A HIGHLY AUTOMATED APPROACH TO OBTAINING ACCURATE CIRCULARLY POLARIZED ANTENNA GAIN

Marion C. Baggett

MI Technologies
4500 River Green Parkway, Suite 200
Duluth, GA 30096-2580
mbaggett@mi-technologies.com

ABSTRACT

At a Department of Defense antenna measurement laboratory, an important measurement is the accurate measurement of gain for circularly polarized antennas. An additional requirement is that a wide population of engineers and technicians that do not spend a significant amount of time using the facility make the measurements as they test the antennas for their projects. The objective was to create a highly automated, accurate test structure that was easily used by visiting engineers to make high quality measurements. Consistency of results across the user population was a paramount requirement. This paper describes the instrumentation and software used to meet this objective.

The paper describes basic measurement techniques, the exploitation of instrumentation capabilities to make the measurements, the software processing of the data and the graphical user interface that was developed to make the test process essentially a "one button" operation. Significant components in the test scenario were the ability to accurately collect data on a linearly polarized Standard Gain Horn in orthogonal polarizations without inducing errors caused by various axes of motion and to provide channel imbalance correction for the orthogonal channels of the instrumentation and range.

Keywords: Antenna Measurements; Commercial Products; Data Acquisition; Instrumentation; Measurement Systems.

1. Introduction

The test range used is a tapered chamber that supports a group of development and test engineers. These engineers need to test different antennas and prototypes that are all of the same class and require essentially the same test metrics for evaluation. In some cases, the test data from the various antennas are compared against one another, requiring a similarity of test procedure and test result presentation. A complicating factor is that the engineers are casual users of the test range, not using it enough to obtain familiarity with detailed complicated procedures. In addition, the prior method for obtaining circularly polarized gain was to perform a 'spinning linear' measurement by rapidly rotating the range feed and calculating the AUT axial ratio from that modulation on the resulting data. Once the axial ratio was estimated from the data, the gain could be computed. This technique leads to variation in interpretation of the pattern modulation and therefore, axial ratio and gain were subject to some variation from user to user. The DOD decided to use the opportunity of upgrading the range instrumentation to develop the basic test procedures and methods to take consistent data and to develop a user-friendly graphical user interface (GUI) that would promote consistency of measurements and ease of use.

2. The Measurement Environment

The test range is a tapered chamber inside a shielded chamber. The test range operates from 100 MHz to above 12 GHz. The range positioning equipment consists of a feed polarization positioner capable of 30-RPM rotation and a medium duty azimuth rotator located at the AUT position in the test chamber. The test articles are relatively small antennas that are mounted on foam columns that bring the AUT up to the centerline of the range in line with the throat. Both single and dual polarization range feeds are available. Probes are mounted on fiberglass poles that fit into a fixture on the feed positioner and extend the probes into the throat of the tapered chamber. A winch to provide access for the range probe and its support can lift the upper half of the throat.

3. The Measurement Problem

The classes of antennas measured in this range are relatively broad beam antennas that are circularly polarized. Due to their broad beams, standard principal planes cuts are not significant other than for determining beam width. The gain of these antennas is an important performance parameter. These antennas are also used as transmitters with associated transmit electronics, so EIRP is also an important measurement. This paper will be limited to a description of the measurement process and tools for obtaining circularly polarized gain measurements on these antennas. A similar process was incorporated for EIRP measurements.

The standard method of determining gain for an unknown antenna is a comparison measurement against an antenna of known gain, usually a standard gain horn. For circularly polarized antennas, this presents a problem in that the SGH is linearly polarized. Some method for obtaining circularly polarized data from the SGH is required. Two primary methods are normally used [1][2] to produce SGH data in circular polarization. In both cases, the SGH is measured in both its vertical and horizontal polarizations in successive measurements, the data is combined and the dual polarization linear data on the SGH is then converted to circular polarizations via well-established equations [3]. One method of obtaining dual linear data on the SGH is to use a linear range feed and rotate it 90 degrees between the successive measurements. This method has the disadvantage of requiring two measurements of the SGH, reducing range throughput and its accuracy is dependent on both the accuracy of the 90-degree rotation, the alignment of the probe in the feed positioner and the alignment of the SGH as the reference antenna. Another method is to utilize a dual ported range feed and an automated switch in the transmit path to excite both transmit polarizations during a single measurement sequence. This method has the advantage that the relationship of the two transmit polarizations can be made accurate in the construction techniques of the dual ported probe and since the probe does not move during the measurement, the probe can easily be aligned to the range orientation via proper fixtures. A disadvantage of the multiplexer approach is the potential for differences in the signal paths between the multiplexer and the range feed. Any channel imbalance of this type needs compensation for accurate dual polarization measurements. The alignment of the SGH at the AUT position is solved by precision mounting fixtures on the AUT azimuth positioner. The method chosen for this range was to use the dual ported feed and transmit multiplexer approach, since the MI-3000 software used contains a module for channel balance correction. Completion of the measurement cycle is to mount and measure the AUT and then to calculate the gain against the SGH data and its gain table.

