WL-TR-1997-7053

Millimeter Wave Reflectivity Measurement System (MRMS) Data Acquisition Controller Upgrade

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DECEMBER 1996

FINAL REPORT FOR PERIOD FEBRUARY 1993 - DECEMBER 1996

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FOR THE COMMANDER

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
16 December 1996

3. REPORT TYPE AND DATES COVERED
Final Feb 93 - Dec 96

4. TITLE AND SUBTITLE
Millimeter Wave Reflectivity Measurement System (MRMS) Data Acquisition Controller Upgrade

5. FUNDING NUMBERS
PE: 62602F
PR: 2068
TA: 20
WU: 09

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Wright Laboratory, Armament Directorate
Advanced Guidance Division
Munition Sensor Technology Branch (WL/MNGS)
101 W. Eglin Blvd., Ste. 287
Eglin AFB FL 32542-6810

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
WL/MNGS
101 W. Eglin Blvd, Ste. 287
Eglin AFB FL 32542-6810

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
WL-TR-1997-7053

11. SUPPLEMENTARY NOTES

Availability of report is specified on verso of front cover.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Millimeter Wave Reflectivity Measurement System (MRMS) is used by researchers to investigate the basic phenomenology, to verify theoretical models, and to assess the effectiveness of actual countermeasures of various materials for target scattering at millimeter wave (MMW) frequencies. The data acquisition portion of the MRMS was constructed using a Hewlett-Packard (HP) 310 computer as the system controller. The data acquisition controller was difficult to operate because its operating system and disk formats were quite different from personal computer (PC) operating system the engineer or scientist was accustomed to using. Off-the-shelf PC products are readily available. There is extensive in-house programming expertise for the PC which is not the case with the HP computer. The limitations with the HP computer-based controller hampered the ability of the MRMS to be an effective tool and meet the needs of the engineer and scientist. The decision was made to switch to a PC-based controller. This would provide software and hardware maintainability, portability, and upgradability; ease of use by engineers and scientists; thus, improving the MRMS capability to be an effective research and verification tool. This report describes the development of the PC-based data acquisition controller for the MRMS.

14. SUBJECT TERM

Millimeter Wave, Target Scattering, Countermeasures, Material Characteristics, Bistatic

15. NUMBER OF PAGES
28

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

PREFACE

This report covers work done under the MMW Research Laboratory Project (20682014) which supports the MMW Phenomenology, Analysis, and Modeling Project (20682009). Project 20682014 is directed by Mr. Darryl G. Huddleston, WL/MNGS. Project 20682009 was directed by Lt Col Keith D. Trott, WL/MNGS.

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I. Background

WL/MNGS personnel determined there was a requirement for a tool to collect data within the MMW frequency band for an in-house quick-look capability. The Millimeter Wave Reflectivity Measurement System (MRMS) was developed to provide such a tool for engineers and scientists to investigate the basic phenomenology of target scattering at MMW frequencies. The system is used to verify theoretical models as well as assess the effectiveness of actual countermeasures of various materials. (Reference 1)

The data acquisition portion of the MRMS was constructed using an HP 310 computer running HP BASIC, as the controller. The computer was connected to HP equipment over the HP Interface Bus (HPIB). The system worked properly, however, the operation of the computer was quite different from the personal computers (PC) the engineer or scientist was accustomed to using. This made it difficult to start the system and execute the controller software. Another problem was the lack of hardware and software upgradability. The HP computer is not compatible with either Apple or IBM compatible PCs, nor are hardware and software upgrades readily available off-the-shelf. Also, data processing and analysis software isn't available for the HP computer. These limitations and problems made it difficult to collect, process, and analyze MRMS data. A lack of knowledge of the HP BASIC programming language made upgrading the acquisition software difficult and time consuming. These problems hampered the capability of the MRMS, now and in the future, to be an effective tool and meet the requirements for which it was designed. After a thorough evaluation, the decision was made to switch to a PC based controller. This would provide software and hardware maintainability, portability, and upgradability. The ease of use would give the engineers and scientists an effective research and verification tool.

This report describes the development of a PC based data acquisition controller for the MRMS. The following chapters describe the hardware comprising the MRMS, the design and development of the controller software, lessons learned during the software development, and future upgrades to the software.

II. Hardware

1. Data Acquisition Hardware

Figure 1 shows the original hardware configuration, while Figure 2 shows the current hardware configuration. The difference between the two is the controller and support hardware. There has been no change to the data acquisition hardware. The data acquisition portion of the MRMS consists of a scalar network analyzer, a sweep oscillator, an RF source module, and an RF detector. These pieces of equipment generate, transmit, and receive the MMW signals. Table 1 lists the equipment, function, and capability (Reference 1).

Table 1 - Data Acquisition Hardware

Equipment	Function	Capability
HP 8350B	Sweep Oscillator	Generates sweep waveform, the range is determined by the plug-in. Communicates over an system interface with the HP 8757C. Sends commands through the HP 8757C.
HP 8757C	Scalar Network Analyzer	Plots amplitude vs. frequency (401 points). Normalizes data and stores in memory. Communicates over the HPIB.
HP 11664D	RF Detector	Detector for AC modulated signal. Sensitivity of -50 dBm. Overall dynamic range of 40 dB.
HP 83550A	HP 8350B Plug-in	Generates 13.25 - 20 GHz of swept frequency at 15 milliwatts.
HP 83554A	Ka-band Source Module	Upconverts signal with X2 multiplier to produce an output frequency range of 26.5 - 40 GHz. Levels power at +7 dBm.
HP 83558A	W-band Source Module	Upconverts signal with X6 multiplier to produce an output frequency range of 75 - 110 GHz. Levels power at 0 dBm.

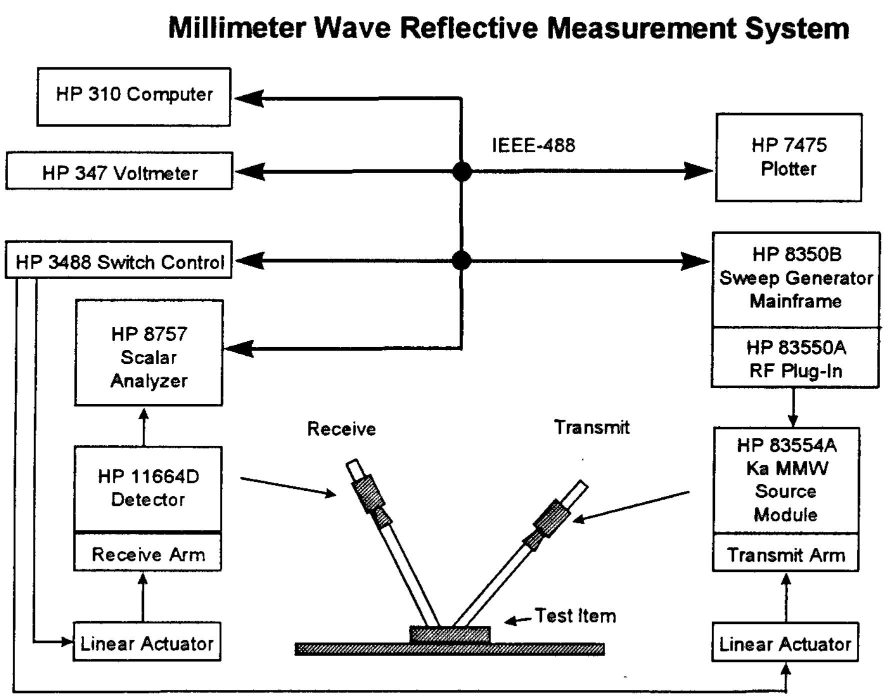

Figure 1 MRMS Hardware Layout (Old)

