

An Automated Test Setup for the Characterization of Antenna in CATR

Faisal Amin, Abdul Mueed, Xu Jiadong

Abstract—This paper describes the development of a fully automated measurement software for antenna radiation pattern measurements in a Compact Antenna Test Range (CATR). The CATR has a frequency range from 2-40 GHz and the measurement hardware includes a Network Analyzer for transmitting and Receiving the microwave signal and a Positioner controller to control the motion of the Styrofoam column. The measurement process includes Calibration of CATR with a Standard Gain Horn (SGH) antenna followed by Gain versus angle measurement of the Antenna under test (AUT). The software is designed to control a variety of microwave transmitter / receiver and two axis Positioner controllers through the standard General Purpose interface bus (GPIB) interface. Addition of new Network Analyzers is supported through a slight modification of hardware control module. Time-domain gating is implemented to remove the unwanted signals and get the isolated response of AUT. The gated response of the AUT is compared with the calibration data in the frequency domain to obtain the desired results. The data acquisition and processing is implemented in Agilent VEE and Matlab. A variety of experimental measurements with SGH antennas were performed to validate the accuracy of software. A comparison of results with existing commercial softwares is presented and the measured results are found to be within .2 dBm.

Keywords—Antenna measurement, calibration, time-domain gating, VNA, Positioner controller

I. INTRODUCTION

OVER the years, CATR has established itself as an excellent alternative to traditional far-field ranges, providing accurate and fast antenna measurements in a controlled environment. Far field conditions are created with the help of Paraboloidal reflectors. The plane wave is then incident on the test antenna and the radiation characteristics are obtained directly [1]. An automated antenna measurement system offers a high degree of repeatability, speed, accuracy, and efficiency with minimum operator interaction. A microwave transmitter and receiver such as VNA (Vector Network Analyzer) are commonly used in a CATR. The test antenna is mounted on a Positioner and is usually, tested in the receive mode. The rotation of the test antenna is controlled by a Positioner control unit, located in the control room. The RF signal is detected and downconverted. A computer subsystem is added to the instrumentation, to automate the entire measurement sequence. Like the IEEE-488, to setup and monitor the individual instruments. After data acquisition is completed, an automated System supports analysis of the measured data such as gain and polarization plus a wide variety of data plotting formats such as rectangular, polar, three-dimensional, and contour plots [2].

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A variety of commercial softwares are available for antenna measurements in a CATR like ARCS from March Microwaves system B.V [3] and Militech [4] to name a few. These softwares do not provide open access to their source code because of propriety rights and hence it becomes difficult to add any new hardware to the existing measurement instrumentation, which may be required for up-gradation of the CATR. This paper describes a cost effective solution for the development of customized software using standard industry tools like Agilent VEE and MATLAB for the implementation of Antenna measurements in a CATR. We have named our software Antenna and RCS Measurement System (ARMS).

II. GENERIC ANTENNA MEASUREMENT PROCESS OF CATR

Microwave VNA (E8363B) from Agilent is used as a transmitter and receiver. The analyzer features an integrated microwave source and receiver in the same instrument. Every VNA is equipped with a GPIB interface card and can be controlled through a set of commands which are available in its user manual [4]. A step-frequency signal is transmitted and received by network analyzer in the system. The signal can be regarded as a series of pulses in time-domain. Fig. 1 shows the transmitted signal. The Positioner controller has an angular accuracy of .01degree, and SGH antennas are used as feed/calibration antennas. A complete schematic of CATR instrumentation is shown in Fig 2.

