A CALCULATOR BASED ANTENNA ANALYZER

by
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ABSTRACT

Automated antenna testing has become economical with the MI Technologies Series 2080 Antenna Analyzer. Since its introduction last year, new computer hardware and software additions have enhanced the system performance.

This paper will provide a brief overview of the system and its enhancements. It is recognized that testing requirements differ and an automated system must be capable of adapting to a specific test. The Series 2080 has a flexible data base and display programs which permit special antenna testing. A discussion of meeting special test requirements and the cost benefits of automated testing will be made.

The introduction of the MI Technologies Model 2083 Antenna Analyzer has allowed many new sites to reap the benefits of automated testing. Designed from a long history of automated systems, the Model 2083A offers measurement accuracy and speed previously unavailable in low cost systems.

Before the Model 2083A is discussed, the required functions of an automatic test system should be reviewed. Figure 1 below shows the four primary requirements of an automated antenna test system. The operator must somehow be capable of specifying how the antenna is to be tested and the system should run automatically without requiring additional operator intervention. After the data has been collected, the operator must be able to specify the type of data output which is to be made. Finally, the system must be capable of producing the data output (typically a plot).

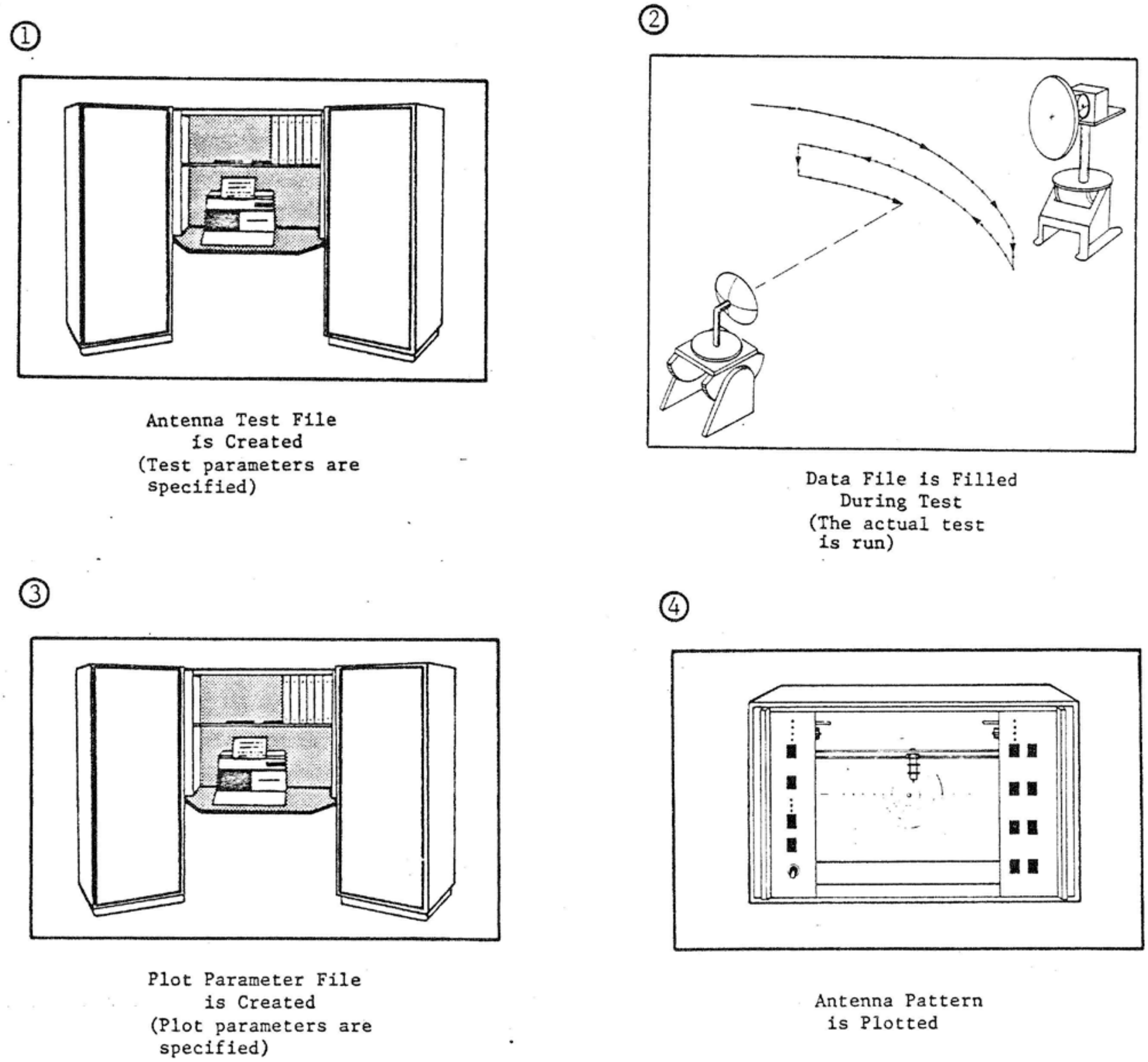

Figure 1. Primary Requirements of Automated Test System

There are many other functions an automatic system can perform, but Figure 1 illustrates the minimum requirements. To perform these functions, a system requires integration of a computer, measurement instrumentation, and output devices.