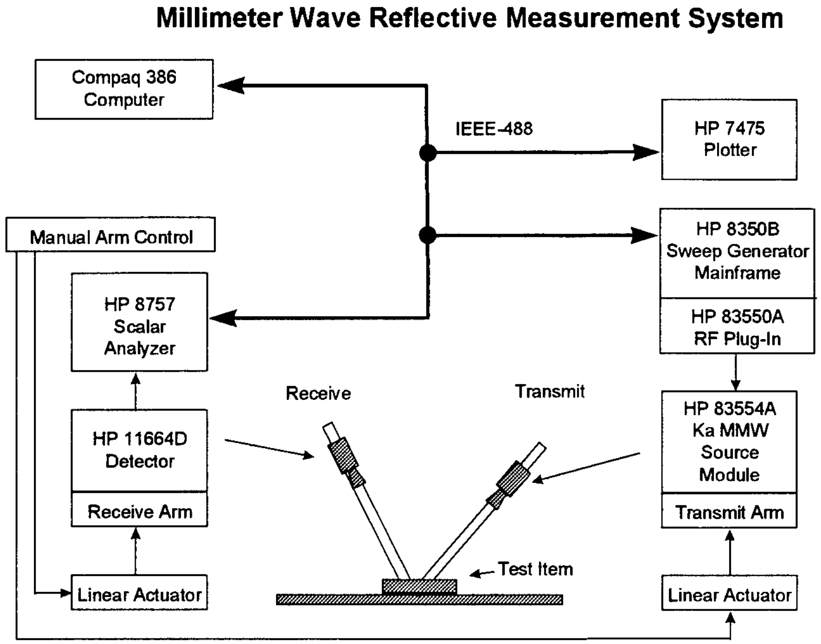

Figure 2 MRMS Hardware Layout (New)

2. Controller Hardware

The data acquisition controller hardware consists of a PC connected to the data acquisition hardware. Communication between the PC and the data acquisition equipment occurs over the HP Interface Bus (HPIB), which is also known as the General Purpose Interface Bus (GPIB) or IEEE-488 bus. The HPIB is a standard port on the HP equipment. As delivered, PCs do not have the ability to communicate over the GPIB. They come with COM and LPT ports which are not compatible with the GPIB; however, there are off-the-shelf boards available to provide PCs with GPIB capability. The controller software was developed on a Micronics 386 to be operated on a COMPAQ 386.

Table 2 - PC Characteristics

	Micronics	COMPAQ
Processor	386DX	386DX
IEEE-488 Card	AT-GPIB	AT-GPIB
Purpose	Development	Operations

3. Support Hardware

The MRMS support hardware consists of the test stand and the equipment to move the arms, along with the devices used to produce hardcopies of the data. Figure 3 is a picture of the MRMS test stand. Table 3 lists each piece of equipment and its function (Reference 1).

Table 3 - Support Hardware

Equipment	Function
HP 3457	Voltmeter measures the position voltage and sends a digital reading to the controller.
HP 3488	Switch controller. Receives commands over the GPIB. Controls the movement of the antenna arms.
HP 7475A	Color plotter
HP 44470A	HP 3488 Plug-in (Multiplexer)
HP 44471A	HP 3488 Plug-in (General Purpose Relay).
Laser Printer	HP LaserJet II compatible printer.
Linear Actuators	Driven by DC motors to move the antenna arms. Voltage applied across potentiometer to determine arm position.
Test Stand	Houses the device under test, antennas, source modules, and linear actuators.

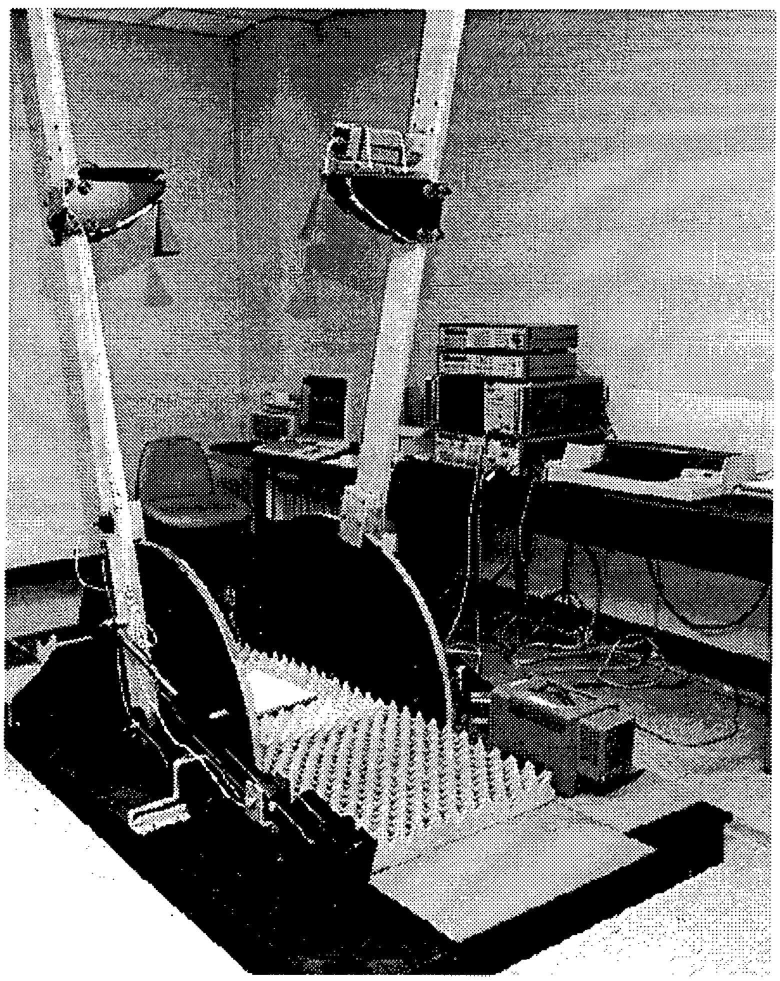

Figure 3 - MRMS Test Stand

III. Software

1. Description of Original Software

The purpose of the MRMS control software is to provide an automated method for operating the acquisition instruments and collecting data. The hardware comprising the MRMS was described in the previous section. The software was written to control the data acquisition equipment using an HP 310 computer as the host controller. Commands and data are transferred between the host computer and the acquisition equipment over the HP Interface Bus (HPIB). This bus is also known as the General Purpose Interface Bus (GPIB) or the IEEE-488 bus. The software was written using the HP BASIC, version 5.0, programming language. The software enabled the user to control the acquisition parameters, acquire and display data, save data to disk, retrieve data from disk, move the arms on the MRMS test stand, and output data to a plotter.