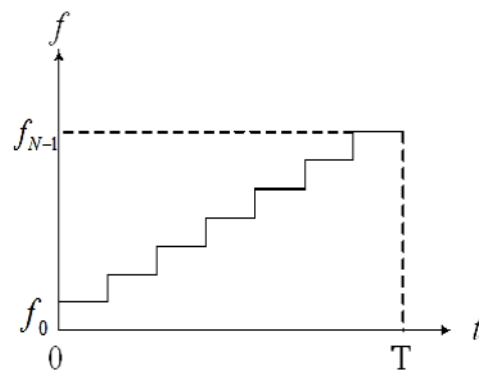


Fig. 1 Transmitted Signal

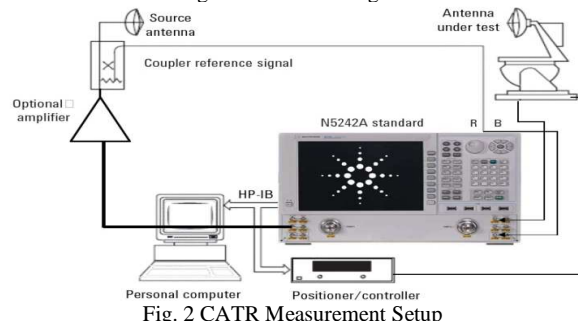


Fig. 2 CATR Measurement Setup

Measurements in CATR are termed relative measurements; therefore Calibration of the CATR is performed before each measurement to check for any losses and degradation in CATR performance. SGH antennas are used for antenna calibration as their frequency Vs Gain plots are available. These plots are generally known as the antenna definition file. During calibration, the SGH is aligned with the main reflector and mounted on the Positioner column. The Positioner column is located in the quiet zone of CATR [1]. A frequency sweep is transmitted through feed antennas and the response of the SGH is detected. The detected response is converted to time domain using inverse FFT (Fast Fourier transform) and a suitable gate is selected by the operator to remove the unwanted signals based on the location of quiet zone of CATR [6]. The gated response is then compared with the antenna definition file of the SGH and stored in the calibration file along with a description of measurement for future reference.

To measure the Radiation pattern of the AUT, it is aligned with the main reflector and mounted on the Positioner column. A frequency sweep is transmitted through feed antennas and the response is detected at each angular position. After each sweep the Positioner is incremented as per the angle step and the process is repeated till data is stored at all angles.

The measured data is converted into time domain using inverse FFT. This data also contains undesired multipath signals e.g. reflections from reflectors, and CATR walls at each angular position. These undesired signals are removed through a suitable gate and the gated response is then compared with the corresponding calibrated data of SGH to obtain the desired response of AUT.

III. SOFTWARE ARCHITECTURE AND ALGORITHMS

Agilent VEE (Visual Engineering Environment) is a powerful graphical programming environment for automated test, measurement and advanced analysis [6]. The hardware control is implemented in VEE. The instrument manager in VEE provides an easy way to control and communicate with individual hardware. Some of the important parameters of the VNA, which need to be setup and controlled during a measurement are listed below:

- **Frequency Span:** The signal provided by network analyzer is equivalent to a series of pulses in time-domain. The width of pulse τ is $1/BW$, where BW is the span of frequency.
- **Number of points:** According to the alias free range of CATR, the maximal interval of frequency Δf_{max} is $c/2R$, which dictates that the minimum number of points be $BW/\Delta f_{max}$.
- **IF bandwidth:** Appropriate IF bandwidths can be helpful in improving the signal to noise ratio (SNR). The narrower the IF bandwidth, the better are the results in terms of resolution. However, if the IF bandwidth is too small, the sweep time will greatly increase leading to an overall increase of the measurement time.
- **Output Power level:** The output power level needs to be set carefully to cater for cable loss and attenuation in space,

also keeping in view that the output of VNA becomes unstable at high frequencies so a power amplifier needs to be used.

These commands are available in the VNA user manual for all the supported interfaces including GPIB. After the successful testing of individual commands, different modules were programmed for the setting up of VNA, Sweep generation/ Completion and data acquisition in the software. The structure of commands differs slightly in different VNAs' therefore; any new VNA can be added by slightly modifying the commands in the corresponding modules.

Similarly, Positioner controller module was designed and tested for the Axis selection (Azimuth and elevation) and rotation of the Positioner through the complete angle span of the measurement as per the given angle step.

The software modules deal with data acquisition and signal processing for complete automation of the measurement process. The user is provided with a single file for complete automation of the measurement process. Fig.3 shows the main screen of the software for operator use. The modules are listed below:

- Calibration Module
- Measurement Module
- Time-domain gating Module
- Data display Module

The data acquisition is done through calibration and measurement modules while signal processing is done in time-domain gating and data display modules.

Fig. 3 Measurement parameters entry window

A detailed description/implementation of each module is given next.