The integration is performed in two areas. Obviously some manner of hardware interconnection must exist to combine the instrumentation together. The other integration function is performed by the system software.

In the Model 2083A, each measurement instrument was designed specifically for antenna testing and to interface with other MI Technologies instrumentation. Because of the dedicated instrumentation, the Model 2083A hardware shown in Figure 2 below offers uncompromised performance for making antenna measurements.

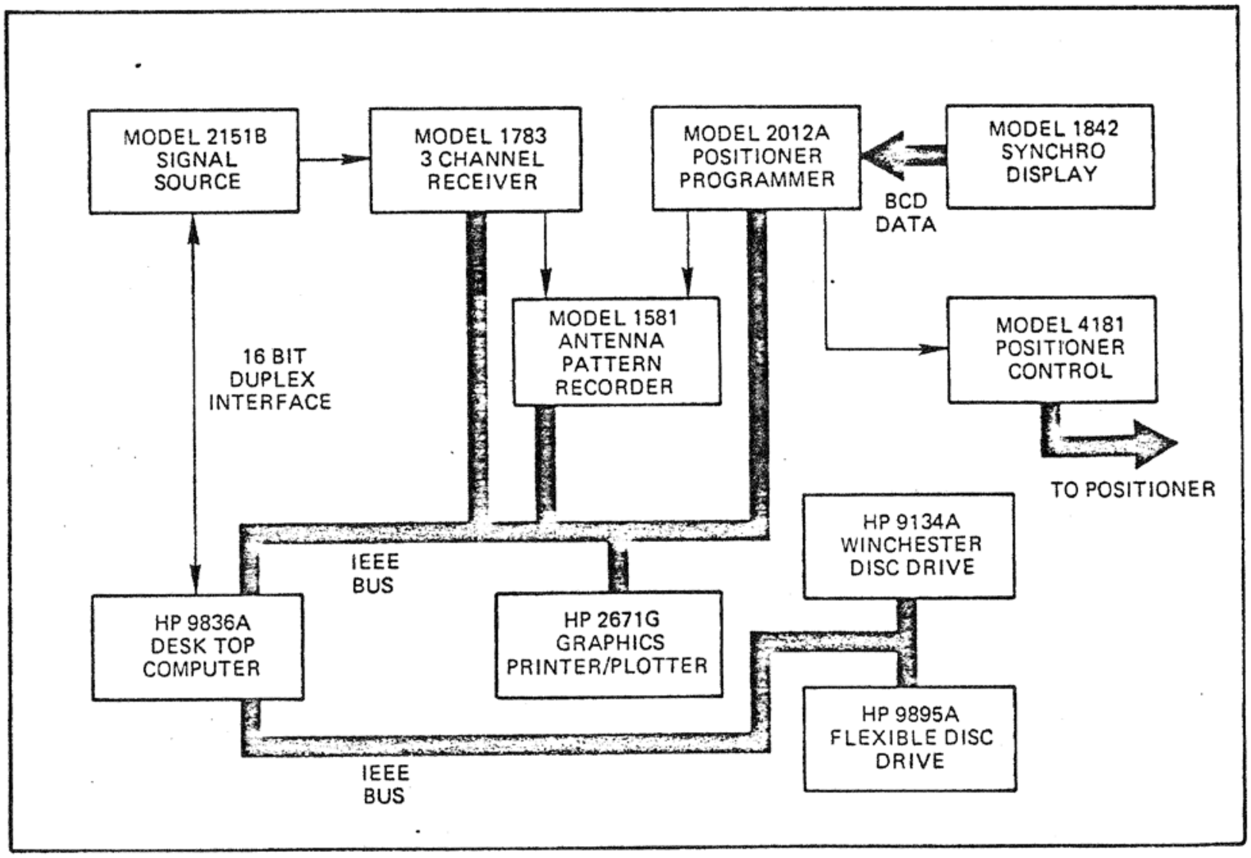

Figure 2. Model 2080 Hardware

MEASUREMENT INSTRUMENTATION

The instrumentation for an antenna test system must perform three functions. It must be capable of generating RF test signals, detecting the response of the antenna under test (AUT) to these signals, and controlling the movement of the antennas in the test setup.

RF signals are generated by the Model 2151B Signal Source. This signal source was designed for direct interface to the MI Technologies phaselock receivers. All frequency steps are controlled to prevent the receiver from losing phaselock while tracking the signal source. This allows fast multi-frequency tests to be made without requiring the receiver to regain phaselock for each new frequency.

The receiver for the system is the Model 1783 three-channel receiver. Far superior to a network analyzer for antenna measurements, this receiver allows fast, high resolution and stable measurements of amplitude and phase. Three amplitude and two phase channels allow dual polarization measurements to be made simultaneously. This offers great reduction in testing time for many types of antennae.

In the Model 2083, three instruments are dedicated to positioner (antenna) movement. The Model 2012A positioner programmer is responsible for automatic positioner movement. The positioner programmer is an intelligent instrument which controls the positioner without constant supervision from the system computer. Featuring an optimized velocity profile algorithm, the positioner programmer insures accurate antenna movement. Actual positioner drive voltages are provided by the Model 4181 Positioner Control. Position information is provided to the programmer by the Model 1842 synchro display which converts the six-axes synchro signals to a digital format.