2. Software Development Environment

The new MRMS controller software was developed on the Micronics 386 PC described in the previous section. Several other software packages made up the software development environment. The software was written using the Microsoft C/C++ Version 7.0 programming language. The graphical user interface capability was written using the National Instruments' LabWindows Version 2.2 development package. The final software package provided the control and communication of the IEEE bus by using the National Instruments' IEEE-488 Software Driver.

3. Design

3.1 Constraints/Limitations

The underlying requirement for the upgraded software was that it must provide the same functionality and capability as the original software; therefore, the original software was the starting point for designing and developing the PC based control software. Two constraints of the design of the original software were (1) taking either 1 or 5 measurements for a single test, and (2) if the source modules frequency range were 75 to 110 GHz, then acquisition range was set at 90 to 100 GHz. The limitation of 401 data points was driven by the capability of the HP 8757C Scalar Network Analyzer. Each of these constraints and limitations were found in the original software. Additional constraints were placed upon the upgraded software.

The original waveform display, along the x-axis, showed the frequency values in units that were not practical to the engineer and scientist. The constraint of having a resolution value to tenths of a GHz was placed on the software. For example a displayed frequency of 93.307 GHz was not acceptable, but a displayed value of 93.3 GHz was acceptable. Another area requiring clarification was data retrieval. When retrieving data, either the acquisition parameters could be changed to those of the retrieved data, or they could be left at the present values. The advantage of changing the parameters is so the user can review and acquire more data with those same parameters without having to manually change them. The disadvantage is that if the user simply wanted to review data for one set of parameters and then continue acquisition with another set of parameters, they would have to manually change the parameters. It was decided to not change the acquisition parameters upon retrieving data. Also, an effort was made to reduce communication over the GPIB. Our approach was to check the new acquisition parameters against those previously sent to the HP 8350B Sweep Oscillator. If a parameter was the same, it was not resent; thus, only changed parameters were sent to the Sweep Oscillator. A final constraint was to match the waveform colors on the plotter to the waveform colors on the screen.

The data files will all have the extension *.dat. This allows a user to easily identify data files versus other types of files.

Table 4 lists each device and the required GPIB parameter value.

Table 4 - GPIB Parameter Values

Parameter	HP 8757C	HP 8350B	HP 7475A
GPIB Device Name	HP8757	HP8350	DEV5
Primary GPIB Address	16	17	5
Secondary GPIB Address	NONE	NONE	NONE
Timeout Setting	T10s	T10s	T10s
EOS Byte	00H	00H	00H
Terminate Read on EOS	no	no	no
Set EOI with EOS on Write	no	no	no
Type of compare on EOS	7-bit	7-bit	7-bit
Set EOI w/last Byte of Write	yes	yes	yes
Repeat Addressing	no	no	no

3.2 Assumptions

Some assumptions were made during the design of the controller software. These assumptions helped to reduce the complexity of the code, thus reducing the time needed to design and develop the software. The first assumption was there was no need to trap IEEE errors. The dilemma with this assumption is assuming there will not be any problems. The reason for this assumption is that the GPIB has worked properly and that errors were generally not the result of the GPIB, but the commands sent over the GPIB. The other assumption was that LabWindows would handle any I/O errors, such as printing problems; therefore, the software did not need to check.

3.3 Capabilities/Functions

Some capabilities were lost in the upgrade, which is contrary to the underlying constraint. The two capabilities lost were (1) movement of the MRMS arms, and (2) the Hi/Low plot mode. The reason for not including the arm movement capability was the user found it easier to move the arms manually. In fact, the HP 3457 Digital Voltmeter and the HP 3488 Switch Controller were removed from the MRMS; thus, there was no hardware for the software to control. A software stub was placed in the code so, if in the future, the capability was wanted, it would be easy for the programmer to include this capability. The reason for deleting the Hi/Low plot mode was it provided no new information beyond the other two plot modes; thus, it was decided to not include this plot mode in the upgraded software.

A number of new capabilities were added to the upgraded software. The option to print the plots to a laser printer versus the HP plotter was added to the user interface. Thus, the user has the choice of sending plots to a color plotter, or a black and white laser printer. Another additional capability is the calculation of the mean and standard deviation for each displayed waveform. This provides the user with additional information which can be used for quick-look analysis and comparisons. The original software did not display the filename of saved or retrieved data, nor did it display which plot mode was active. The display of this information was added to the title of the displayed data in the upgraded software. Two major capabilities added were the graphical user interface, and data storage in PC format. The graphical user interface allows the user to simply point 'n' click using a mouse. This makes it easier for a user to operate the MRMS data acquisition system. By saving data in PC format, a user can merely copy the data to diskette and take it to another computer for further processing and analysis. Table 4 shows the format for saved data. In order to retrieve data, it must be in exactly the same format.

Table 5 - File Format

File Entry	Description
WAVEFORMS= %d	Contains the number of waveforms in the file
START-FREQ(GHz)= %f	States the starting acquisition frequency
STOP-FREQ(GHz)= %f	States the ending acquisition frequency
WAVEFORM#%d	Indicates which waveform's data follows
%f,	Floating-point data value followed by a comma

As stated previously, the underlying constraint on the upgraded software was it had to provide the user with the same capabilities. Table 5 lists the functions from the original MRMS data acquisition software. These were the basis for the design of the upgraded MRMS software. As stated, additional capabilities were added to the upgrade and only the arms function was not implemented, though it was included in the design.