A. Calibration Module

CATR is first setup for Calibration. An SGH antenna is mounted on the Positioner column for reference. In the software, variables are defined for all the VNA parameters that need to be controlled.

After setting up the VNA, a frequency sweep is generated as per the input parameters.

The software then reads the status register of VNA for the completion of the sweep operation. This is implemented in a loop by 60msec of polling time and masking the 5th bit of VNA status register, which indicates the completion of frequency sweep. VNA has four forms of data output but for our purpose, we read Raw data in the “corrected format” out of VNA and store in the form of an complex array. The data is in frequency domain, comprising of both magnitude and phase. This data contains the response of the entire chamber. A hamming window is used to smooth out the data.

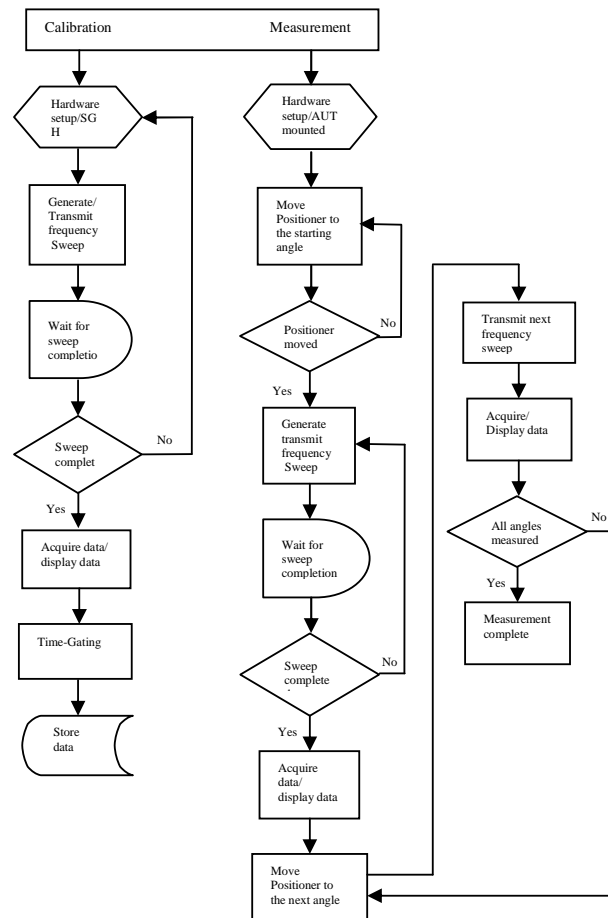
Time domain cancellation provides a good way to cancel out the reflections from the Paraboloidal reflectors and chamber walls. This data is then converted to time domain with an Inverse FFT (Fast Fourier Transform). To get the isolated response of the SGH antenna, a suitable gate is selected by the operator based on the location of the quiet zone of CATR [7]. We have designed a rectangular window (gate), which produces an array of binary 1's based on the operator inputs and performs a binary AND operation with the data in time-domain. This operation is termed as Time-domain gating. The gating program is interactive, when the user changes a gating parameter; the effect on the measured data is recomputed and displayed immediately. After gating out the response of the AUT, the data is converted back to the frequency domain for comparison with antenna definition files. Linear interpolation is used to match the frequency vs. Gain points of the SGH antenna to the measurement frequency points. The measurement frequency points depend on the measurement frequency band. The linearly interpolated data is subtracted from the measured response in frequency domain and stored in a calibration file. The calibration file contains both the linearly interpolated data points and the subtracted data alongwith with the description of the measurement. This file is later used in the measurement and time-gating module of the software.

B. Measurement Module

For the measurement, AUT is mounted on the Positioner column. The calibration file is loaded to the software enabling it to read the measurement parameters. In case of narrow band antennas, an electronic alignment process is performed first, in which the response of AUT is read for small angle span in both azimuth and elevation axis. However, for broad-band antennas, a visual alignment of the AUT with the main reflector will suffice. The hardware is set up accordingly by the variables stored in the calibration file. Axis of rotation of Positioner, normally the azimuth axis, and angle span of the measurement is selected. At each angle, a frequency sweep is transmitted, data is stored, and Positioner is incremented. The rotation of the Positioner is controlled by a loop.