In terms of range operations, the measurement problem is a cross between an engineering development facility and a production facility. In an engineering facility, the emphasis is on providing a large number of single purpose hardware and software tools that can be used flexibly and in various combinations. As a consequence, the user is expected to very familiar with the instrumentation, software tools and the metrology of the measurement to be made. In a production facility, the user is expected only to respond to instructions from the software, which is customized for the specific AUT and measurements required. A fixed set of measurements is performed and in many cases, customized reports and data plots are produced automatically, without significant user intervention. While the operations in this range are not a strict production operation, it was desired that all users of the range take data in a consistent and similar manner as described above. The problem was to create a user environment with software that struck a good compromise between the challenge of flexibility and a restrictive production approach.

4. The Measurement Tools

The instrumentation used in the range is the MI Technologies MI-2097 Automated Microwave Measurement System. This system included an optional two port multiplexer as discussed in Section 3 above. The receiver was the MI-1797 Microwave Receiver. It controls the multiplexer during measurements to obtain two channels of data at the sampling rate of the receiver, which is 10,000 single frequency measurements per second.

The MI Technologies MI-3000 family of Data Acquisition and Analysis software formed the control software. Supporting this core software were Visual Basic scripts that tied basic operations together and a custom designed GUI for the test range users.

The MI-3000 software provides many features that were ideal for this test environment. Some of them are:

- Data can be grouped in “projects” as defined by the user. Projects contain acquisition, plot and analysis configurations as well as data and analysis results. The projects can be segregated by user, antenna type or even by antenna serial number.
- “Definition” files control acquisitions, plots and analyses. These definition files can be created and tested in a matter of minutes. Once the definitions are correct, they can be used as many times as desired and the measurement, plots and analyses will be conducted in a consistent way every time the definition is used.
- A Sequencer function allows the user to create script files in Visual Basic to tie the more simple

tasks together. Not only is the power of Visual Basic available in the script, the Sequencer provides key words that execute the standard functions of the MI-3000 software. The Sequencer module also allows the construction of operator messages and prompts for the entry of information to manage to flow of operations. Any program available on the control computer can be called for execution via the Sequencer module. The Sequencer itself can be invoked from other programs written outside the MI-3000 package. In addition to command line arguments, variables can be passed to and from the Sequencer module via the Windows™ registry on the control computer.

- Several data manipulation utilities are provided that are of critical use in this measurement scenario. A utility that stores measured channel imbalance data in dB and phase and can correct dual polarization data files for this imbalance is part of the MI-3000 suite. Another standard function used was the module to convert dual linear data to circular and vice versa.
- Data files are in Microsoft Access format, allowing programmatic usage by external software.

A custom GUI was developed that prompts the user for significant data on their test antenna, such as frequencies, name and serial number. This GUI then invokes the MI-3000 Sequencer module to run a specific Visual Basic script, which in turn invoke the basic acquisition, plot, analysis and report functions. This custom GUI, developed by the end user, provides a simple user interface to invoke a complex measurement and evaluation sequence without significant operator intervention other than mounting and dismounting test articles. The GUI itself is in html format. The custom software uses standard WQL queries to alter the configuration of standard acquisition definitions for user-selected frequencies and scan angles.

5. The Solution

The solution of the measurement problem consisted of:

- Defining and testing the basic acquisition, plot and analysis operations for the measurement. MI Technologies and end user personnel developed and tested the basic operation definitions over a two-day period.
- Development of a script to perform the complete measurement scenario. This script was developed and debugged in a single day. The flowchart in Figure 1 shows the entire gain measurement sequence from start to finish. MI-3000 standard operations and modules perform all script actions shown.
- Determine the parameters that the user would be allowed to enter and control from the custom GUI.
- Develop the GUI and tie it into control of the measurement scenario. This GUI was prototyped within two weeks by DOD personnel.
    - Figure 2 shows the high level flow of the custom GUI software and its effects on files and operations. The screens are written in html.
    - The primary screen, shown in Figure 3, allows the user to create a new project for a particular antenna or use an existing project. The MI-3000 User Project Manager module is used to create the files and default configurations of a new project or to make an existing project the active one. The primary screen also allows the user to select from three measurement scenarios (EIRP, linear polarization gain or circular polarization gain) or to make "manual" measurements directly with the components of the MI-3000 software.
    - The Circular Gain screen, shown in Figure 4, allows the user to select frequencies, scan angles and the specific SGH used as the reference. When the user has made all necessary entries, the software uses SQL operations to update the standard acquisition definitions for collecting SGH and AUT data with the user entered frequencies and scan angles. This screen invokes the MI-3000 Sequencer module to run the circular gain script of Figure 2.
    - Once the script is complete, the user is returned to the primary screen.
- Test runs with some of the target user population were used to refine the custom GUI.

6. Summary

This development effort shows that a user population with limited training and experience with the instrumentation can perform a fairly complex measurement scenario. Standard data collection, correction, plot and analysis modules were tied together to perform the measurement scenario in a consistent manner while prompting the user through any required manual operations. The range is made considerably more efficient by the fact that measurements are made correctly the first time and provide consistent results. The average test time for a given antenna has been reduced from several hours down to approximately 15 minutes. The automated channel balancing and gain analysis have resulted in more accurate and consistent results, the bottom line for any test facility.

7. References

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[2] Krauss, Antennas, Chapter 15, McGraw-Hill, 1950.

8. Acknowledgments

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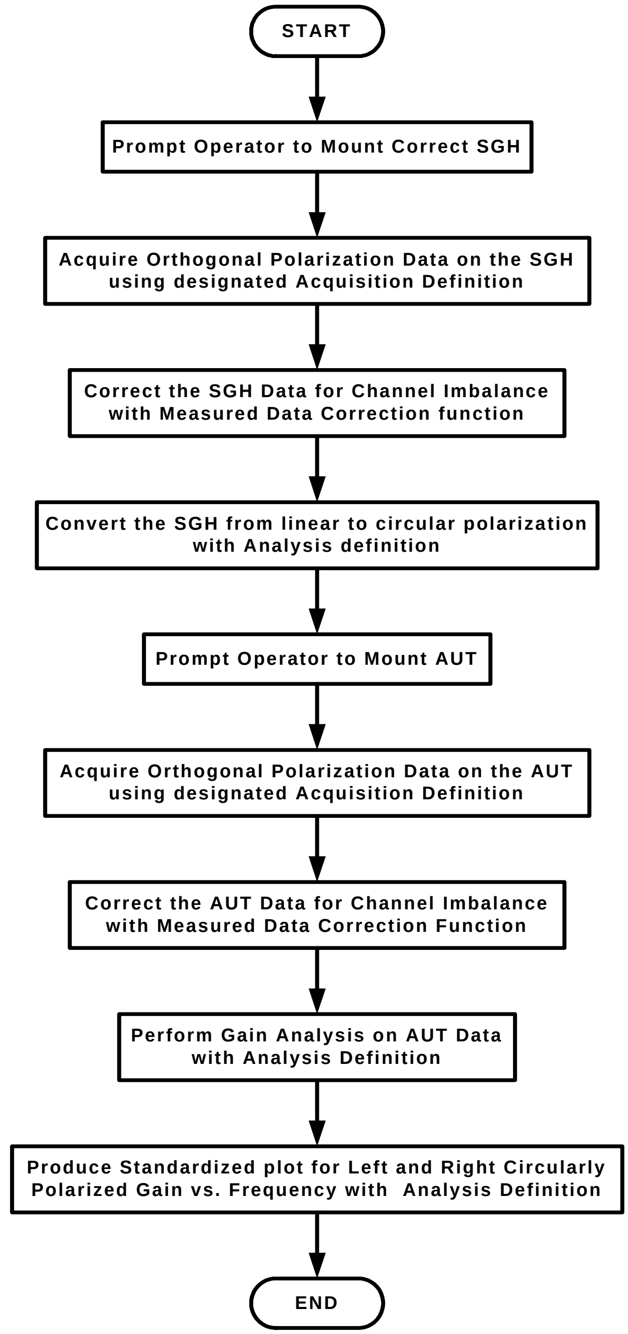