Table 6 - User Capabilities

Function	Description
Arms	Move the MRMS arms
Change Parameters	Change the acquisition parameters
Measure	Take a measurement
Display Envelope	Plot the envelope waveforms on the screen
Plot Data	Plot the waveform
Display Raw	Plot the raw waveforms on the screen
Print Data	Print the waveform
Quit	Quit the program
Retrieve	Retrieve data from a previously measured file
Save	Save data to a file

3.4 User Interface

The heart of the upgrade is the use of a graphical user interface (GUI). With the use of a mouse, the user is provided with point 'n' click capability to provide a user-friendly operating environment. The basis for the design and development of the GUI are the functions listed in Table 6. Examining the functions, the main function is taking a measurement and supporting interface for the data display functions. The other functions support the measurement function. Thus, the design of the GUI centered around data display. The rest of the options could be buttons or menu options. These buttons or menu items could open other screens for further inputs. The following functions required further inputs: Change Parameters, Retrieve, Save, and Arms. Obviously for the Change Parameters function the user needs to enter the new parameters. For the Retrieve and Save functions the user would need to enter a file name. The user would have to enter the new angles for the Arm function, if it were implemented. The remainder of the functions simply need to be executed without user input.

4. Development

4.1 Data Structures

This section discusses the main data structures used in the software. Not all variables are listed here since each variable has an associated comment, in the code, describing its role. There are two constants which are used in the data structure definitions. They are (1) NUM_SWEEPS and (2) NUM_PTS. NUM_SWEEPS denotes the maximum number of sweeps allowed, currently set at 5. NUM_PTS denotes the number of data points per measurement. Maximum number of points is 401.

Three important variables contain the addresses of each GPIB device. They are: (1) "board" which is the address of the GPIB board in the PC, (2) "sna" which is the address of the HP 8757 Scalar Network Analyzer, and (3) "passthru" which is the address of the HP 8757's pass through mode, the HP 8350 Sweep Oscillator. Without this information, the software would not be able to communicate with the data acquisition hardware. These are defined as global variables. Most functions need access to this information and it would be time consuming and confusing to pass them as function parameters.

There are four data structures which hold the waveforms and two which hold information about the waveforms. Table 7 lists each of these global variables along with the data type, array sizes, and purpose.

Table 7 - Waveform Data Structures

Variable	Array Size	Precision	Description
data_avg	[NUM_PTS]	double	Average waveform of 5 sweeps
data_max	[NUM_PTS]	double	Maximum, point-by-point, waveform
data_min	[NUM_PTS]	double	Minimum, point-by-point, waveform
mean_data	[NUM_SWEEPS+1]	double	Mean value of each sweep
std_dev	[NUM_SWEEPS+1]	double	Standard Deviation of each sweep
sweep_data	[NUM_SWEEPS+1][NUM_PTS]	double	Data for each sweep

Another data structure included in this section is the one which contains the data read from the HP 8757 Scalar Network Analyzer. That data structure is aptly named "data." It is declared as a string of 4000 characters. The data from the HP 8757 is output as ASCII data in the form of sDD.DDD, where s is the sign, D is a digit, and the comma following the last D separates each data point. This is read into a single string and then transferred to the appropriate entry into sweep_data using a LabWindows construct.

4.2 Software Engineering

Software engineering principles were used during the design and development of the MRMS software upgrade, such as modular code and documentation. The original code, written in HP BASIC, can best be described as "spaghetti" code. The advantage of newer programming languages is they provide the means to modularize code by providing functions and subroutines. This does not force a programmer to use these constructs; however, they must make a special effort to employ them. During the design and development of the upgraded software, that effort was made. The reason to modularize code is it makes it easier to understand, maintain, and upgrade. A programmer does not have to spend hours trying to figure out what the code is doing, or hours trying to debug it. By modularizing the code with clear and meaningful variable and subroutine names, a programmer can, within a few minutes, know the flow of the software. Another principle employed was code documentation.

Not only is this technical report fulfilling this requirement, extensive documentation was included within the code. These comments not only described the operation of the code, but also indicated where problems had occurred and their solution. Thus another programmer will not only understand the operation of the software, but also where previous pitfalls were encountered.

4.3 Functions

Table 6 in the design section lists the functions needed to provide the user with the same capabilities as the original software. As the software developed, a number of user options were added which further defined those of Table 6. Table 8 is a comprehensive list of the user options found in the newly developed user interface.

Table 8 - User Interface Options

Menu Item/Button	Description
Arms	Move the MRMS arms
Auto Scale	Auto scale the display
Change Parameters	Change the acquisition parameters
Change Scale	Change the amplitude scale on the display
Measure	Take a measurement
Plot Envelope	Plot the envelope data on the screen
Plot Graph	Send the graph to the plotter
Plot Panel	Send the panel to the plotter
Plot Raw	Plot the raw data on the screen
Print Graph	Send the graph to the printer
Print Panel	Send the panel to the printer
Quit	Quit the program
Retrieve	Retrieve data from a file
Save	Save data to a file

Additional functions are simply expanded definitions needed to provide the user with a friendly and useful interface. They allow the user to easily change the displayed waveform or select the type of output. The difference between selecting a graph or a panel is the graph selects only the plot, while the panel selects the entire screen. The next section describes the user interface and each of the screens presented to the user.

The following paragraphs describe each of the routines that comprise the execution level of the software. These functions are called by the user interface routines. They are listed in the order they occur in the code.

4.3.1 main

This is the main routine for the MRMS data acquisition system. It handles the user input and calls the corresponding routines. The "Welcome" screen is displayed while the init_system subroutine is executed. Upon completion the "Main" screen is displayed. The file mrms.uir contains the information needed to display the screens. The code then waits for user input. There are two types of inputs: user selected a menu item, or a pressed button. The plot envelope function first clears previous plots then, if five sweeps were taken, plots the average, minimum, and maximum waveforms. Next, the mean and standard deviations for the three waveforms are displayed with zeros in the last two waveform data areas. The labels are changed to reflect the type of waveform display. If only one sweep was taken, the raw waveform is plotted, with its associated mean and standard deviation. The quit option clears the HP 8757C Scalar Network Analyzer and puts the analyzer into local mode, then control of the GPIB is released and the PC's IEEE card is disabled. There are no input or output parameters for the main routine.

4.3.2 init_system

This subroutine initializes the MRMS data acquisition system. First the GPIB must be initialized and control taken, also the HP 8757C Scalar Network Analyzer is cleared which ensures it is ready to accept IEEE-486 bus control. The Scalar Network Analyzer is then initialized and the start and stop frequencies from the HP 8350B Sweep Oscillator are read. The values are converted from text values in Hz to floating point values in GHz. Abiding by the hardware constraint, if the start frequency is 75.0 GHz, it is changed to 90.0 GHz; likewise, if the stop frequency is 110.0 GHz it is changed to 100.0 GHz. Upon completion of pass through mode, talking to the Sweep Oscillator, a blank command is sent to the Scalar Network Analyzer which takes it out of pass through mode. There are no input or output parameters for the init_system subroutine.