System Controller

Selecting a system controller required careful study. The computer had to be economical and easy to use without sacrificing computational or I/O speed. The Hewlett Packard 9826 was originally chosen because of simplicity and speed. This has since been upgraded to the HP9836 which has an extra disc drive and a larger CRT. This series of desktop computers offers the I/O interfaces necessary (RS232, IEEE/488, 16 bit duplex) necessary to control the instrumentation and communicate with other computers and peripherals.

The computer is configured with (2) IEEE/488 interfaces, (1) 16 bit duplex interface and 589K bytes of RAM. To provide flexibility, a RAM based version of BASIC is used. This allows easy updates to the HP software and access to other programming languages.

To allow long periods of unattended operation during data acquisition a large disc drive is required. The combination of a HP9895 eight-inch flexible disc drive and HP9834 Winchester drive allows file backup with a total capacity of 5.7M bytes. This is independent of the 1/2 Mbyte disc storage provided by the computer itself.

Two digital output devices are available for the system. The HP2631G Graphics Printer allows program listings and CRT hardcopy dumps to be made to its thermal paper. The MI Technologies Model 1580 Pattern Recorder allows high resolution rectangular and polar antenna plots. In addition, the digital interfaces of the recorder to the receiver and positioner programmer allow manual antenna plots to be made independent of the computer.

System Software

Measurement capability in an automatic system can be inefficiently used if the software does not complement the hardware. Furthermore, the total system throughput can be significantly affected by a poor operator interface. The Model 2083 software package was carefully written to maximize the measurement and throughput capability of the system.

The system software has to accomplish the functions originally shown in Figure 1. There must be a way of specifying test parameters, running a desired acquisition program, specifying the parameters of the plot, and then plotting the data. The software architecture shown in Figure 3 below allows the operator to perform these functions.

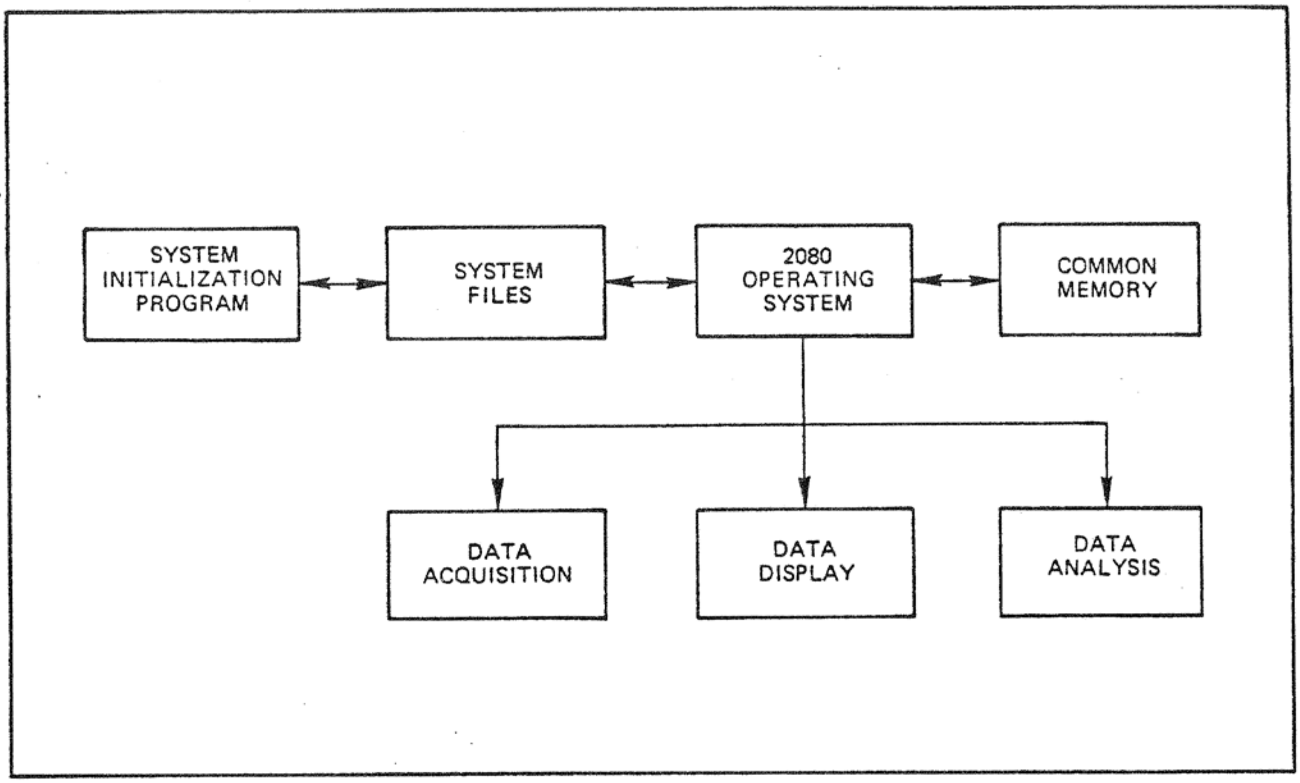

Figure 3. Software Architecture

The software is broken into logical modules to perform the functions required of Figure 1. The programs to specify the test parameters and collect the antenna data are placed in the Data Acquisition Module. Programs to specify the plot parameters and plot the data are placed in the Data Display Module. Programs to analyze the data (not a function of the original diagram) are placed in the Data Analysis Module. The functions of these modules are discussed separately below.