Figure 1 -- Flowchart for Circular Gain Visual Basic Script

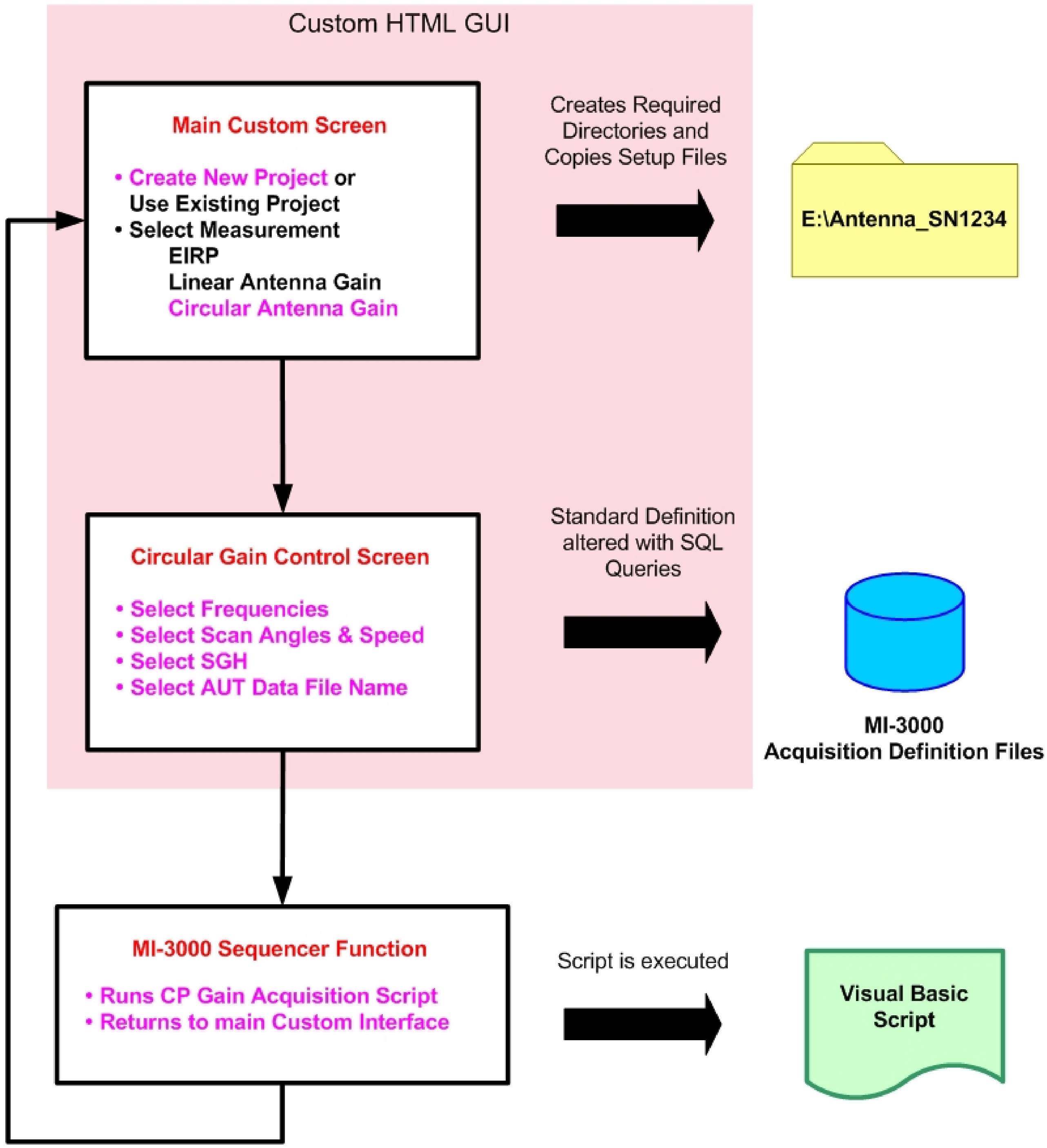

Figure 2 – Custom GUI Flowchart and Operations