4.3.3 change_params

This subroutine is used to change the parameters for the MRMS system to acquire data. The "Change Parameters" screen is displayed for the user to enter the new parameters. If the user pressed the "Cancel" button, the routine is exited without making any changes. If the "Done" button was pressed then each parameter is checked. If it is the same as the previous value nothing happens. If it has been changed, the value is updated and sent to the Sweep Oscillator if needed. The frequency parameters are checked to ensure they are not out of bounds for the device and the stop frequency is greater than the start frequency. There are no input or output parameters for the change_params subroutine.

4.3.4 measure

This subroutine commands the MRMS system to acquire data. The data display is cleared as an indication the system is in the acquisition mode. The HP 8757C is sent commands to begin the acquisition process. The user is prompted before each measurement, and must press OK before the measurement is taken. First a reference measurement is taken which is subtracted from each data measurement. A loop is executed which takes the data measurement, transfers it to the PC, converts it from string to floating-point, and stores it in the sweep_data data structure. The loop corresponds to each sweep. After all the data is collected, the process_data subroutine is called, then the raw data is displayed by the plot_raw_data subroutine. There are no input or output parameters for the measure subroutine.

4.3.5 process_data

This subroutine processes the data. First the mean and standard deviation are calculated for each waveform. If more than one sweep was taken then three other waveforms are calculated which are: (1) minimum, (2) maximum, and (3) average. These waveforms are calculated point-by-point. Finally the mean and standard deviation are calculated for the minimum, maximum, and average waveforms. There are no input or output parameters for the process_data subroutine.

4.3.6 minimum

This subroutine will return the minimum value for the five values sent. The input and return parameters are floating-point.

4.3.7 maximum

This subroutine will return the maximum value for the five values sent. The input and return parameters are floating-point.

4.3.8 retrieve_data

This subroutine will read data from a file. The "Retrieve Data" screen is displayed which allows the user to change disk drives, directories, and select a file. If the file is found and opened, the header is read, followed by the data. Table 6 shows the format for the data file. Next, the file name is extracted, by calling the extract_filename subroutine, since the variable filename actually contains the entire path. This file name is placed in the title of the data display. Finally, the subroutine process_data is called. There are no input parameters, but the status of the retrieve operation is returned. If the status is good, the data is displayed by calling plot_raw_data from the retrieve section of the main routine.

4.3.9 save_data

This subroutine saves the data to a file on a disk. Like the retrieve_data subroutine, a screen is displayed which allows the user to change disk drives, directories, and enter a file name. If the file already exists, the user is given the choice of overwriting it. The user remains within this routine until either the save is completed, or the user has pressed the "Cancel" button. When saving data, the header is written followed by the data. Table 6 shows the format for the data file. There are no input or output parameters for the save_data subroutine.

4.3.10 extract_filename

This subroutine will extract the filename from a full path. The full path is the input parameter. There is no output parameter. The file name is stored in a global variable, file_name. A global variable is used because this information is needed by each of the data plot routines.

4.3.11 plot_raw_data

This subroutine plots the raw data. It is a separate function so that other functions such as retrieve, measurement, and the plot button can all access this capability. The first action is to clear out the displayed waveforms. Then each of the waveforms with associated mean and standard deviation are displayed. If there was only a single waveform, zeros are displayed in the windows for the other waveforms. There are no input or output parameters for the plot_raw_data subroutine.

4.3.12 move_arms

This is the stub for the function to move the MRMS test stand arms. It currently performs no operation, but is a place holder should this function be desired in the future. There are currently no input or output parameters for the move_arms function call.

4.4 Graphical User Interface

The heart of the upgrade is the graphical user interface (GUI) furnished by LabWindows. LabWindows provides an easy method for developing a GUI which is itself a GUI. The developer has menu options for creating screens and placing buttons, screens, and text on the screen. The developer uses point 'n' click for the placement of the items on the screen and is presented supplementary screens for those items which require additional parameters. Figures 4-8 show each of the MRMS GUI screens. Figure 4 is the screen displayed while the system is initialized. After initialization, the "Main" screen, Figure 5, is displayed. When the user selects the change parameters menu option, the screen in Figure 6 is displayed. The "Save Data" screen, Figure 7, is displayed when the user has selected the save menu option. If the user selects the retrieve menu option then the "Retrieve Data" screen, Figure 8 will be displayed.

