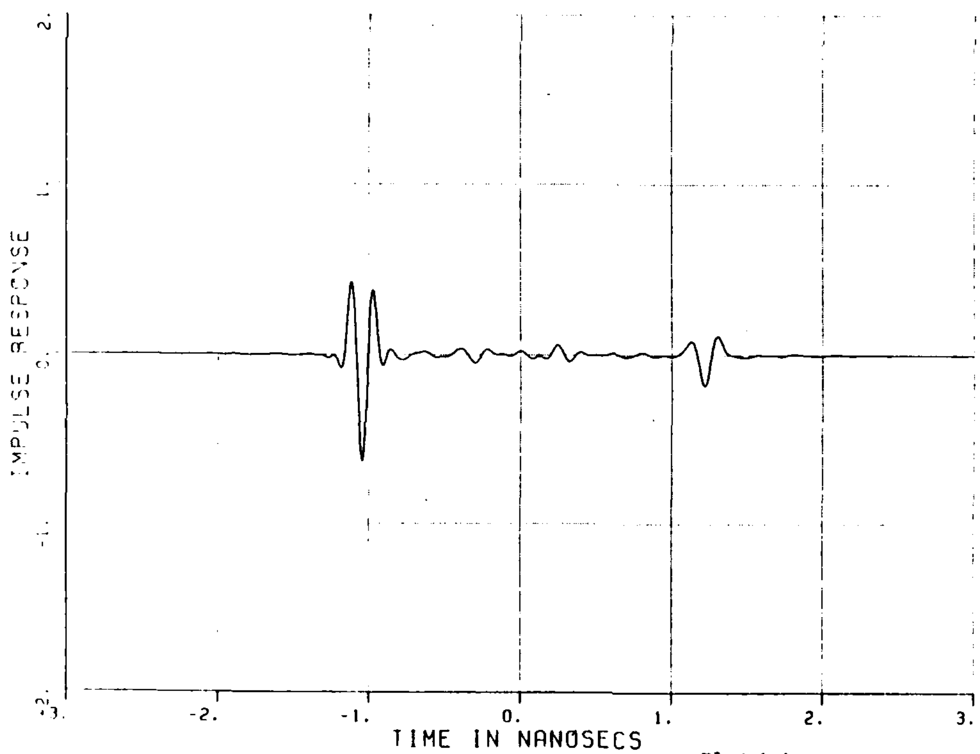


Figure 2.2-5 Ftran Command Illustration



Plot(b) repeated



Plot(g)

WIN - IFT - RPL **Command Sequence**

Figure 2.2-6 Ftran WIN Command Illustration

2.3 MODIFIED FTRAN COMMANDS

The modified version of FTRAN, called FTRAN_DB, includes the capability of accessing a frequency formatted data base file and calculating circular polarizations and elliptical polarization parameters.

The additional modified FTRAN commands, shown in Figure 2.3-1, are set apart from the original FTRAN commands and flaged with the message " DATA BASE FILES ONLY ".

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

     POL : VECTOR PLOT OF THE AMPLITUDE AND PHASE DATA
     EXI : TERMINATE THIS PROGRAM SESSION

  MODIFIED FTRAN COMMANDS       ( DATA BASE FILES ONLY )

        LDB : LOADS A DATA BASE ASPECT - VV, HH, VH  COMPONENTS
        VVP : SPECIFIES " VV " LINEAR POLARIZATION FOR PROCESSING
        HHP : SPECIFIES " HH " LINEAR POLARIZATION FOR PROCESSING
        VHP : SPECIFIES " VH " LINEAR POLARIZATION FOR PROCESSING
        RCP : SPECIFIES " RR " CIRCULAR POLARIZATION FOR PROCESSING
        LCP : SPECIFIES " LL " CIRCULAR POLARIZATION FOR PROCESSING
        XCP : SPECIFIES " LR " CIRCULAR POLARIZATION FOR PROCESSING
        RPC : SPECIFIES & PLOTS " RCP-XMIT " POLARIZATION PARAMETERS
        LPC : SPECIFIES & PLOTS " LCP-XMIT " POLARIZATION PARAMETERS
        DPA : REMOVES POSITIONAL ERRORS AND RE-CAL*S CP COMPONENTS
        PUT : STORES PROCESSED DATA AND RE-CAL*S CP COMPONENTS


        Figure 2.3-1     Additional menu commands

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

A detailed explanation of the workings of the modified FTRAN commands are discussed in Sections 2.3.1 through 2.3.6.

2.3.1 LDB command

The LDB command loads three data records of a data base file into the FTRAN_DB run-time program memory.

On execution of the LDB command the user is prompted for the name of the data base and then the aspect angle. Next, the data base file is opened and the three linear polarization types (HH, VV, and VH) at the specified aspect angle are retrieved. If all three linear polarizations exist, a common frequency bandwidth is found between them and the circular polarizations (RCP, LCP, and XCP) are calculated over this common bandwidth. If data does not exists at one or more of the linear polarization types, the circular polarization types are not calculated; a message is displayed informing the user of this condition.

The co-polarized circular components are denoted by RCP, for transmit right circular receive right circular, and LCP, for transmit left circular receive left circular. The cross-polarized circular component XCP denotes either transmit right circular and receive left circular or transmit left circular and receive right circular.

The algorithms used in calculation of the circular polarization types are the following:

For RCP

$$RCP = (HH - VV) / 2.0 - j (HV)$$

For LCP

$$LCP = (HH - VV) / 2.0 + j (HV)$$

For XCP

$$XCP = (HH + VV) / 2.0$$

After the LDB command is sucessfully executed, a three-line information block is displayed. On the first line, the accessed data base name is displayed, on the second line, the first comment line of the data base file is displayed. On the third line, the number of data points, the start frequency, and frequency increment of the common frequency bandwidth are displayed. Also on the third line, the aspect angle, and polarization type are displayed.

When the LDB command is first executed the polarization type is displayed as "NOT SPECIFIED", this indicates that no data is stored in the processing array called AMP and PHASE. To store data in the processing arrays, other modified FTRAN commands must be executed (see Sections 2.3.2 - 2.3.3).

The information block is formatted as shown in Figure 2.3.1-1 where NL denotes the number of data points, FF denotes the first frequency, IN denotes the frequency increment, AA denotes for the aspect angle requested, and POL denotes the polarization type specified.

****

```
DATA BASE NAME
FIRST COMMENT LINE OF DATA BASE FILE
NL 221 FF= 1000 IN=   50    AA =   20   POL = NOT SPECIFIED
```

Figure 2.3.1-1 LDB informatin block

****

Additional calls to LDB routine will allow the user to default to the last data base called by entering a "D" (for default) into the file name prompt.

2.3.2 VVP command

The VVP (transmit vertical receive vertical polarization) command loads the co-polarized vertical polarized data string into the FTRAN_DB processing array buffers called AMP(*) and PHASE(*). These two arrays provide access to all the original FTRAN commands such as IFT, FFT, APP, etc. After the VVP command has been successfully executed, the information block is again displayed, but with the polarization type changed to VVP as shown in Figure 2.3.2-1.

****

```
DATA BASE NAME
FIRST COMMENT LINE OF DATA BASE FILE
NL 221 FF= 1000 IN=   50    AA =   20   POL = VVP
```

Figure 2.3.2-1 VVP informatin block

****

2.3.3 HHP, VHP, RCP, LCP, XCP commands

The commands HHP, VHP, RCP, LCP, and XCP similar to the VVP command, load the corresponding data string into the AMP and PHASE processing data arrays. After any one of these specifing commands are executed, the information block is displayed with the polarization type updated accordingly. If any requested components do not exist, the user informed that the polarization is unavailable for processing and the last data string specified is still stored in the processing arrays. The current data string stored in the processing arrays can be checked with the LAB command, this command will displays the information block.

2.3.4 RPC and LPC command

The RPC and LPC commands enables the user to plot the elliptical polarization radar return from either right and left handed transmitted circular polarization, respectively. After an RCP or LCP command is executed, a sub-menu of commands is displayed as shown in Figure 2.3.4-1. This allows the user to select either a rectangular or POINCARE' sphere [6] projection plotting format.