The time required for the Positioner to move to the next angle is programmed by reading the status register of the Positioner though a spolling operation. GPIB interface allows time sharing between VNA and Positioner. The process is repeated till data is stored at all angles. The measurement file contains the calibration data and complex data of each frequency sweep at each angle step.

The overall flow of the calibration and measurement process is displayed in flow chart given below.



C. Time Gating Module

The measured data contains the response of the entire chamber at each angle step. To get the isolated response of the AUT, a windowing operation is performed at each angle step to remove the unwanted signals. The measured file is loaded to this module, enabling it to read the calibration factor, measured data and measurement parameters. Time gating can be done against frequency or angle. In frequency gating, an angle has to be chosen for the application of window, which in normal practice is the boresight angle. In angle gating, a frequency is chosen for the application of window, which in normal practice is the center frequency of the measurement. The data at the selected frequency or angle is converted to time domain using inverse FFT. A rectangular window is generated based on the location of quiet zone of CATR to filter the unwanted signals. The user can control the position, width and taper of the gate. The data is computed and displayed in real time if any parameter is changed by the user. The data is multiplied with this gate and converted back to the frequency domain. The calibration factor is then subtracted from this gated response in the frequency domain.

This serves as a reference for other angles and frequencies of measurement.

This particular gated response is then applied on all the measured frequencies/angles through a loop and data is displayed for each angle step. A snapshot of the gating process is shown in Fig.4.

D. Data Display Module

A variety of data display options are supported. The radiation pattern can be displayed versus angle or frequency in rectangular plots. The maximum gain and 3dB data markers are available along-with the measurement name and date etc. The radiation pattern can also be displayed in polar plots. Printing options as well as jpeg and data storage is available for measurement database.

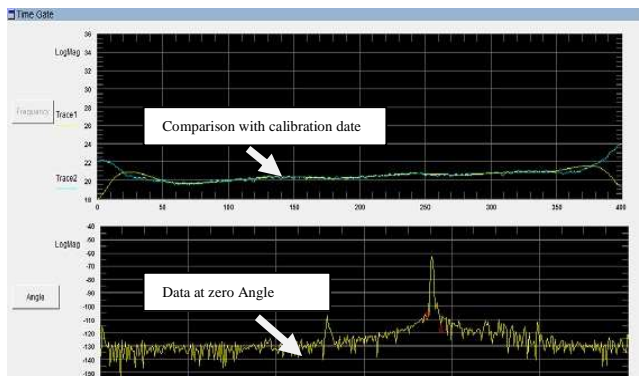


Fig. 4 Time-Gating

IV. MEASURED RESULTS

Fig. 5 shows the radiation pattern of an X band SGH antenna versus angle and Fig.6 shows the gain response versus frequency. The gain of the antenna is 20dBi and 3-dB bandwidth is 18 degrees. The measurement is done with an angle span of 180 degrees and the frequency band is from 10 to 12GHz. Fig.6 shows gain Vs frequency and it can be seen that the gain increases linearly with frequency. Fig.7 shows the polar plot of the same antenna.