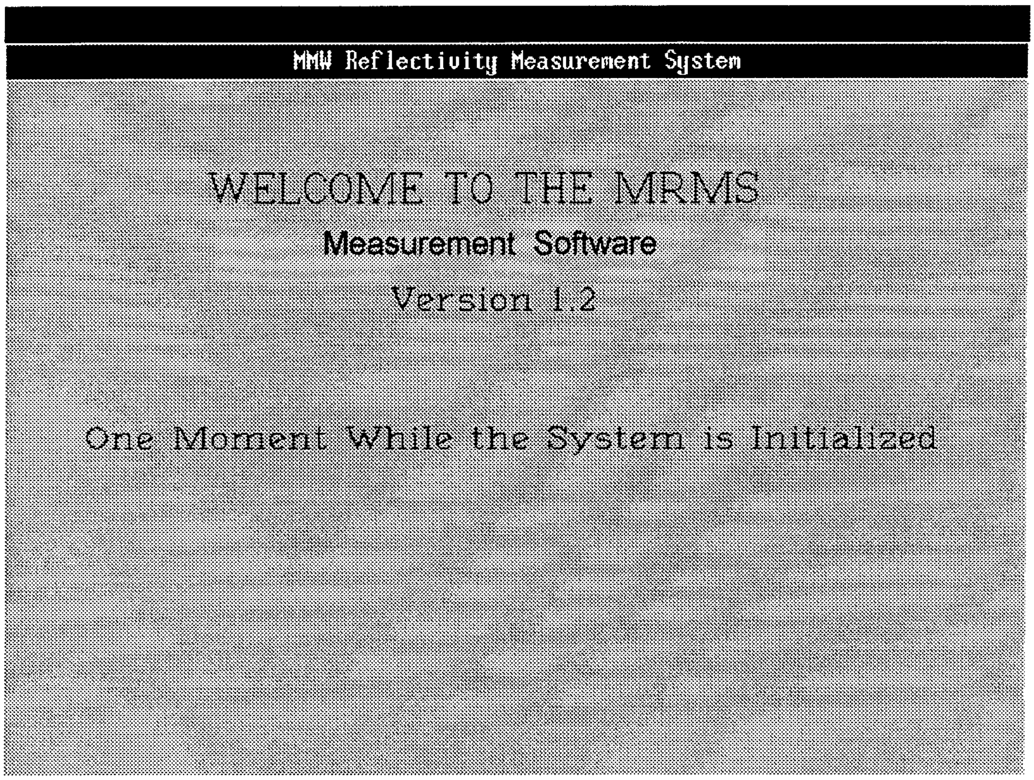

Figure 4 - Welcome Screen

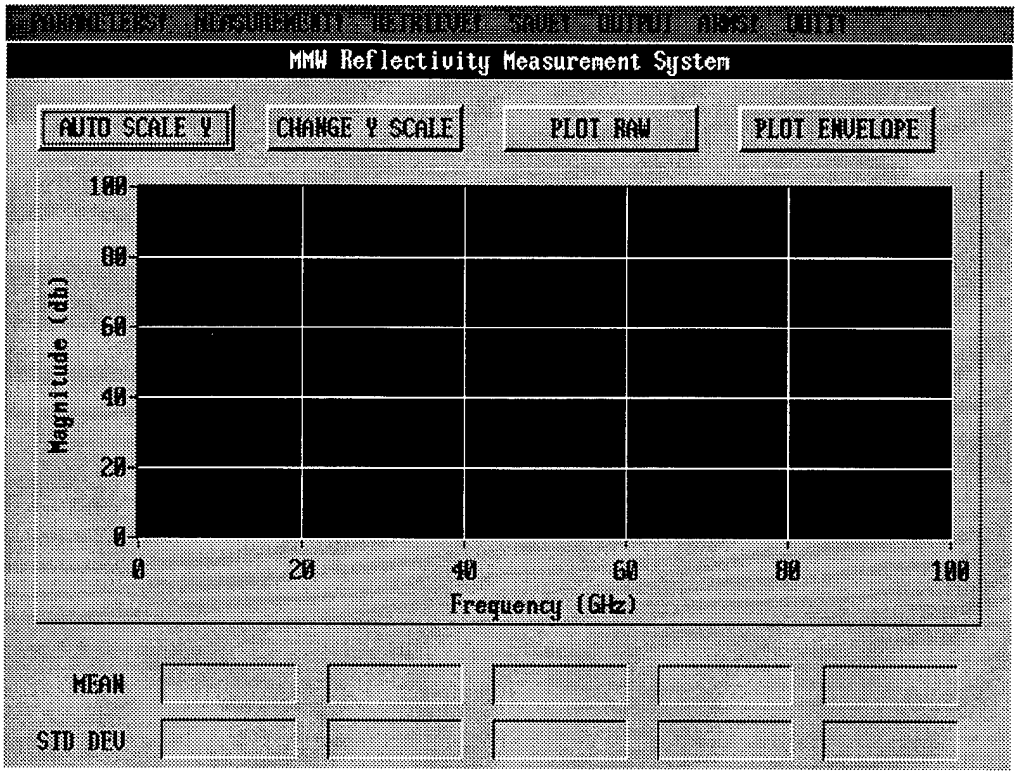

Figure 5 - Main Screen

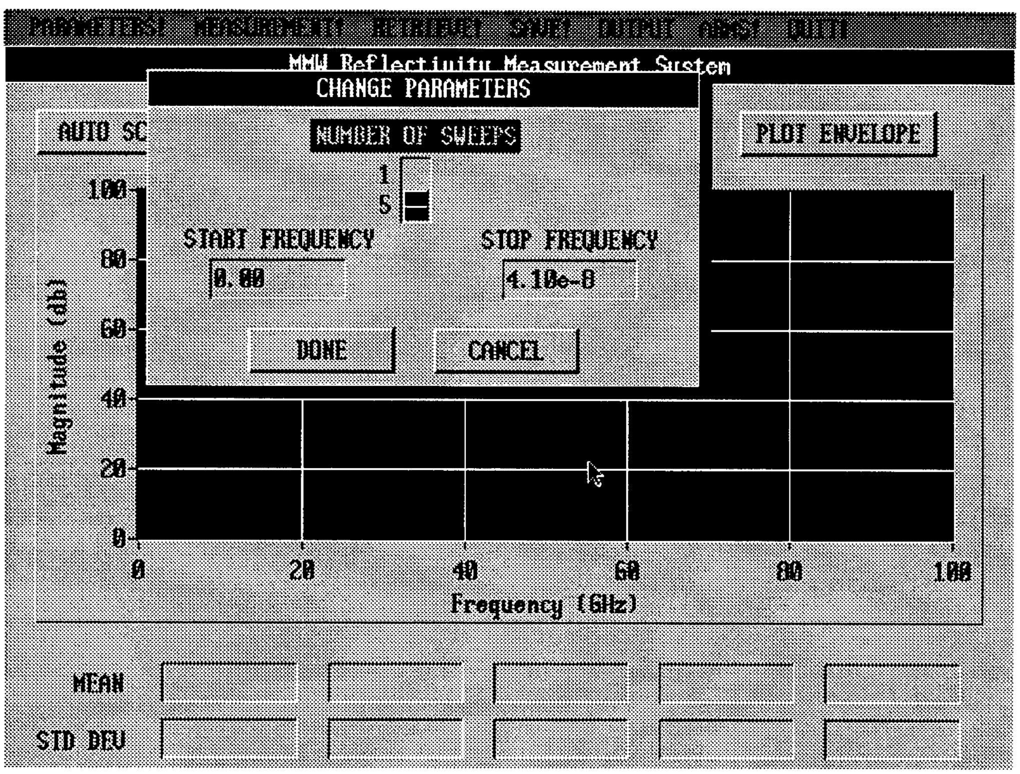

Figure 6 - Change Parameters Screen

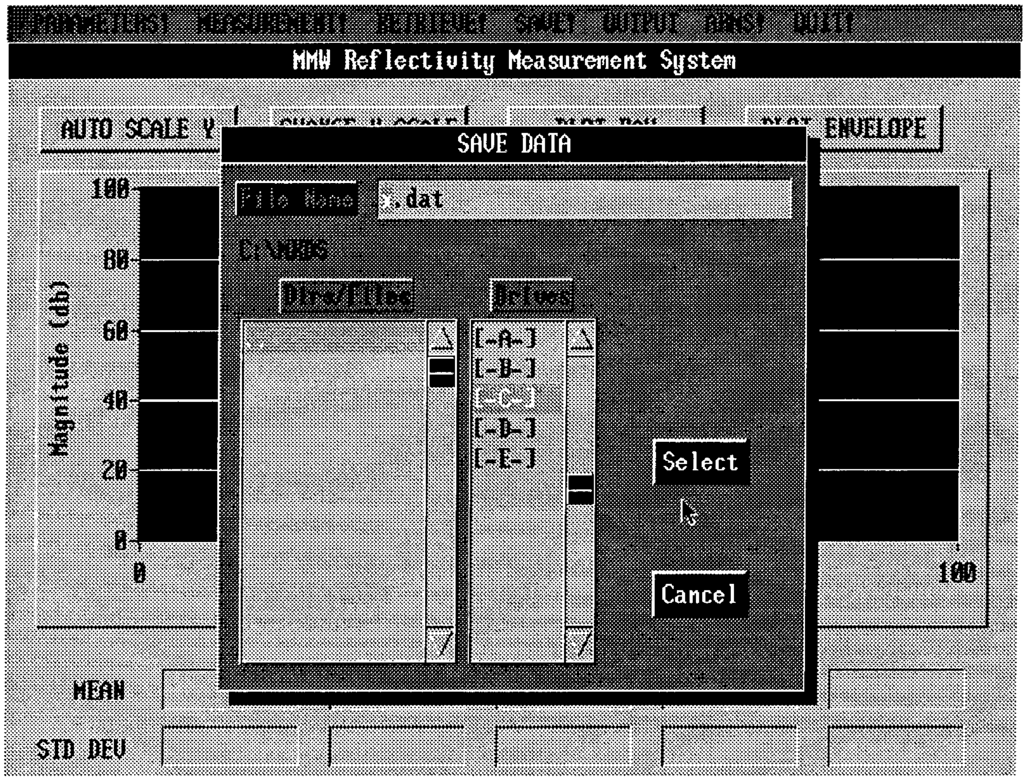

Figure 7 - Save Data Screen

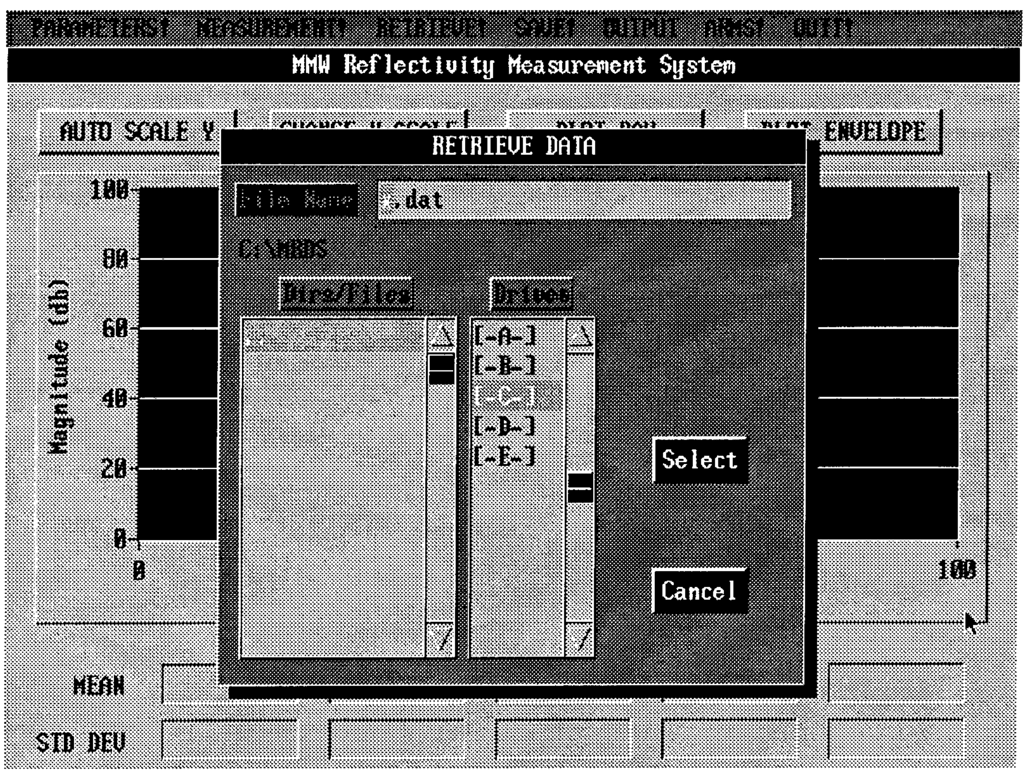

Figure 8 - Retrieve Data Screen

The user is not limited to the mouse. The keyboard can still be used. For the menu options the user can press the Alt key while, at the same time, pressing the first letter of the option. Within each screen, the user can press the TAB key to move between input fields and/or buttons.

4.5 IEEE Communication

Communication between the PC controller and the HP data acquisition equipment is over the GPIB. The software sends commands that the equipment executes. Table 9 lists each of the commands, its function, the device to which it is sent, and the routine sending the command. Refer to either the software, the HP 8757C User's Manual (Reference 4), or the HP 8350B User's Manual (Reference 5) for the exact format of each command.

Table 9 - HP Equipment Commands

HP Command	Description	Device	Routine
C0	Turn off Active channel	HP 8757C	init_system
C1	Channel 1 On and Active Channel	HP 8757C	init_system measure
C2	Channel 2 On and Active Channel	HP 8757C	init_system
FA	Change Start Frequency	HP 8350B	init_system change_params
FB	Change Stop Frequency	HP 8350B	init_system change_params
FD0	Format Data ASCII sDD.DDD,	HP 8757C	measure
FI0	CW filter Off (8350A)	HP 8350B	init_system
IP	Instrument Preset	HP 8757C	init_system
M-	Display normalized data	HP 8757C	init_system
ON	Output Normalized Data	HP 8757C	measure
OPFA	Output Start Frequency	HP 8350B	init_system