Separating the programs into modules allows the operator to run a program without having to learn the commands of the computer itself. Whenever the operator wishes to run a program, he presses one key (softkey) and the MI Technologies software will handle the details of finding the program location on disc and loading the program.

Some of the blocks in Figure 3 are not modules. They are part of the MI Technologies operating system. Because the calculator does not have a real time executive (actually an advantage), a user would have to specify many commands which requires a working knowledge of the computer itself. The operating system of the Model 2083A allows the operator to circumvent these commands by pushing a softkey. The MI Technologies software does the work of issuing computer commands.

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When programs are running, typically they often require calling other programs to run and then returning. With the HP9836 computer, these programs cannot talk to each other. The operating system manages a system memory common with mailboxes that the programs may leave messages that a later program can read and use.

Another feature of the operating system is the error dictionary program which performs an error lookup for system and instrumentation error messages. Executing programs can detect system errors, and pass the appropriate error numbers to the error dictionary. From these error numbers, the program will display on the CRT a text message identifying the error. In Figure 4 below, a rasterscan data acquisition program has aborted. The error dictionary displays the type of equipment failure or error which minimizes system downtime.

Another function of the operating system is to configure the operating software for the computer hardware and positioner hardware present at that particular range. An interactive program requests data from the operator and this data is stored on a disc file. Each time the system is turned on, this file containing range information is loaded into the common memory area for use by the various programs.

```
ERROR DICTIONARY PROGRAM
ERROR MESSAGES
   7.UNRECOVERABLE RECEIVER ERROR
  29,PAU ERROR-INTERNAL CALIBRATION FAIL
  45,A1A9 HARDWARE FAILURE.A/D TIME OUT
```

Figure 4.   Error Dictionary Display

Many customers will wish to write application programs for their systems and the operating system provides utility programs that allow them to use the MI Technologies operating system. A user-written program can be added to one of the system modules and it can be run like a MI Technologies program. The error dictionary file can be expanded to accommodate error messages that are unique to a user program.

FREQUENCY SCREEN, GENRSAQ
DEPRESS SOFTKEY FOR NUMBERS K0-K9
DEPRESS SHIFT SOFTKEY FOR NUMBERS K10-K19

K0 NUMBER OF FREQUENCIES 10	K1 FREQUENCY #1 (GHZ) 9.000	K2 FREQUENCY #2 (GHZ) 9.100	K3 FREQUENCY #3 (GHZ) 9.200	K4 FREQUENCY #4 (GHZ) 9.300
K5 FREQUENCY #5 (GHZ) 9.400	K6 FREQUENCY #6 (GHZ) 9.500	K7 FREQUENCY #7 (GHZ) 9.600	K8 FREQUENCY #8 (GHZ) 9.700	K9 FREQUENCY #9 (GHZ) 9.800
K10 FREQUENCY #10 (GHZ) 9.900	K11 AUXILLARY SOURCE NO	K12 FREQUENCY SYNTHESIS NO	K13 FREQUENCY SECURITY NO	K14
K15	K16	K17	K18	K19 RETURN

WAITING FOR SOFTKEY

Figure 5. Operator Interface (Display Screen)

Before making a test, the operator interacts with the test file generator program to specify the many parameters required for a test. When the operator presses one of the labeled softkeys on the keyboard, the program will prompt him to enter the required parameter. This parameter is checked for validity and then the display screen is updated with the new parameter. The display screen formats allow the operator to view a large number of relevant parameters at one time and minimizes the keystrokes necessary to specify test conditions. This format also minimizes the training required because the program prompts the operator for each command.

After the operator has completed specifying the test conditions, they are stored on a disc and can be used by the actual data acquisition program or edited. This allows test to be repeated without requiring the operator to re-specify test conditions. In addition, the test file can be stored as a test record along with the resulting data file. At a future time, the same test can be run to re-verify the antenna.

The standard data acquisition program supplied with the system is a rasterscan acquisition program. Features of the rasterscan data acquisition program include:

1. Single or multiple frequency
2. Beam maximum search
3. Autoranging of receiver IF attenuation
4. Auxiliary signal source
5. Multiple disc files
6. Buffered data in memory
7. Online CRT plots
8. Record on positioner retrace

Raster scan data acquisition was chosen for data acquisition in the Model 2083A because of its speed and accuracy in making measurements. Figure 6 below shows how a rasterscan antenna measurement is made. The test is made on any two axes by continuously sampling across one axis and then stepping the next axis when the sampling is complete. As soon as the measurement is complete, the positioner is moved to the next step angle and the scan axis is again sampled. By recording in both directions, the test is made quickly without extraneous positioner movement.