****

```
POLARIZATION PARAMETER PLOTS

  POINCARE sphere projection
  RECTANGULAR plots
  EXIT plots '

 ENTER TYPE ->
```

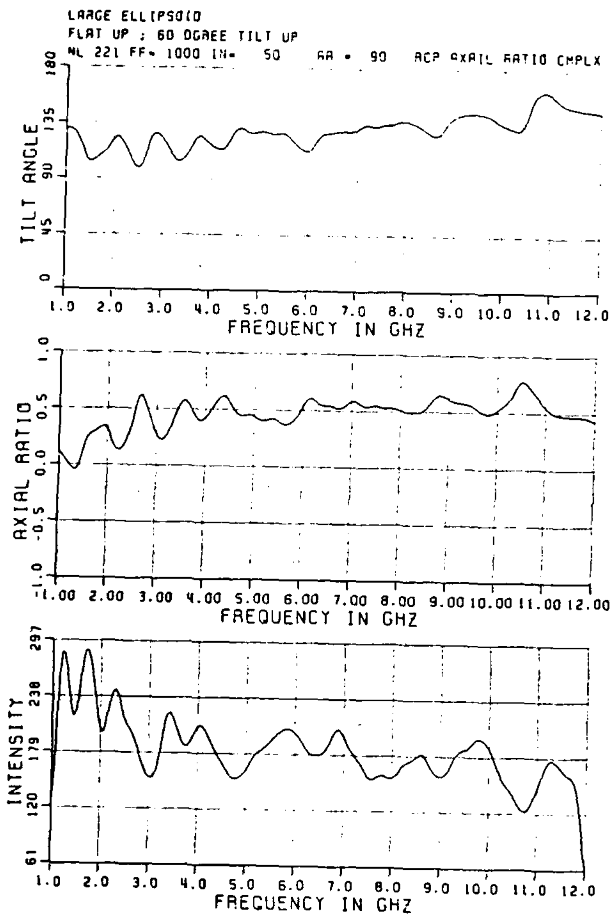
Figure 2.3.4-1 Plot menu

****

Wave polarization can be described as a polarization ellipse [7] and decomposed into components of axial ratio (ratio of minor and major axis of the polarization ellipse), tilt angle of ellipse (angular rotation of ellipse from a reference axis), and the wave intensity (a measure of the area contained in the ellipse).

The rectangular plots and POINCARE' plane sphere projections are two ways of displaying this information. Each method provides the user with a different perspective of the data string. Figures 2.3.4-2 & 2.3.4-3 illustrate the two methods of display.

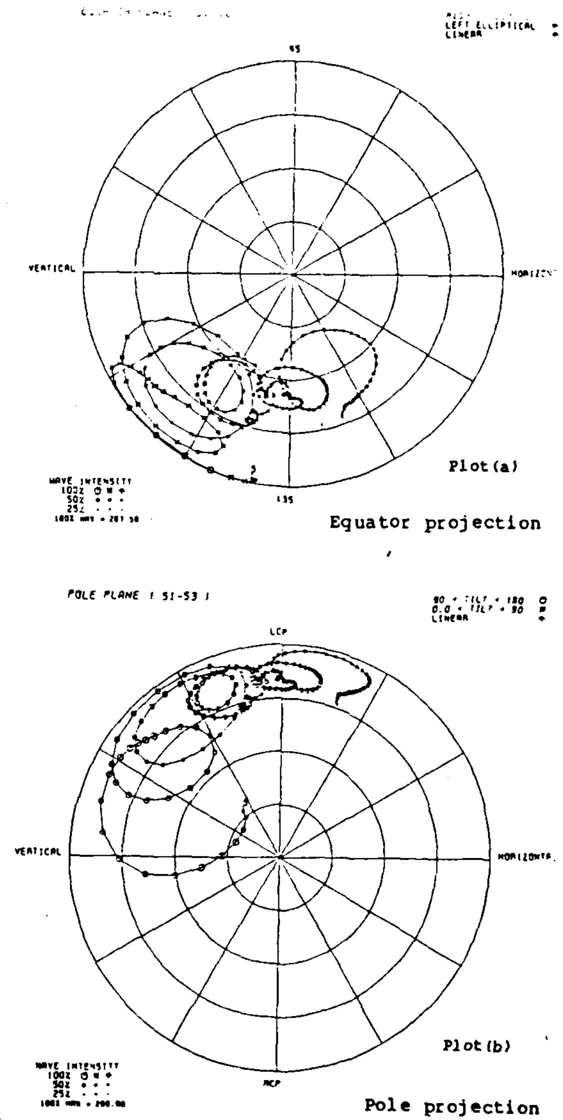
In Figure 2.3.4-2, the elliptically polarized radar return is displayed in rectangular format. The figure consists of three rectangular plots describing the decomposed elliptical polarization parameters. The top plot, plot(a), displays the tilt angle of the polarization ellipse versus frequency. Zero degrees on the tilt angle axis represents a vertical orientation of the polarization ellipse, and ninty degrees represents a horizontal orientation. The middle plot, plot(b), displays the axial ratio of the polarization ellipse versus frequency ranging between one and minus one. Data on the positive side of the axial ratio plot represents right-hand elliptical polarization while data on the negative side represents left-hand elliptical polarization. Data points at one and minus one represent right and left circular polarization, respectively, while data points at zero represent linear polarization. The last plot, plot(c), displays the wave intensity of the the radar return versus frequency, and represents a measure of the power contained in the polarization ellipse. The ordinate axis for the wave intensity is automatically scaled according to the maximum and minimum values of the plotted data string.



Plot (a) Tilt Angle

Plot (b) Axial Ratio

Plot (c) Wave Intensity



Plot (a) Equator projection

Plot (b) Pole projection

Polarization parameters

Figure 2.3.4-2 (rectangular format)

Figure 2.3.4-3 (Poincare' format)

Figure 2.3.4-3 illustrates the second display mode: plane projections of the Poincare' sphere. Two plane projections of the Poincare' sphere are available to the user when the Poincare' plot is requested. They are the equator plane, as shown in plot(a), or the pole plane as shown in plot(b). The three elliptical polarization parameters: tilt angle, axial ratio, and wave intensity, are all described in the single Poincare' plane projection.

For the equator plane projection, the degree of ellipticity (ie. axial ratio of the polarization ellipse) is described by the distance from the center of the circular grid. The center of the grid represents circular polarization and the poles of the polarization sphere, while the outer circle of the grid represents linear polarization and the equator of the sphere. The tilt angle of the polarization ellipse is described by the angular position on the plane projection. Four tilt angle positions are indicated on the plot for reference. They are: horizontal (ie. zero or one-hundred-eighty degrees), 45 (or 225), vertical (90 or 270), and 135 (or 315). The sense of polarization (ie. right or left elliptical polarization) is indicated by the symbols "circle", for right elliptical (lower hemisphere), and "star", for left elliptical (upper hemisphere). Additionally, a "arrow" symbol is provided to indicate linear polarization. The wave intensity, a measure of Poincare' sphere radius, is normalized by maximum value of the intensity data string and is displayed by the size of the plotted symbols. A table in the lower left area of the plot identifies the maximum value of wave intensity and corresponding symbol sizes for one hundred, fifty, and twenty-five percent of the maximum value.

A pole plane projection for the same data string, as shown in the equator plane projection, is shown in plot(b). Here the planar projection of the sphere is the pole plane containing the horizontal and vertical equator locations. The pole plane projection redefines the plotting symbols to indicate polarization locations from the front or rear hemisphere. Data points from the rear hemisphere are indicated by the "star" symbol, and represent polarization ellipses having a tilt angle between zero and ninty degrees. Data points from the front hemisphere are indicated by the "circle" symbol, and represent polarization ellipses having a tilt angle between ninty and one hundred eighty degrees. And data points that lie on the equator, as in the equator plane plot, represents linear polarization are indicated by the "arrow" symbol.

The start, middle, and final frequencies or the formatted data string are indicated on the plot by the capital letters S, M, and F. The corresponding frequency values for the start and final positions are displayed in the fourth text line of the header. The letters FF represent the first frequency, IN represents the frequency increment, and NL represents the number of lines or points. The numeric values for frequency are in megahertzs, and the final frequency can be calculated by: FF + (NL * IN).

Markings in the upper left corner of the plot indicate whether the plot is an equator and pole plane projection. The S1, S2, and S3, markings in parentheses indicate the Stokes parameters used to generate the plot projection.

2.3.5 DPA

The DPA command allows the user to offset postional displacments between the HH, VV, and HV linear polarizations and recalculates the circular polarization components RRC, LLC, and RLC. Positional displacments occur between the linear polarizations for many reasons including those listed in Table 2.3.5-1.