OPFB	Output Stop Frequency	HP 8350B	init_system
PT19	Pass Through Address = 19	HP 8757C	init_system
RF0	RF Power Off	HP 8350B	measure
RF1	RF Power On	HP 8350B	measure
SD10	Scale = 10 units per division	HP 8757C	init_system
SM	Store Measurement Data in Memory	HP 8757C	measure
SV1	Save settings to register 1	HP 8757C	init_system

5. Compilation/Linking/Execution

LabWindows provides two ways of executing the user program. One way to run the program is from within the LabWindows programmer's interface. This provides the developer a debugging environment for program development and testing. The second way is by compiling the source code into an executable program that does not require LabWindows. This method is the preferred way to take debugged code to other computer systems for execution. The source can be compiled in the LabWindows programmer's interface or by using the DOS based LabWindows program LWMAKE. Both methods result in a .exe program file.

LabWindows uses predefined file name extensions on the programs to identify the program type. The file types and their purpose are listed in Table 10.

Table 10 - Files Types Used

File Extension	Description
.app	Build Executable Information, used by lwmake
.c	Source Code
.exe	Executable
.h	C code header file
.mak	Make file information
.uir	User Interface Resource (GUI Information)

To execute the MRMS control software two files are needed. The user executes the *.exe file which uses the *.uir file. Without the *.uir file, the software will report it cannot load the user interface and will exit.

6. Problems Encountered

A number of problems were encountered during the development of the MRMS upgraded control software. The following paragraphs document the problems and the solutions.