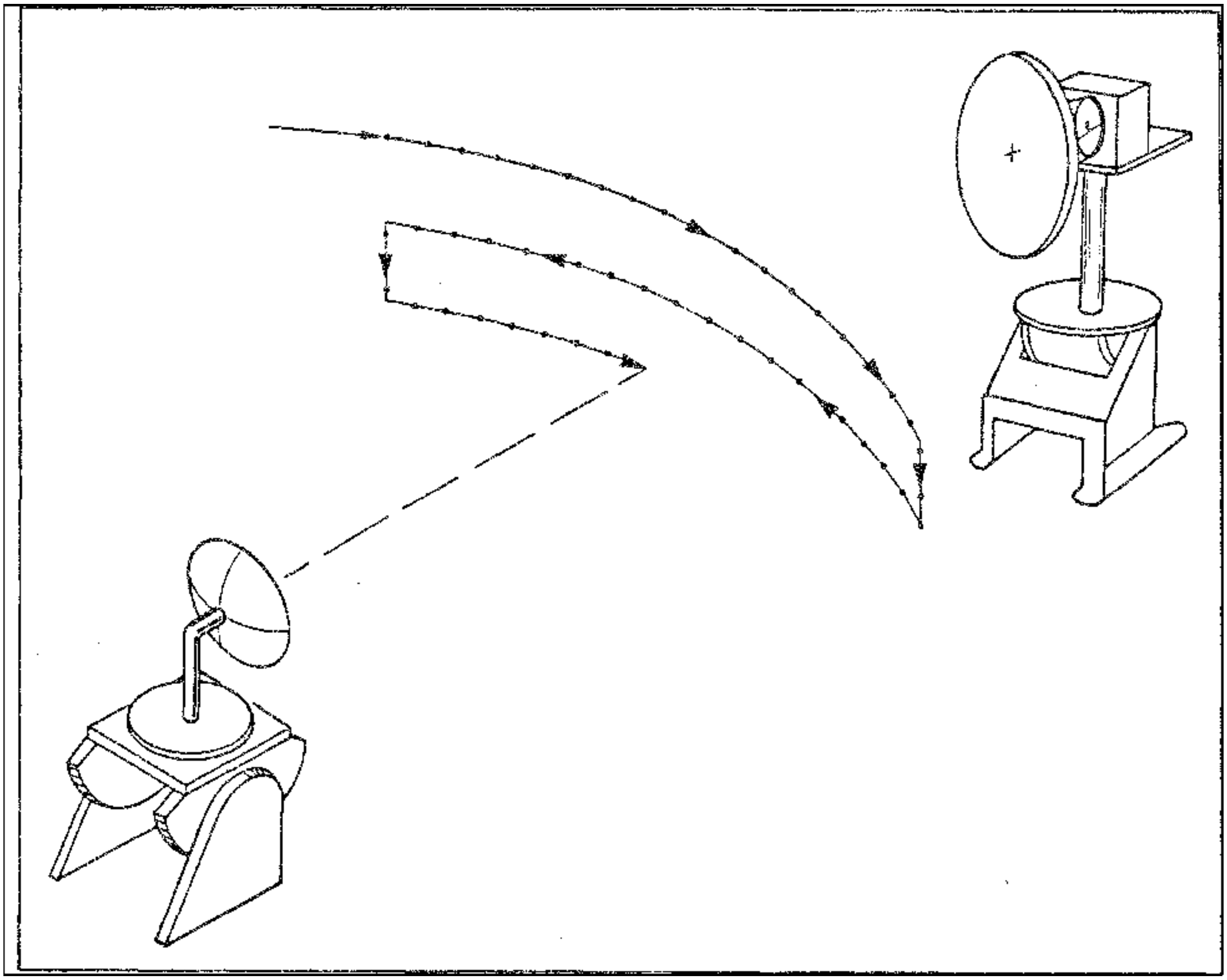

Figure 6 Diagram of Rasterscan Data Acquisition

This method of taking data "on the fly" requires significant intelligence and accuracy in the measurement instrumentation. If the data is to maintain constant spacing throughout the test, some method must be used to predefine the data windows where the antenna is to be sampled. When the antenna moves through one of the windows, the measurement instrumentation must be triggered to sample the data and this measurement must be completed before the antenna arrives at the next window. The positioner programmer and controller in the Model 2083A are designed to maintain the required constant sampling intervals. The positioner programmer is continuously reading the angular position of the antenna and signaling the computer when a measurement must be made. It will also detect if the measurements are not completed in time and for the computer to take appropriate action.

The standard synchro display in the system will maintain a positioning and sampling resolution to .01 degrees. By using an optical encoder this resolution can be increased to .001 degrees.

As Figure 6 indicates, rasterscan data acquisition is not limited to azimuth and elevation. Any two axes (with proper control and outputs) can be used for measurement. For example, the polarization axis can be scanned with the azimuth axis stepped if required by the test.

Data Display Module

With the standard software, the data display module contains a plot file generator program and plot output programs for the computer's CRT and the Model 1580 Pattern Recorder. Figure 1 showed a typical plot sequence where the operator specifies the desired parameters and the output device. The plot programs use a plot file generator program which interacts with the operator in display screens as discussed earlier.

The plot files allow the same plot to be made without re-specifying the plot parameters. If a test is made and the resulting plot is outside of specifications, the antenna can be adjusted and the same test and plot can be made without requiring the operator to enter the parameters again.

Output devices for the plot programs include the CRT (dumped to the printer) and the Model 1580 pattern recorder. Both the CRT and pattern recorder may plot amplitude and phase data for either a scan angle (typically azimuth) or step angle (typically elevation). Polar plots are available on the pattern recorder. Figure 7 is a rectangular plot made on the CRT and dumped to the graphics printer. Figure 8 is a rectangular plot made on the Model 1580 Pattern Recorder.