****

Rotation of transmitt antenna for orthogonal polarizations
Measurements for different polarizations taken days apart
Non-repeatable placement of target and calibration sphere

Table 2.3.5-1 DPA conditions

****

The postional adjustment prompts the user to enter the offsets values, in meters, for each of the linear polarization types. Each time the DPA routine is executed, the orginal values read from the data base file are altered. Plots illustrating the usage and effect of this command are shown in Figure 2.3.5-1. The plots(a, b, & c) show time domain plots for the ellipsoidal body at a tilt angle of sixty degree (see Figure 2.2-4) for the polarizations HH, VV, and HV, at an aspect angle of zero degrees. Notice that the minimum impulse response values for the HH, VV, and HV polarizations are located at approximately .52, .47, and .37 nanoseconds , respectively. This minimum location, in each case, represents the the same physical location on the target's body. With the DPA command the time domain plots(a, b, & c) can be adjusted to the plots of (d, e, & f) with HH, VV, and VH, offset of -.078, -.070, and -.055 meters, respectively. The alinement correction can make a substantial difference in the elliptical polarization responses as illustrated by the Poincare' plots in Figure 2.3.5-2. Plot(a) shows the ellipsoid data of Figure 2.3.5-1 plots(a, b, & c) plotted on the Poincare' sphere equator projection, versus plot(b), which shows the adjusted data of Figure 2.3.5-1 plots(d, e, & f) plotted with the same Poincare' projection. Thus, care must be taken to ensure the proper alinement of the data strings HH, VV, and HV, before plotting the circular polarizations RCP, LCP, XCP, and circular polarization components RPC, AND LPC.

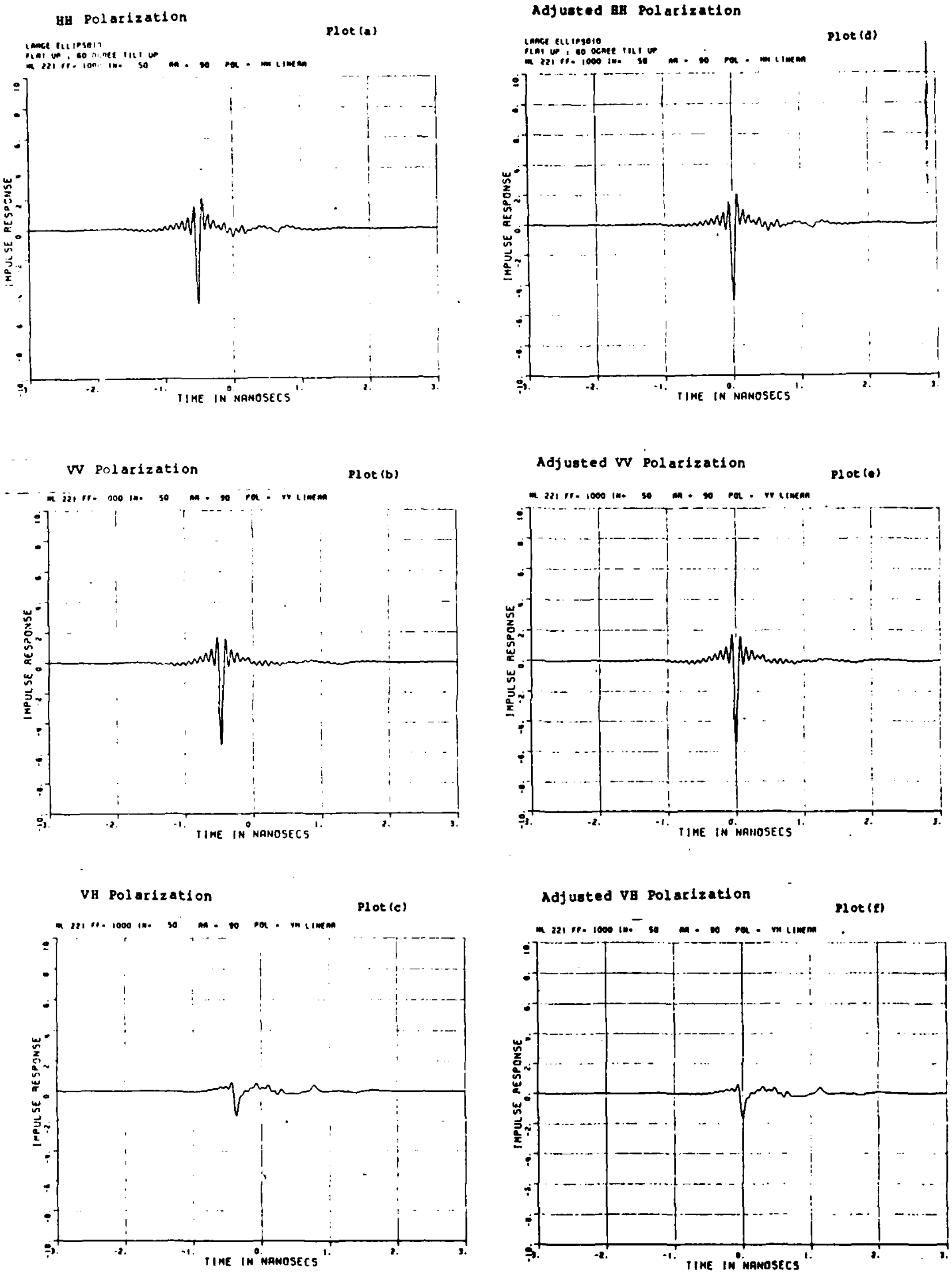
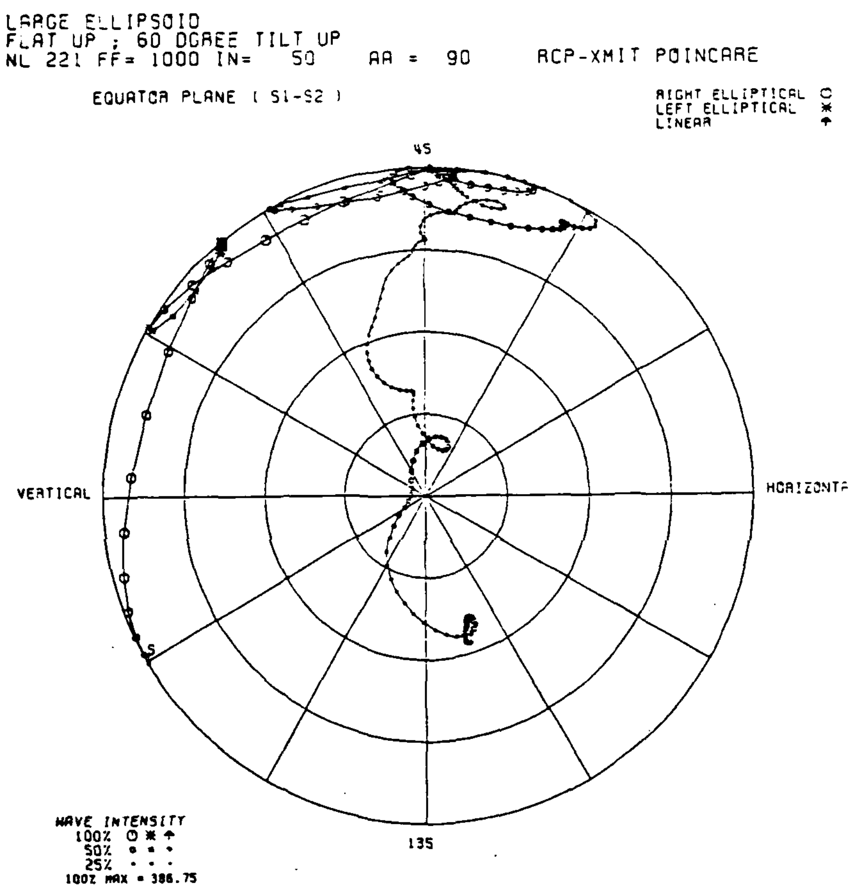
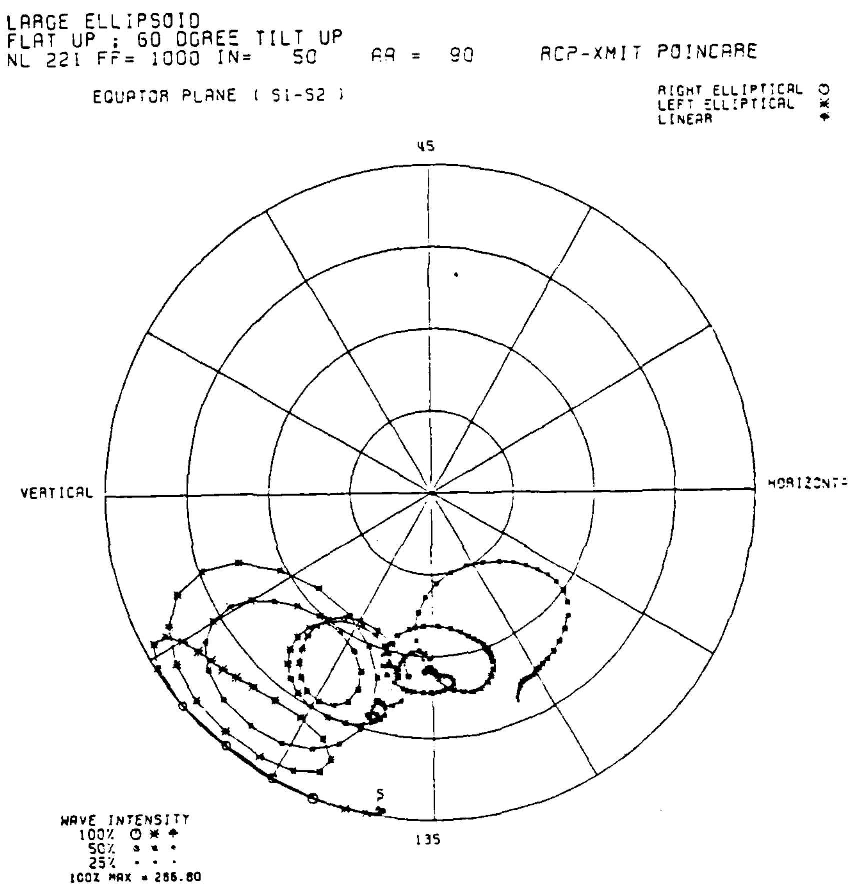