The first problem encountered was with the HP 8757C Scalar Network Analyzer. The GPIB status lights on the front of the device indicated it never went into remote mode; thus, it was not reading information off the GPIB. One of the GPIB lines, Remote Enable (REN), was not going active. The solution was to send an activate REN command to the GPIB controller ,the National Instruments GPIB card in the PC. The command sent was *ibsre(board, 1)*, where the variable board is the GPIB address of the IEEE card. (Reference 3)

Another problem encountered was that neither the Scalar Network Analyzer nor the Sweep Oscillator was returning data when commanded. After reviewing the user's manuals for each of the devices, it was discovered that a carriage return and a line feed were needed at the end of every command. Once these characters were appended to each command, data was returned.

When reading the start and stop frequencies from the HP 8350B Sweep Oscillator, a number of problems were experienced. At first it was thought the problems were independent; however, once one problem was solved, all the problems disappeared. Thus, the problems were simply symptoms of a single problem. The first symptom was a long initialization time. The original software initialization took a few seconds while the new software took approximately one minute to perform the same initialization. Another symptom was the Sweep Oscillator sometimes returning to the stop frequency. The National Instruments GPIB Analyzer was used to monitor the data on the GPIB. It was determined the command to read the frequencies from the GPIB was requesting the incorrect number of bytes. At first 14 bytes was the value, expecting a carriage return and line feed. Monitoring of the GPIB revealed the data only had a line feed with no carriage return; therefore, the requesting number of bytes was reduced to 13. With this change, the initialization time was reduced to a few seconds and the software consistently read the Sweep Oscillator's stop frequency correctly. One change to the user interface resulted from this problem. Originally the "Change Parameters" screen expected the user to make changes, there was no "Cancel" button. With the stop frequency problem the software had a stop frequency of 0.0 GHz which would lock up the software. The only choice to recover was to reboot. The "Cancel" button was added to get around this problem; however, it is still useful because it does not force the user to make changes if that option was selected.

A separate problem with the Sweep Oscillator occurred in the change parameters routine. At first a command was sent to the Scalar Network Analyzer to get it out of pass through mode following each frequency change command. Thus if no change had occurred, meaning the Scalar Network Analyzer had never been placed into pass through mode, the command to get it out of pass through would not be sent. This would appear to be a logical sequence of events; however, the Scalar Network Analyzer reported "UNKNOWN COMMAND - ZF" each time a frequency was changed. Once the command to get the Scalar Network Analyzer out of pass through mode was placed following the frequency changes, and executed whether or not a change had occurred, the program operated properly. Why this sequence versus the original sequence works is not known.

Another problem was reading data from the HP 8757C Scalar Network Analyzer. When performing a 5 sweep data acquisition the first two waveforms looked correct while the last three contained only zeros. The data is sent over the GPIB as a single string of ASCII characters containing all 401 data points and the software reads this string and extracts the data. The first step to finding the cause of the problem was to save the data and examine the file. The file contained data for the first two waveforms and zeros for the last three. The next step was to monitor the data coming over the GPIB to ensure the Scalar Network Analyzer was sending data for all five sweeps. The Scalar Network Analyzer was transferring data to the PC for all five sweeps. That left two possible causes: the command to read the data off the GPIB or the conversion from string to floating-point data. To check the reading the string was displayed each time it was read. It became apparent that something was wrong with the reading command. The data for the first waveform looked correct, but the second and subsequent waveforms had problems. Each set of data had commas as part of the value and some were missing their sign character. After a careful examination of the monitored data it was determined the read command did not include an end of data (EOD) character. Thus the original read command was only reading 3208 bytes, which is 8 characters per data point (401 * 8 = 3208). Once the number of bytes read was increased to 3209 (data plus EOD characters) the software read in all five waveforms correctly.

Porting the executable software to the COMPAQ computer caused another problem. The first attempt to run the software on the COMPAQ resulted in the following error:

run-time error R6000 - stack overflow

The stack of the executable was too small for the COMPAQ. Looking up the error (Reference 6), the proposed solution is to run the DOS command EXEHDR with the stack switch (Reference 7) to increase the stack size of an executable program. The stack option in the linker was not set and the executable defaulted to a stack size of 4096 which will not work on the COMPAQ. The command EXEHDR /S:9256 MRMS.EXE was executed to fix the error. After running EXEHDR, a screen of information appeared along with ERROR U1105: minimum allocation less than stack, correcting minimum. The executable worked with no problems even with this error. An easier solution was to add the stack switch to the list of parameters in the LabWindows lwmake program. This would cause the linker to use the proper stack size instead of the default resulting in an executable that runs correctly on the COMPAQ without changes.

7. Future Software Upgrades

There are a few potential upgrades to the software. The first upgrade would be to include arm movement capability. This would provide the user with an automated method of moving the arms. An added bonus would be to include the arm positions in the header of the data file. Thus, the analyst would have angle of incidence information when analyzing the data. Another upgrade would be to have the capability to display multiple measurements. This is not referring to multiple waveforms from the same measurement as is the case presently. When in the five sweep mode, all five waveforms are displayed simultaneously to the user. This upgrade would allow the user to display the waveforms from more than one measurement providing the capability to compare data from multiple measurements, a quick-look capability. Lastly, incorporating an analysis capability would greatly enhance the software. This would allow the analysis of data in real-time without having to port the data to another computer for further processing and analysis.

IV. Conclusions

The use of LabWindows as the development environment greatly eased the development of the graphical user interface (GUI). LabWindows provided a simple method of creating and modifying each of the screens. It also automated the handling of the variables used to identify each element on the screen. Another advantage was the plain commands LabWindows had for the operation and manipulation of the screens. The LabWindows package provided numerous C programming language examples which were considerable help writing the source code to operate and process the data in each of the screens.

The upgraded MRMS software greatly aids the user in acquiring millimeter wave data. The upgrade provides a much enhanced user friendly interface. An engineer or scientist can easily acquire and save data in a format compatible with signal processing and analysis packages on PCs. The operation of the controller PC is the same as most other computers the engineer or scientist uses. The new interface utilizes Microsoft Windows type operations, thus making it very familiar to the user. Several new capabilities were included in the upgraded software. The user can now print to a laser printer, save data in a PC format, specify the location to retrieve or save data, to name a few.

This new MRMS data acquisition software meets the requirements set forth in the upgrade. The user can operate the system in a timely and efficient manner. Also the new software employed techniques that ease maintainability and upgradability. This upgrade allows the MRMS to be an effective tool in the research and exploitation of millimeter wave phenomenology.

V. References

1. K.D. Trott and J.R. Walker, Jr., "Millimeter Wave Reflectivity Measurement System," Technical Report, WL-TR-93-7027, Eglin AFB, Florida, September 1993.
2. National Instruments LabWindows Manual
3. National Instruments IEEE Manual
4. HP 8757C Manual
5. HP 8350B Manual
6. Comprehensive Index and Errors Reference (Microsoft C/C++)
7. Environment and Tools (Microsoft C/C++)

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