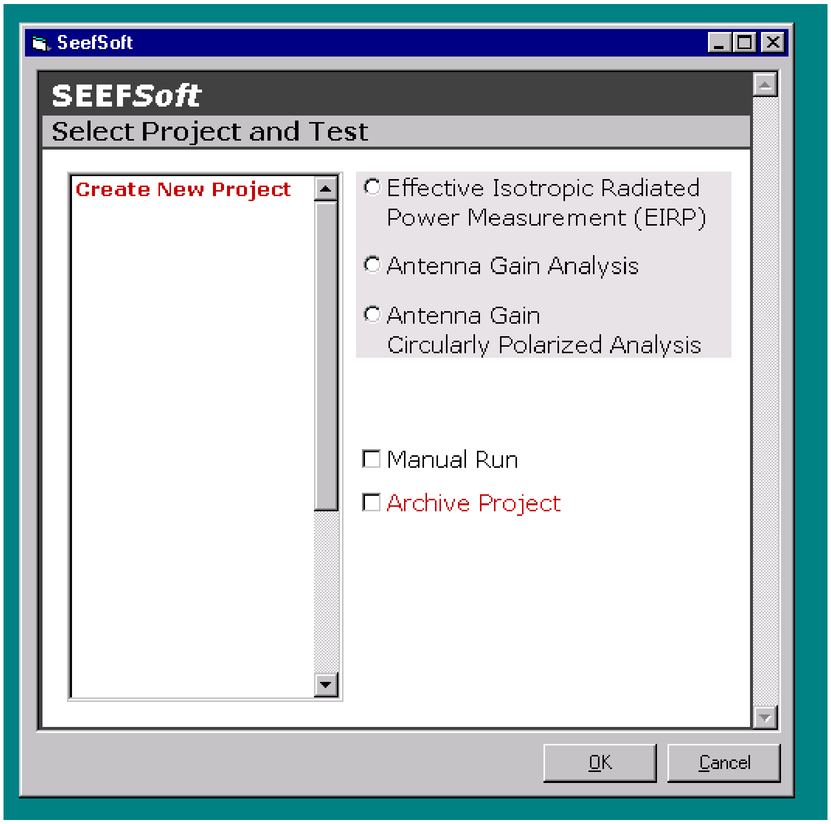

Figure 3 – Primary Custom GUI Screen

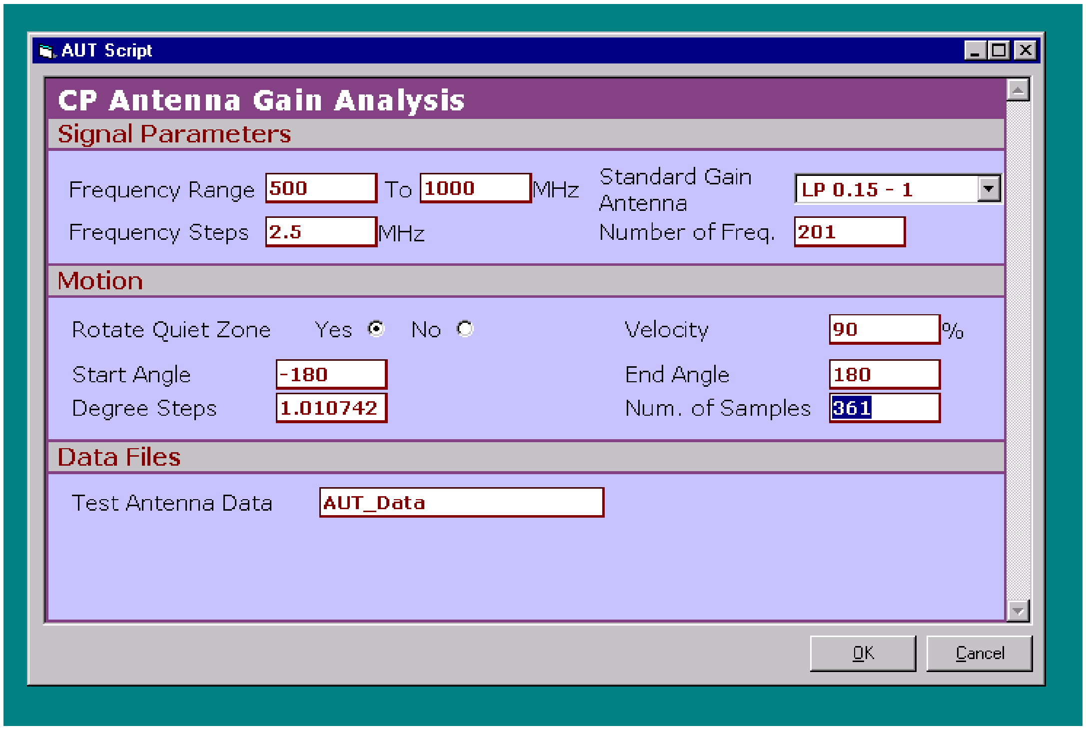

Figure 4 – Custom Circular Gain User Screen