Figure 2.3.5-1 DPA Command Illustration



Plot(a)

Non-Alined Polarizations



Plot(b)

Alined Polarizations

Aligned and Non-Aligned polarizations plotted on a Poincare' plane projection.

Figure 2.3.5-2

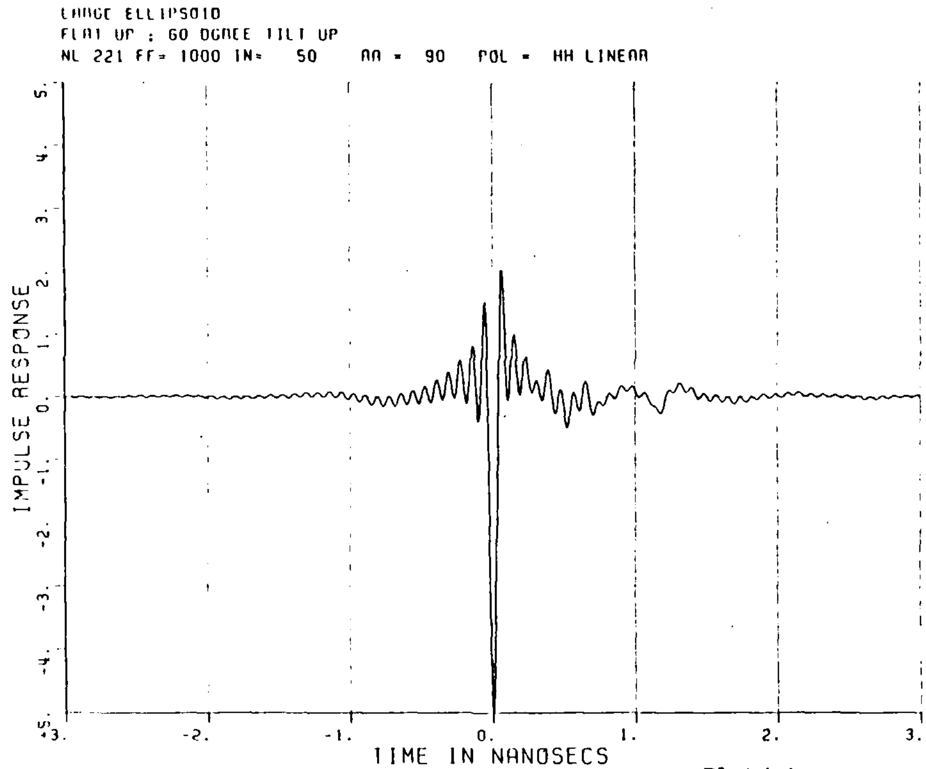
2.3.6 PUT

The PUT command allows the user to recalculate the circular polarizations and elliptical polarization parameters after the processing (ie. IFT, GAT, FFT, etc..) of any linear polarization. If only the circular polarizations are processed, only the elliptical polarization parameters are recalculated.

The useage of this command and some of the FTRAN_DB data string processing commands are presented here in a series of figures. Again, data from the sixty degree tilted ellipsoid body (see Figure 2.2-4) is used to demonstrate the commands. After the LDB command has been executed to load the data strings in to executable memory from a data base, the DPA command is used to remove the positional errors in the three linear polarizations, as illustrated in the DPA command section. Once the positional errors have been removed, the HHP command is executed to load the HH linear polarized component into the processing array buffer. Next, the IFT command is executed to transform the frequency domain data into time domain data. Once the transformation is completed, the GAT command is used to separate the predominate specular return from the creeping wave and the other scattering mechanisms. The data represented in Figure 2.3.6-1 shows the results of this procedure for the HH linear polarization component. The time gate was set from minus one-half to plus one-half nanoseconds. Next, the FFT command was executed to transform the time formatted data back into the frequency format shown in Figure 2.3.6-2. Finally the PUT command is executed, and new circular components and elliptical polarization parameters are calculated.

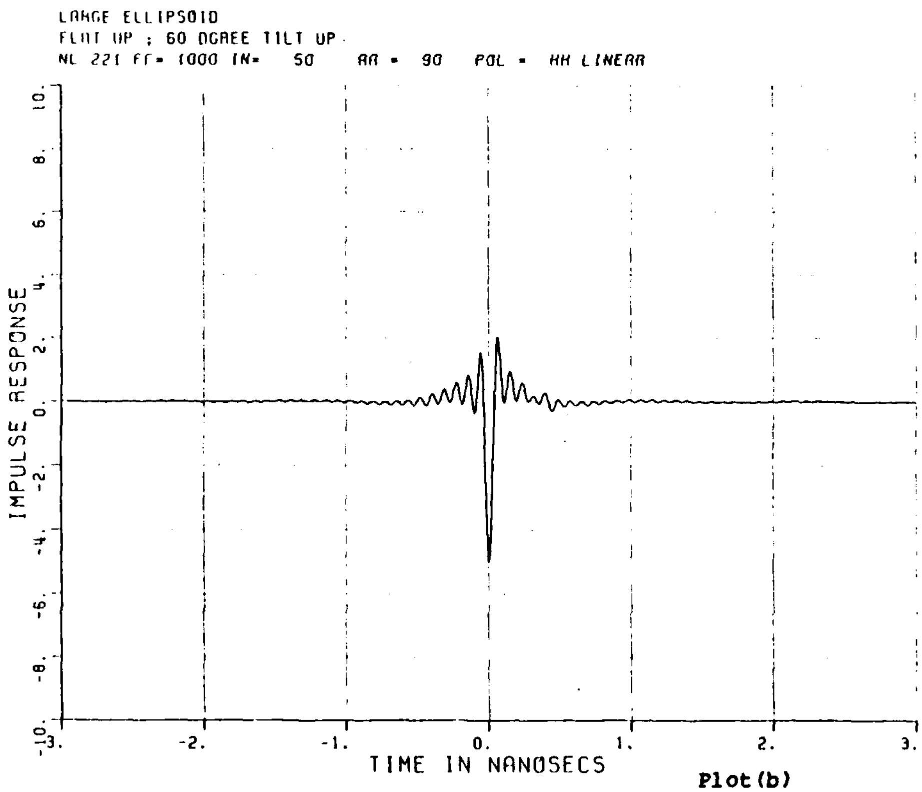
To achieve meaningful circular polarizations and elliptical polarization parameters, the same procedures that processed the HH linear polarization must also be repeated for the VV and VH polarizations.

Figure 2.3.6-3 shows the Poincare' equator plane projections after the above procedures are accomplished. Plot(a) shows that the specular return begins linearly polarized, at wavelengths comparable to the size of the ellipsoid, at a tilt angle of sixty degrees from the horizontal reference. As expected, the specular return gradually approaches towards circular polarization along the elliptical tilt angle of sixty degrees as the frequency increases. Using the same technique, plot(b) shows the Poincare' equator plane projection of the creeping wave and other scattering mechanisms contained in the time gate set from minus one-half to two nanoseconds.