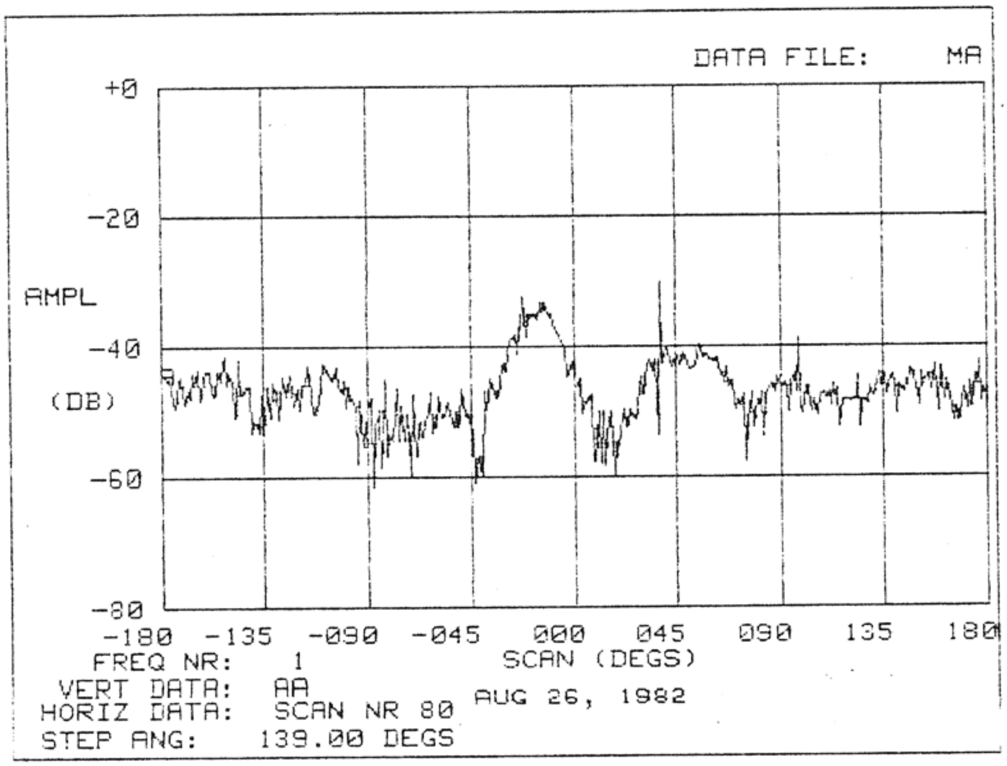

Figure 7. Antenna Pattern from CRT

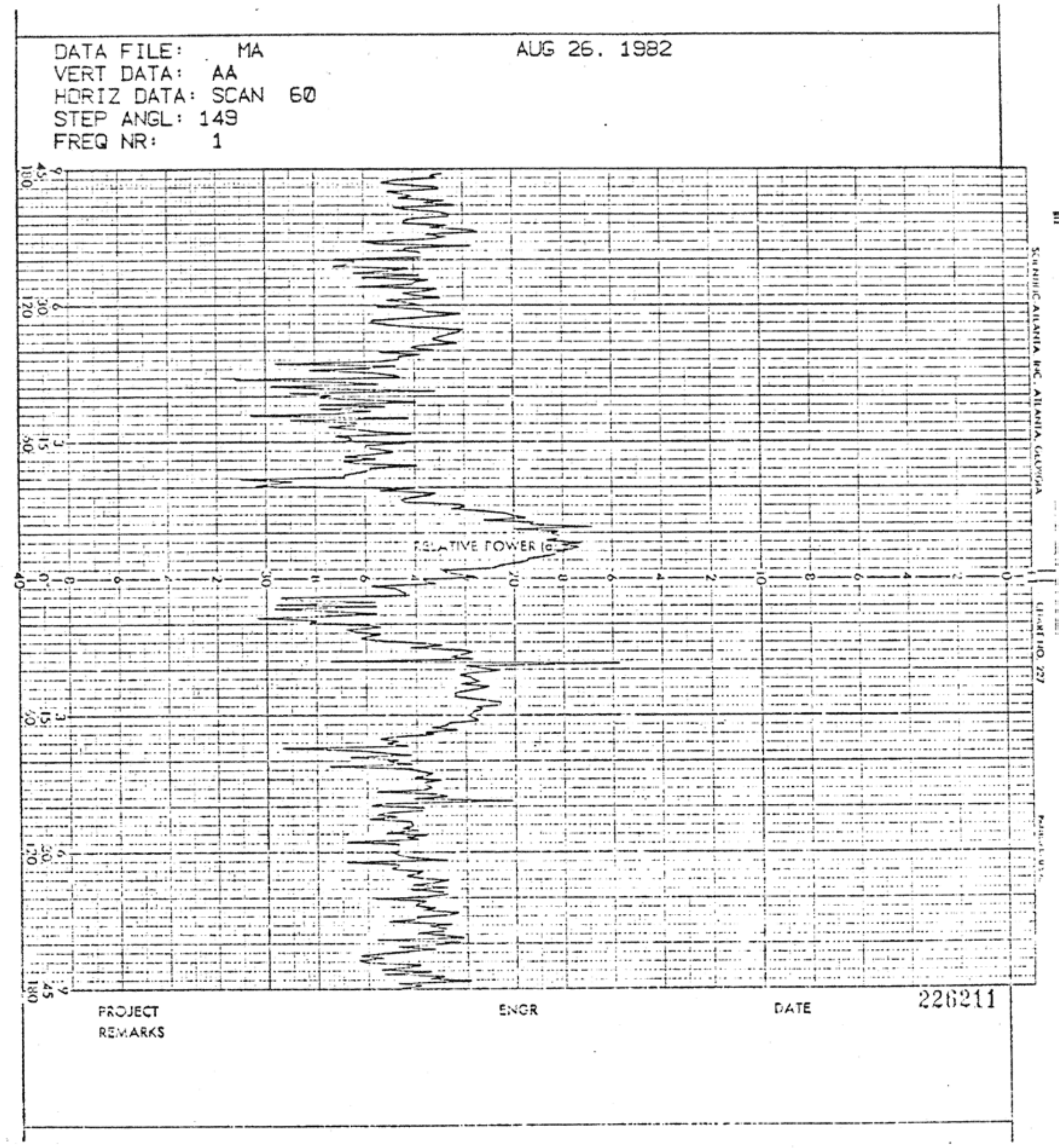

Figure 8. Antenna Pattern from Pattern Recorder

Data Analysis Module

The standard software supplies one program in this module. A data list program lists the data acquisition file numerically. An example of a data listing is shown in Figure 9. The data listed in the scan angle, amplitude A, amplitude B, and phase A.

BEGIN SCAN	1		
SC	AA	AB	PA
-179.000	-49.040	20.070	159.600
-179.050	-47.640	20.410	40.100
-179.130	-46.360	20.740	315.800
-179.200	-49.120	20.340	132.600
-179.270	-54.340	20.740	10.500
-179.340	-48.400	19.680	112.900
-179.400	-46.880	20.660	67.800
-179.470	-49.370	20.490	63.200
-179.550	-51.680	19.690	115.500
-179.620	-55.740	19.510	196.900
179.990	-50.100	20.230	65.600
179.930	-48.580	20.080	187.100
179.860	-46.070	20.750	296.500
179.790	-51.350	20.360	358.200
179.710	-52.720	20.600	96.700
179.650	-50.240	19.700	141.300
179.590	-45.980	20.660	38.100
179.520	-45.690	20.490	57.500
179.430	-48.400	19.670	103.900
179.360	-47.830	19.500	195.700
179.000	-56.570	20.720	99.800
178.940	-53.730	20.210	7.200
178.860	-48.940	20.780	110.900
178.800	-47.170	20.350	124.500
178.740	-50.640	20.580	98.000
178.670	-48.900	19.710	100.300
178.590	-49.520	20.660	58.500
178.510	-48.230	20.490	278.800
178.430	-49.650	19.620	92.500
178.360	-55.710	19.520	130.600
177.990	-58.200	20.200	178.800
177.940	-47.030	20.120	109.400
177.850	-48.840	20.740	97.800
177.790	-50.930	20.360	105.500
177.720	-50.200	20.380	324.600
177.650	-46.170	19.750	116.300
177.580	-48.010	20.670	33.200
177.510	-46.180	20.490	71.500
177.430	-51.250	19.660	75.600
177.370	-49.240	19.510	197.200
177.000	-54.630	20.730	96.600
176.940	-48.040	20.130	59.000

Figure 9. Sample Data Listing

SYSTEM ADAPTABILITY