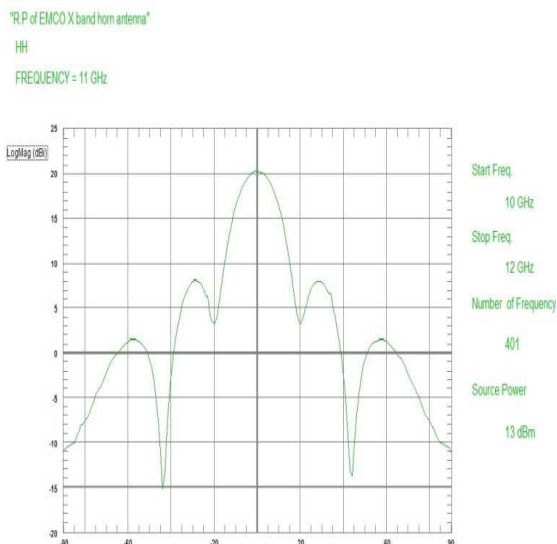


Fig. 5 Radiation pattern of an X band SGH antenna vs. angle

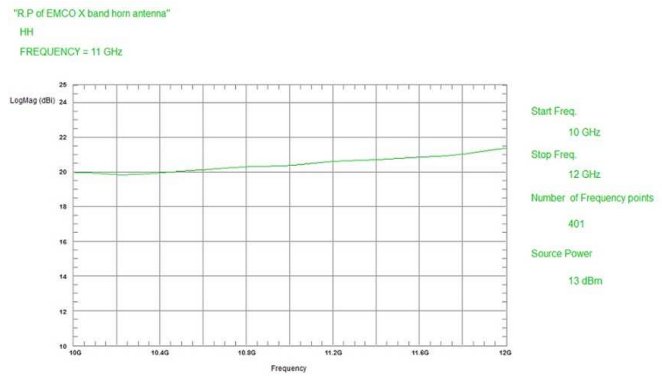


Fig. 6 Gain vs. freq response of an X band SGH antenna

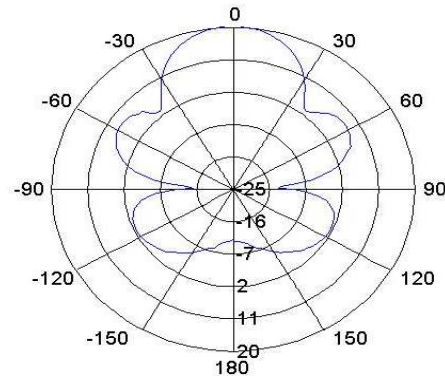


Fig. 7 Polar Plot of an X band SGH antenna

V. RESULTS COMPARISON

To authenticate the measured results, a variety of corresponding measurements are performed with ARCS software from March Microwaves using SGH. The comparisons of results show an excellent agreement.

Fig. 8 shows the result of C band SGH antenna measured with ARCS and ARMS. The solid line shows the result measured with ARCS whereas the dotted line shows the result of ARMS. As can be seen, they are in excellent agreement and are within the limit of .2dB, which is the uncertainty limit of CATR. Fig.9 shows a similar comparison of an X band horn antenna. Again, they are in excellent agreement.

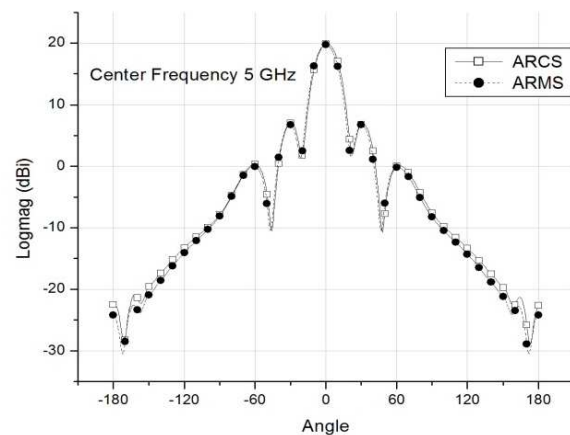


Fig. 8 Radiation pattern comparison of C band SGH antenna

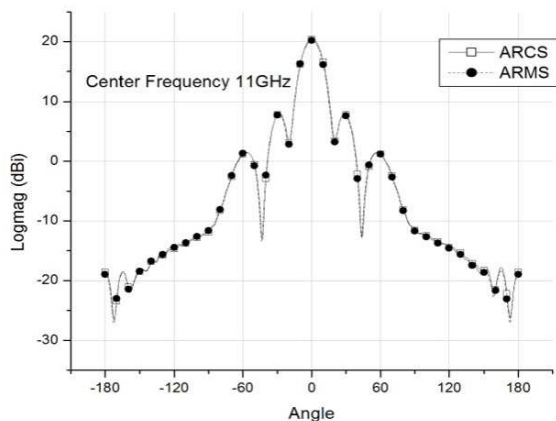


Fig. 9 Radiation pattern comparison of X band horn antenna

VI. CONCLUSION

A cost effective solution for the automation of CATR is presented using standard tools like Agilent VEE and Matlab. A variety of network analyzers can be added to the software with slight modification. The software can generate results in a variety of formats. The measured results are in excellent agreement with existing commercial softwares.

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