Plot(a)

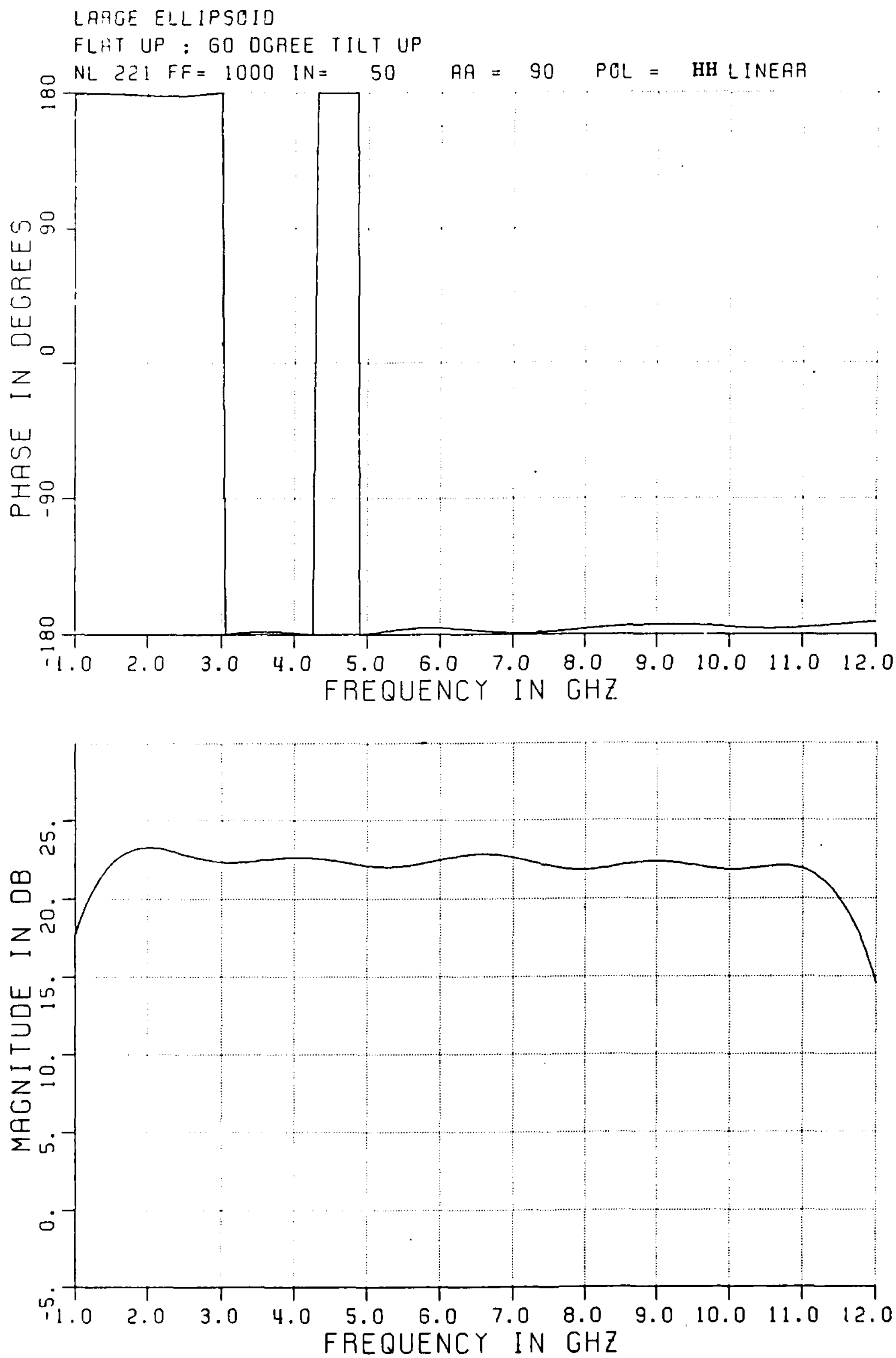
HH Polarization " Time Domain response "



Plot(b)

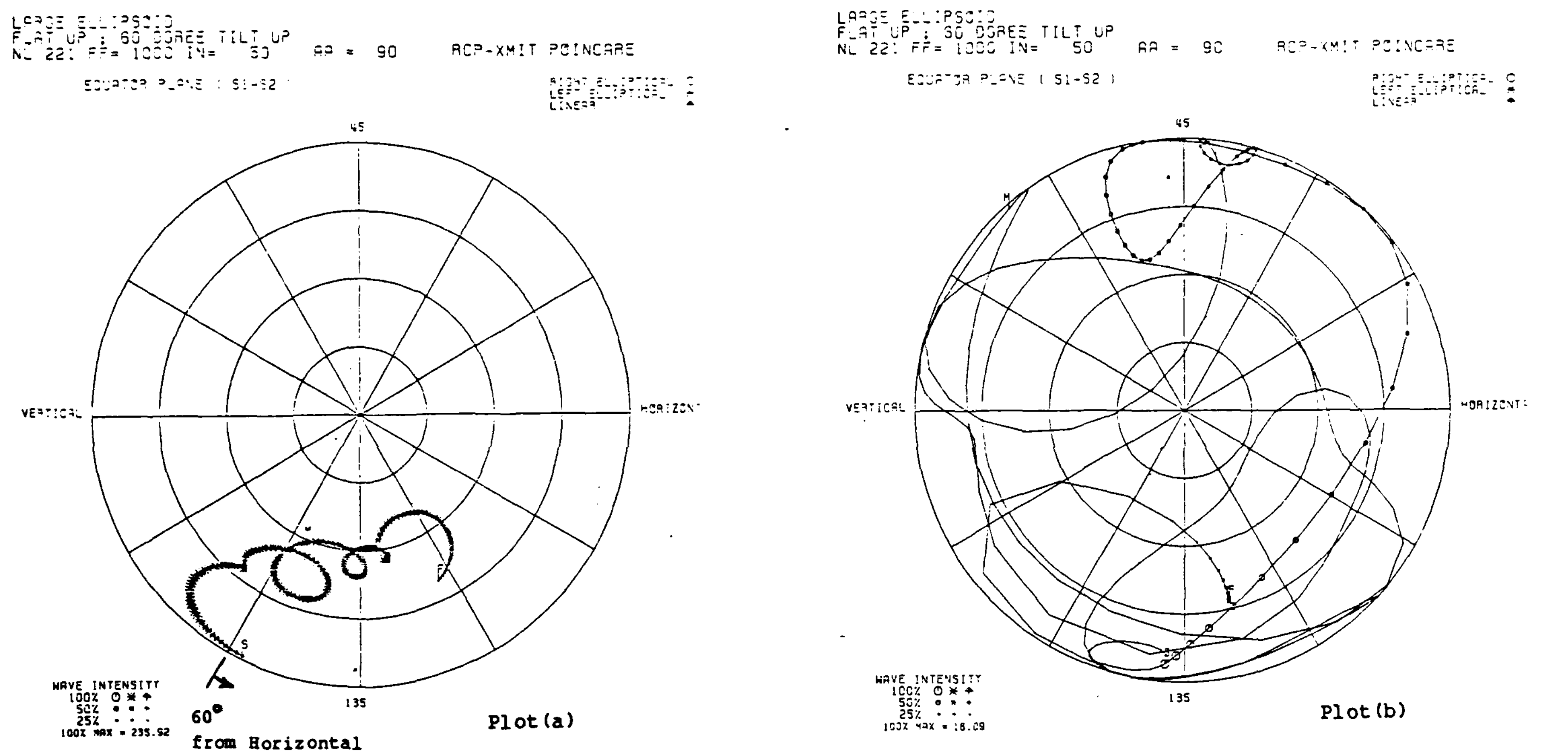
HH Polarization " Gated Time Domain response "

Figure 2.3.6-1 Data Processing for PUT Command Illustration



HHP - AAP Command Sequence after PUT Command Execution

Figu.e 2.3.6-2 Result of PUT Command



Specular Return (Time Gate -.5 to .5 nanoseconds)   Other Scattering Mechanisms (Time Gate .5 to 2.0 nanoseconds

Figure 2.3.6-3 Poincare' Projections of Time Gated Radar Returns

SECTION 3

3.1 PROGRAM: RADAR SYSTEM SIMULATION AND EVALUATION (RSSE) PROGRAM

The RSSE program was designed to simulate a variety of radar systems, and evaluate their ability to classifiy RCS measurements for practical systems.

The RSSE program represents the third generation of simulation programs written at the ESL. This latest version incorporates a modular programming style which allows for expansion of new radar types, identification routines, and noise models. Other new features included in this new program are run time allocated (dynamic) data arrays, and DATA BASE file usage.

3.2 MENU LISTING

The RSSE program has several menus of operation, the main menu as shown in Figure 3.2-1 consists of eleven commands.