With today's changing test requirements, few manufacturers of automatic test equipment can guarantee their standard software will meet every test requirement. The best defense against obsolescence is creating a programmable general purpose architecture. Allowing the test engineer to easily program special tests into the system is mandatory. It is important that the system software have a structure that can be easily adapted and used by future programs. Furthermore, it is imperative these "hooks and handles" be well documented so the test engineer can utilize them.

Design goals for the system dictated that the software be accessible by the test engineer. A detailed software manual which describes the program algorithms and their operation is standard with each system. The programs may be listed to the system printer to allow modification and adaptation of standard programs. A high importance was made upon choosing a system programming language that would allow the test engineer to quickly modify the standard software and write new programs. For this reason, BASIC was chosen as the programming language rather than PASCAL or assembly language. The BASIC supplied with the system allows structured programming with enhanced graphics and I/O capabilities. This allows the test engineer to write very simple programs to control IEEE/488 instrumentation without having to use a special software package to control the bus.

The interpretive BASIC also detects most syntax errors as the engineer enters a program line and avoids the debugging difficulty of assembly or compiled languages.

Although it is difficult to categorize the adaptability of a software system, there appear to be three critical areas for an antenna measurement system. They are the operating system, data base, and display output drivers.

The operating system of the Model 2083A is designed to allow programs to schedule each other, pass parameters, and pass file names if necessary. Generalized disc I/O routines allowed the new HP9834 Winchester disc drive to be easily added to the system. The module approach allows the test engineer to add custom programs to the system and be scheduled identically as with MI Technologies programs.