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

Radar System Simulation and Evaluation (RSSE) Commands :

   CREATE a data matrix.
   CHANGE features of the data matrix.
   DISPLAY the features of the data matrix.
   EXIT from the program.
   HELP messages.
   IDENTIFICATION routines.
   MAP the data matrix.
   MENU of commands.
   PLOT package setup.
   $ " any VAX/VMS DCL command ".

 All commands may be abbreviated
 Answer YES or NO for all questions. The default is YES
   unless stated otherwise.
```

Figure 3.2-1 Main menu

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

3.2.1 MENU SUMMARY

A brief introduction to the main menu commands are as follows:

CREATE : Creates a data matrix from requested DATA BASE files, frequencies, aspect angles, and polarization types.

CHANGE : Allows the user to change the data matrix by requesting new DATA BASE files, frequencies, aspects angles, or polarization types.

DISPLAY: Allows the user to display the parameters entered in the CREATE or CHANGE command.

EXIT : Exits the program and returns the user to VAX/VMS operation.

HELP : Helps the user develope proper execution procedures and corrective measures for program error messages.

IDENTIFICATION : Invokes a sub program that is menu driven to perform; the generation of test and catalog subsets, the execution of different identification algorithms, and display formats to summarize the results.

MAP : Shows the user the data strings that are read into the data matrix and assigns an identification number to each string for one method of subset generation.

PLOT : Selects the plotting devices for the ESL plot package.

$ " DCL COMMAND " : Allows the user to enter a VAX/VMS DCL command for execution while the program is running.

A detailed discussion of the top level RSSE commands is given in the following sections.

3.2.1.1 CREATE

The CREATE command creates a data matrix from the requested data base records (see Section 1). When the CREATE command is executed, the user is first prompted to enter an integer value for the number of data bases to be read. For each data base, the file name, scale factor, and elevation angle are entered as follows :

```
FOR DATA BASE  # 1
ENTER NAME  -> TARGET_2.DAT
ENTER SCALE FACTOR -> 20.0
ENTER VALUE OF ELEVATION ANGLE -> 10

FOR DATA BASE  # 2
ENTER NAME  -> TARGET_1.DAT
ENTER SCALE FACTOR -> 10.0
ENTER VALUE OF ELEVATION ANGLE -> 0

   Etc...
```

The file name is entered as a character string with a maximum length of sixty characters. The scale factor is entered as a floting point number and must be between the limits of one and five-thousand. Finally, the elevation angle is entered as a integer value between the limits of zero one and three-hundred-sixty degrees. All entered values throughout the RSSE program are processed through a checking routine to ensure that the values that have been entered are within the preset limits.

Presently, only frequency formatted data bases can be processed by the RSSE program (ie. data bases where the record's data strings are indexed by frequency at a single azimuth angle and polarization type).

Next, the user is prompted to enter an integer value for the number of azimuth angles to be read. After the azimuth angles values have been entered, a integer number of polarization types, six maximum, is entered. While only three linear types of polarizations are available in a data base (ie. HH, VV, and VH), the three circular polarizations types RRC, LLC, and RLC, can be calculated if the three linear polarizations at the specified azimuth angles exists (see Section 2.3.1). If the maximum number is not selected, the polarization types are then entered as character strings, shown in Figure 3.2.1.1-1, as follows:

```
FOR POLARIZATION # 1
ENTER THE POLARIZATION TYPE -> VVP

FOR POLARIZATION # 2
ENTER THE POLARIZATION TYPE -> RRC

   Etc...
```

The first character represents the transmitted polarization the second character represents the received polarization. When the two characters are the same, as in HHP, the radar system is said to be co-polarized. When the two characters are different, as in VHP, the radar system is said to be cross-polarized.

****

The polarization types are :

HHP horizontal - horizontal linear
VVP vertical - vertical linear
VHP vertical - horizontal linear
RRC right - right circular
LLC left - left circular
RLC right - left circular

Figure 3.2.1.1-1 Polarization types

****

Finally, the user is prompted for the scaled frequency range start, and stop values, and the number of frequency points. The start and stop scaled frequency values are entered as floating point numbers, and the number of frequencies are entered as an integer.

After the prompts for creating the data matrix have been completed, a summary of the entered prompts is displayed for user verification. If an error exists in the display summary, the user can request a change in the data matrix before the data acquisition routine is executed (see Section 3.2.1.2). If no errors exists in the display summary, the user defaults on the change parameter prompt and data acquisition begins. After data acquisition is completed, the user is informed as to how many items were not read into the data matrix.

The data acquisition routine uses run time (dynamic) memory allocation for the data matrix elements. If the data matrix is changed or recreated, the existing data matrix is deallocated and new memory space is allocated to accomodate the new data matrix size. During the data acquisition routine, the amplitude and phase data are converted from power quantities to voltage quantities, changed to complex form, scaled by the target's scale factor, and additionally scaled by a factor of one-hundred. The additional scaling (ie. the one-hundred factor), changes the data base quantities from centi-meters to meters.

An example of the data matrix display summary is shown in Figure 3.2.1.1-2. A titled hardcopy of the display summary is available if the hardcopy prompt is set.

****

5 TARGETS

TARGET INDEX # 1 -> PLANE_1

ELEVATION ANGLE = 0
SCALE FACTOR = 200.00

TARGET INDEX # 2 -> PLANE_2

ELEVATION ANGLE = 0
SCALE FACTOR = 200.00

TARGET INDEX # 3 -> PLANE_3

ELEVATION ANGLE = 150
SCALE FACTOR = 150.00

TARGET INDEX # 4 -> PLANE_4

ELEVATION ANGLE = 0
SCALE FACTOR = 200.00

TARGET INDEX # 5 -> PLANE_5

ELEVATION ANGLE = 0
SCALE FACTOR = 200.00

---

3 AZIMUTH ANGLES

ANGLE INDEX # 1 -> 0
ANGLE INDEX # 2 -> 45
ANGLE INDEX # 3 -> 90

---

3 POLARIZATION TYPES

POLARIZATION INDEX # 1 -> HHP
POLARIZATION INDEX # 2 -> VVP
POLARIZATION INDEX # 3 -> RRC

START FREQUENCY -> 8.00 MHz
STOP FREQUENCY -> 58.00 MHz
FREQUENCY INCREMENT -> 10.00 MHz

Figure 3 2 1 1-2 Data matrix display summary

****

3.2.1.2 CHANGE

The CHANGE command is available to the user after a CREATE command has been executed.

If the CHANGE command is requested, a sub-menu, as shown in Figure 3.2.1.2-1 is displayed. This sub-menu allows the user to change a section of the data matrix acquisition parameters. Once the CHANGE command has been executed the data matrix display summary (Figure 3.2.1.1-2) appears updated with the new parameters. After the first CHANGE command has been completed, and the display summary displayed, the user is prompted for additional changes. If the user defaults on the additional changes, the data acquisition routine begins with the new data matrix parameter.

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

   Targets
   Azimuth angles
   Polarizations
   Frequencies

Enter Feature to change ->
```

Figure 3.2.1.2-1 Change parameters sub-menu

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

3.2.1.3 DISPLAY

The DISPLAY command allows the user to display the current data acquisition parameters as shown in Figure 3.2.1.2-1. The display routine allows the user to request a hardcopy of the display; a sixty character label can be added for documentation.

3.2.1.4 HELP

The HELP command provides the user with information pertaining to the top level commands, error messages, and additional software that uses the data base format. The HELP command is supported by the DEC VAX/VMS V4.0 system software and allows the help routine to be set up in a multi level structure (ie. the help topics branch down to subtopics) [4], [5]. Figure 3.2.1.4-1 shows the major help topics currently available to the user, and an example of a help message display.

****

Information available:

```
AUTHOR      CREATE      CHANGE      DISPLAY     ERRORS      MAP
IDENTIFICATION          MENU        PLOT        START_UP    $DCL
```

Topic? IDENTIFICATION

Invokes a sub program that is menu driven to perform ; the generation of test and catalog subsets, the execution of different identification algorithms, and different display formats to summarize the results.

Additional information available:

```
DISPLAY     GENERATE        NEAREST
```

Sub Topic?

Figure 3.2.1.4-1 Main RSSE Help display

****

3.2.1.5 IDENTIFICATION

The IDENTIFICATION command transfers the user to the identification menu format. This new menu, shown in Figure 3.2.1.5-1, contains seven commands that allow the user to do target identification.

At present, only the single nearest neighor algorithm [8] is available for feature identification. Future modifications of the RSSE will incorporates additional techniques such as correlation, adaptive, and the k-nearest neighbor, for feature identification.

****

IDENTIFICATION ROUTINE COMMANDS

GENERATE a test & catalog set. (ie. subsets of the MAP)
NEARESET neighbor technique to identify test set targets.
DISPLAY results
HELP messages
EXIT the RSSE program.
QUIT identification routines.
$ " any VAX/VMS DCL command ".

All commands may be abbreviated
Answer YES or NO for all questions. The default is YES
unless stated otherwise.

SELECT AN OPTION FOR EXECUTION - >

Figure 3.2.1.5-1 Identification Menu

****

3.2.1.5 IDENTIFICATION MENU COMMANDS

3.2.1.5.1 GENERATE

The GENERATE command allows the user to create two subsets from the data matrix. The two subsets, called the test set and catalog set, and are queued once a radar type has been selected. Three radar types are availible (see Figure 3.2.1.5.1-1), and are derived from the six polarization types listed in Figure 3.2.1.1-1. The ARBITARY radar type allows the user to simulate radar systems of any of the six polarization types, while the DIVERSE radar types, LINEAR and CIRCULAR, allows the user to simulate "post-detection" linear and non-linear combinations of the six polarization types.

After the selection of a radar type has been determined, the user is prompted to choose elements for the test and catalog subsets. The first subset of the data to be created is the test set. The test set, in identification schemes, denotes the set of data that is to be corrupted with noise and then identified as a simulated radar return. The catalog set, denotes the set of data that is to be used to identify the elements in the test set.

The ARBITARY radar type allows the user to create the two subsets with any valid elements from the map listing (see Figure 3.2.1.6-1). Five index file keys enable the user to create the arbitary radar subsets by specifing either the ID number key (see Section 3.2.1.6), target name key, azimuth angle key, elvation angle key, or polarization type key. In each case, the user can select individual elements or a range of elements by specifing quantities associated with with the chosen key. For example, if the azimuth angles of 0, 15, 30, 45, 50, and 90, degrees are in the data matrix and the user desires angles between the limits of 0 and 45 in the test set, the user would choose the azimuth key type and select the range option for angles between these limits. The test subset would then be created with all the elements in the map listing containing the azimuth angles 0, 15, 30, and 45 degrees. With the target and polarization key types, the range selection option works on an apha-numeric ordering. If any element in the map listing is denoted with an asterisk, it is invalid and excluded from the subset generation.

The LINEAR DIVERSE radar types allows the user to create the two subsets with combinations of the linear polarization types HH, VV, and VH. The HH, VV, and VH combinations consists of a complex sum of the three components (ie. HH + VV + VH), a concatenation of the three components, and ratio combinations of the components (ie. HH/VV, or HH/VH , or VV/HH, or VV/VH, etc..). The CIRCULAR DIVERSE radar types allows the user to create subsets consisting of various combinations of the circular polarization types RRC, LLC, and RLC. The circular diverse types, similar to the linear diverse types, allows the selection of either a complex sum, or concatenation of circular components. However, instead of a ratio of components, the circular diverse offers the axial ratio of the polarization ellipse [7].

The sub-menus displayed in the RSSE program for the radar type selections are show in Figure 3.2.1.5.1-2 plots(a,b,c).

****

RADAR TYPES

ARBITARY polarization radar (ie. LINEAR & CP elements)
LINEAR polarization diverse radar (ie. HH, VV, VH combinations)
CIRCULAR polarization diverse radar (ie. AXIAL RATIO & CP combinations)

ENTER THE TYPE OF RADAR - >

Figure 3.2.1.5.1-1 RSSE radar type menu

****

ARBITRAY RADAR TYPE CREATE COMMANDS :

ID# key.
TARGET name key.
AZIMUTH angle key.
ELEVATION angle key.
POLARIZATION type key.

Select a key type to create the set ->

(a) Arbitray radar types

LINEAR POLARIZATION DIVERSE RADAR TYPES:

COMPLEX sum of linear components.
CONCATENATION of linear components.
RATIO combinations of HH, VV, & VH

ENTER POLARIZATION DIVERSE TYPE ->

(a) Linear diverse radar types

CIRCULAR POLARIZATION DIVERSE RADAR TYPES:

COMPLEX sum of circular components.
CONCATENATION of circular components.
AXIAL ratio (right or left) components.

ENTER POLARIZATION DIVERSE TYPE ->

(c) Circular diverse radar types

Figure 3.2.1.5.1-2 RSSE radar types

****

When the test and catalog subsets are created, the average power for each element of the subsets is calculated. This is done by taking the average value of the sum of the squares of the magnitude of the complex voltage samples contained in each subset.

The calculation is made by summing the appropriate polarization types that make up the radar type selected. That is, for example, if two frequencies samples are choosen, the average power calculation for a circular diverse radar type would be:

(RRC(1)**2 + LLC(1)**2 + RLC(1)**2 + RRC(2)**2 + LLC(2)**2 + RLC(2)**2) / 6.0

while, for a linear diverse ratio radar type, say HH/VV, the average power calculation would be:

(HHP(1)**2 + VVP(1)**2 + HHP(2)**2 + VVP(2)**2) / 4.0 .

The average power results are useful when examining the mis-classification percentage tables (see Section 3.2.1.5.3). Approximate signal-to-noise ratios can be determined by comparing the table's noise powers to the average power of the subset elements.

3.2.1.5.2 NEAREST

The NEAREST command invokes the 1-nearest neighbor algorithm to perform target identification. The nearest neighbor algorithm provides the user with a Euclidian distance measure between elements of the test set and catalog set. The shortest distance measure between an element of the test set and the members of the catalog set is used to identify the test set element.

In the nearest neighbor routine, the user is prompted for four parameters to define the radar simulation process. These parameters are; noise power range, noise model type, distance type, and the number of experiments. The noise power range, specified in dB-sm, is entered by a start, stop, and increment value. These noise steps are applied to the elements in the test set according to the noise model selected. Currently, only an additive Gaussian noise model is available, this noise model simulates a radar environment with many independent noise sources. Noise models [8] in later versions of the RSSE program, will allow the user to simulate many more types of radar environments.

Corrupting the non-linear diverse radars types with noise, requires that the noise corruption be applied to the six polarizations types HH, VV, VH, RR, LL, and RL before any non-linear combination of polarization types are calculated. For example, if a ratio of HH/VV is requested, the noise steps are applied to the HH and VV polarizations before the ratio operation is executed.

Two distance types are available for obtaining the Euclidian distance measure. They are the "coherent" (vector) and "non-coherent" (magnitude) distance metrics. The vector distance is based on the two dimensional "complex" subtraction between the samples of the the test set and catalog set samples, while the magnitude distance is a one dimensional "real" subtraction of the magnitudes of the samples in in the test set and catalog set elements. The mathematical representation for the two distance types are:

For vector "coherent" distance

Distance(Ti, Ck) = sqrt(sumx(mag(Ti(x) - Ck(x)) ** 2)

For magnitude "non-coherent" distance

Distance(Ti, Ck) = sqrt(sumx(abs_val(mag(Ti(x)) - mag(Ck(X))) ** 2))

Where "Ti(x)" denotes the complex sample vector of the ith test set element and "Ck(x)" denotes the complex sample vector of the kth catalog set element.

The "number of experiments" prompt, allows the user to enter the number of times the nearest neighbor algorithm is to be executed on elements of the test and catalog sets. Each time the algorithm is executed a random noise seed is injected into the test set corruption routine, thus allowing for a calculation of misclassification statistics.

A flow chart in figure 3.2.1.5.2-1 illustrates the logical progression of commands to execute the NEAREST neighbor algorithm.

****

```
                          ___________
                         |  CREATE   |
                          -----------
                          DATA MATRIX
                               |
                               |
                       _________________
                      | IDENTIFICATION  |
                       -----------------
                               |
                               |
                          ____________
                         |  GENERATE  |
                          ------------
                          RADAR TYPE
     ______ CATALOG SET               TEST SET  ______________
    |                          |                               |
    |                          |                               |
    |                                                          |
    |                      ___________                         |
    |                     |  NEAREST  |                        |
    |                      -----------                         |
    |                      # OF EXP                            |
    |                      ERROR RANGE                         |
    |                      ERROR MODEL ------------ INSERT ERROR
    |                                                          |
     --------- NEAREST DISTANCE DECISION --------------
                              |
                      TABULATE RESULTS
```

Figure 3.2.1.5.2-1   Procedures to execute the NEAREST command

****

3.2.1.5.3 DISPLAY

The DISPLAY command allows the user to display the results of the last classification algorithm executed. The results can be displayed in either a text or tabular style. Both styles display the number of times, out of the total number of experiments, that a test set element was identified as one of the elements in the catalog set.