Probably the most critical design in an automatic acquisition system is the data base. The data base must be adaptable to handle unknown future test and data requirements and data formats. The Model 2083A data base allows specifiers; which means a programmer can specify how the data will be written on the discs and the generalized data base interface programs will be able to read the data. For example, a special test program for a phased array might require elements to be switched during the test. A test engineer or programmer could write a data acquisition program and specify the data format. The data retrieval programs of the Model 2083 would be able to interpret this format specification and return the appropriate data.

Another area of interest is the display capability. Many test installations will have particular output devices they would ultimately like to have the data output on. At the same time, it would probably be a requirement to communicate with another computer. The display programs of the Model 2083A have a filter program which extracts the required data and places it in a disc dile for later access by CRT of pattern recorder programs. This resulting filter file contains the X and Y coordinates of the plot in IEEE floating point format.

EXAMPLE CUSTOMER APPLICATIONS

Pass/Fail Testing

Often in a production environment, it would be desirable to have a production person test an antenna and have the system compare the collected data with the required specifications. After numerically evaluating the antenna, the system would give the production person a Pass/Fail evaluation of the antenna.

It is very difficult for MI Technologies to write a Pass/Fail program due to the large number of variables associated with a particular antenna test. Using the supplied software however, the customer can write a simple program to accomplish a particular test. Figure 10 shows the steps required to write such a program.

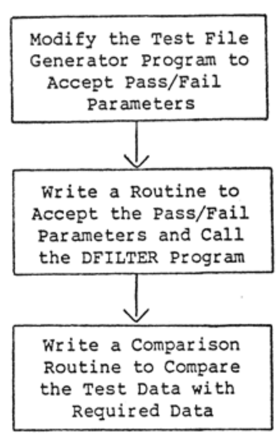

Figure 10. Writing a Pass/Fail Program

By using a copy of the MI Technologies test file generator program, a new pass/fail generator program can be created. The modifications required would be simply changing the characters output to the CRT and the variables accepting the operator inputs. This program would then have the ability to accept different pass/fail parameters and store them on a disc file.

A program skeleton would be required to accept the pass/fail parameters and send it to the MI Technologies plot filter program (DFILTER) for setup information. The DFILTER program would access the comparison data file and place it in memory or on a disc file. The DFILTER program would then be setup to read test antenna's data file and place it in memory. A comparison algorithm would compare the data between the two data files and check for pass/fail. This comparison would take place over the number of scans or data points specified by the pass/fail generator program. At the end of comparison, the antenna would be certified as PASS or FAIL.

This type of program would require some original programming by the customer but the most difficult portions of the algorithm are performed by the standard MI Technologies programs. All of the difficult data file access is handled by DFILTER and most of the required programming would be supplying the program with setup parameters.

Plotting to Color Terminals/Plotters

Despite some recent efforts by DEC, INTEL, and TEKTRONICS, there is no industry standard for graphics. There are a large number of color terminals and plotters available which makes it difficult for MI Technologies to write a general program which will happen to interface to a particular facility's color output device. The standard programs supplied with the system however, can be used to provide most of the required software. Figure 11 shows the programming steps required.

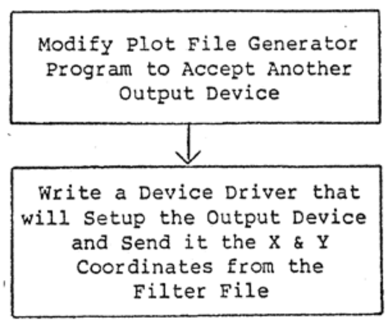

Figure 11. Adding Another Output Device for Plotting

The plot parameters would probably remain the same and the only modification to the plot file generator program would be to allow selection of another plotting device. The plot file generator program would schedule the DFILTER program as with the present software.

After the DFILTER program completes, a disc file with the X and Y coordinates in IEEE floating point format is made available to the new output device driver. This driver program would be responsible for setting up the output device and sending the appropriate commands. Typically this involves sending the X and Y coordinates with the pen status (up or down) to the device.

For this example, very little additional software is required is required to add a color terminal/CRT. Most of the difficult software is handled by the plot file generator program and DFILTER.

Computer Interface

Interfacing with an external computer is dependent upon the computer itself. For short communication distances either IEEE/488 could be used or a RS232 link. Most data files are large enough to create a large data transfer times with a link using less than 9600 baud. For long distances, it is recommended that a removable storage media be used such as floppy disc or magnetic tape.

COST BENEFITS OF AUTOMATIC MEASUREMENTS

For discussion purposes, assume a test site is to test a production run of antennas. Suppose the antenna is to be tested over a half sphere with a sampling increment of .5 degrees.

Number of record increments in a scan = 360/.5 = 720

Number of scans = 90/.5 = 180

Total number of data points = 720 x 180 = 129,600

The Model 2083A can collect data at approximately 25 data points/second.

Time required = 129,600/25 = 87 minutes

The time above does not include the time of moving the positioner for each scan step. This can be estimated at 10 seconds per scan.

Step time = 10 x 180 = 30 minutes

The entire test then should take about 117 minutes which would allow four antennas to be tested in an eight hour shift.

CONCLUSION

Fundamental to the design of the Model 2080 was flexibility and performance. By using antenna test instrumentation, the system is capable of high data acquisition rates without sacrificing sensitivity or accuracy. The flexible software architecture allows programs to be easily added to the system while retaining the friendly user interfaces.