The tabular format also calculates and displays mis-classification percentages. The mis-classification percentages can be chosen to provide mis-classification statistics based on either the target name, azimuth angle, elevation angle, or polarization type.

The results of the classification algorithms are displayed as a function of the average power of the noise. The display routine allows the user to display any one of the error levels by requesting a page number. A list of page numbers with their corresponding error power is presented in a sub-menu for the user to choose from. A hardcopy of the results can be requested along with the terminal display. The sub-menu command "ALL" allows the user to scroll through all the noise power level pages.

If the tabular display is requested, the first items are a list of the test and catalog elements mapped to a index number. The index numbers allows the tabular display format to maintain a compact matrix style. All information pertaining to the creation of the subsets (ie. target name, azimuth angle, elevation angle, and radar type) is displayed. The average power of each element in the test and catalog sets is also displayed in this listing.

An example listing of the tabular output of the identification display routine, for a single error power, is shown is figure 3.2.1.5.3-1.

****

Nearest-Neighbor "vector" distance measure:

TEST TARGET INDEX MAPPING

```
INDEX: 1  PLANE_1  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW =  7.78
INDEX: 2  PLANE_2  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 20.53
INDEX: 3  PLANE_3  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 20.53
INDEX: 4  PLANE_4  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 14.48
INDEX: 5  PLANE_5  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 23.41
```

CATALOG TARGET INDEX MAPPING

```
INDEX: 1  PLANE_1  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW =  7.78
INDEX: 2  PLANE_2  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 20.53
INDEX: 3  PLANE_3  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 20.53
INDEX: 4  PLANE_4  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 14.48
INDEX: 5  PLANE_5  AZ =  0 Deg  EL =  0 Deg  RADAR = HHP  AVER_POW = 23.41
```

Nearest-Neighbor "vector" distance measure:

Classification Table for Noise power = 25.00 DBSM

TT#/CT#	1	2	3	4	5	% MIS-CLASS
1	50	5	11	30	4	50.00
2	8	79	9	1	3	21.00
3	9	6	70	4	11	30.00
4	18	13	5	64	0	36.00
5	3	4	7	0	86	14.00

Average mis-classification percentage : 30.20 %

Mis-classification percentage is based on the test targets name.

Figure 3.2.1.5.3-2 DISPLAY command example

****

3.2.1.5.4 HELP

Similar to the HELP command of Section 3.2.1.4, but providing information pertaining to the identification menu only. Figure 3.2.1.5.4-1 shows the major identification help topics currently available to the user.

****

Information available:

DISPLAY GENERATE NEAREST

Figure 3.2.1.5.4-1 Identification HELP routine display

****

3.2.1.5.5 QUIT

The QUIT command allows the user to return to the main RSSE menu.

3.2.1.6 MAP

The MAP command allows the user to view the data entered into the data matrix. The MAP command also assigns an identification number to each element in the data matrix, thus allowing for easier generation of test and catalog sets (see Section 3.2.1.5.1). If the acquisition of any element requested for the data matrix fails in any part of the data acquisition routine, an asterisk is placed beside the corresponding element. Reasons for data acquisition error are listed in Table 3.2.1.6. An example of a map listing for a data matrix consisting of five plane, four azimuth angles, and three polarization types is shown in Figure 3.2.1.6-1. The map listing corresponds to the data matrix dispaly summary list of Figure 3.2.1.1-2.

****

ANGLE OR POLARIZATION TYPE REQUESTED ARE NOT IN THE DATA BASE
REQUESTED SCALED FREQUENCIES ARE OUTSIDE EXISTING DATA RANGE
HH, VV, OR VH COMPONENTS MISSING FOR THE CALCULATION OF CIRCULAR POLARIZATIONS

Table 3.2.1.6 Data Matrix Error Conditions

****

MAPPING OF THE DATA BASE

ID#	TARGET	AZ	EL	POL	
1	PLANE_1	0	0	HHP	
2	PLANE_1	15	0	HHP	
3	PLANE_1	45	0	HHP	
4	PLANE_1	0	0	VVP	
5	PLANE_1	15	0	VVP	
6	PLANE_1	45	0	VVP	
7	PLANE_1	0	0	RRC	
8	PLANE_1	15	0	RRC	*
9	PLANE_1	45	0	RRC	
10	PLANE_2	0	0	HHP	
11	PLANE_2	15	0	HHP	
12	PLANE_2	45	0	HHP	
13	PLANE_2	0	0	VVP	
14	PLANE_2	15	0	VVP	
15	PLANE_2	45	0	VVP	
16	PLANE_2	0	0	RRC	
17	PLANE_2	15	0	RRC	
18	PLANE_2	45	0	RRC	
19	PLANE_3	0	0	HHP	
20	PLANE_3	15	0	HHP	
21	PLANE_3	45	0	HHP	
22	PLANE_3	0	0	VVP	
23	PLANE_3	15	0	VVP	
24	PLANE_3	45	0	VVP	
25	PLANE_3	0	0	RRC	
26	PLANE_3	15	0	RRC	
27	PLANE_3	45	0	RRC	
28	PLANE_4	0	0	HHP	
29	PLANE_4	15	0	HHP	
30	PLANE_4	45	0	HHP	
31	PLANE_4	0	0	VVP	
32	PLANE_4	15	0	VVP	
33	PLANE_4	45	0	VVP	
34	PLANE_4	0	0	RRC	
35	PLANE_4	15	0	RRC	
36	PLANE_4	45	0	RRC	
37	PLANE_5	0	0	HHP	
38	PLANE_5	15	0	HHP	*
39	PLANE_5	45	0	HHP	
40	PLANE_5	0	0	VVP	
41	PLANE_5	15	0	VVP	
42	PLANE_5	45	0	VVP	
43	PLANE_5	0	0	RRC	
44	PLANE_5	15	0	RRC	*
45	PLANE_5	45	0	RRC	

NOTE -> * indicates feature does not exist

Figure 3.2.1.6-1 Illustration of MAP output

****

3.2.1.7 PLOT

The PLOT command allows the user to initialize the plot devices in ESL plotting libray. Potting commands such as device number, metafiling, and hardcopy unit, are present in this routine to eliminate the repetitious nature of the ESL plotting library for multi-device use.

3.2.1.8 $ DCL COMMAND

The $ DCL command allows the user to execute VAX/VMS DCL (direct command language) statements [4] without terminating the program session.

3.3 SPECIAL FUNCTION STATEMENTS

Some special functions statements have been included in the RSSE program to allow the user to manipulate the program in a easier fashion.

The first special statement is the "REDO" command. It allows the user to return to the top level of a nested entry loop. The nested entry loops always begin with the top entry command "ENTER IN THE NUMBER OF XXXXX". If REDO in entered in any of the following nested prompts, the user will return to the top entry command.

The second special statement command allows the user to execute a VAX/VMS COMMAND file [9], stop it, and then restart it again from an interactive terminal. The command file is stoped by the statement "QCOM", placed anywhere in the command file. The statement "GOCOM" enables the command file to resume at the prompt where the user enters the GOCOM statement.

3.4 NESTING OF MAJOR SUBROUTINES

```
                              RSSE

CREATE      DISPLAY      EXPERIMENT      HELP      MAP      MENU      PLOTPACK
  CKBASE      POLFIND      SUBSETS
  POLTYPES                   ARBITRARY
  DISPLAY                      LOADIT
    POLFIND                      SETGET
  ALLOCATION                     ALLOCATE3
  MATRIX                         ENTER_VALUES
    CALCP                      LIST
      DB_READ                    INDEXIS
      SCALE                  CHKTHREE
    LINEAR                   POL_DIVERSE
      DB_READ                  AXIAL
      SCALE                    LINEAR_RATIOS
    POLFIND                    AVAILABLE
                               ALLOCATE3
                               CONCAT
                               AXRAT_CAT
                               HHVV_RATIO
                               COMPLEX_SUM
                           IDENTIFY
                             ALLOCATE2
                             CLEAR_TABLE
                             NEAREST_NEIGHBOR
                               CORRUPT_TEST_SET
                                 CORRUPT
                                 AXL_RATIO
                                   CORRUPT
                                 HH_VV_VH_RATIOS
                                   CORRUPT
                                 SUM_COMPLEX
                                   CORRUPT
                               DISTANCE
                               TABULATE
                           DISPLAY_RESULTS
                             INDEX_LIST
                               INDEXIS
                               POLFIND
                               NEW_POL
                             TABLE_PRINT
                               MISS_PERCENTAGE
                             TEXT_PRINT
                               INDEXIS
                               POLFIND
                               NEW_POL
```

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