Pakistan Journal of Engineering and Technology
ISSN (Print): 2664-2042; ISSN (Online): 2664-2050
Received: 2024-03-15
Accepted: 2024-06-28
https://doi.org/10.51846/vol7iss2pp72-78

PAKJET
Pakistan Journal of Engineering & Technology

Article

Automated Gain Measurement System for Wide-Band Antenna Based on Instruments Remote Access Techniques: Direct SCPI Commands

Ali Ameen Mohammad [1], Bashar Alwannos [2], and Alaa Salman [2,*]

[1] Department of Electronic Systems Engineering, Higher Institute for Applied Science and Technology, Damascus, Syria
[2] Department of Communication Engineering, Higher Institute for Applied Science and Technology, Damascus, Syria
* Correspondence: Alaa Salman (alaa.salman@hiast.edu.sy)

Abstract: A novel approach to wide-band antenna gain measurement is presented in this article, offering practical solutions to address the challenges posed by traditional measurement methods. The proposed system enhances efficiency, reduces complexity, and improves accuracy, making it a valuable tool for antenna testing in research and industry settings. A discussion of the challenges and complexities involved in measuring the specifications of manufactured antennas is made. We are particularly focusing on wide-band antenna gain measurement. It highlights the need for special equipment and expertise to conduct these tests effectively, especially for wide-band antennas. The proposed automated measurement system aims to simplify and streamline the gain measurement process by remotely driving the necessary instruments and reducing the complexity of the measurement mechanism. The novelty of this new automated measurement system can be divided into two branches. The first branch improves the standard approach of wide-band antenna gain measurement. The second branch modifies the structure of the software of the traditional remote access applications by mixing the operational instructions of the instrument with the direct SCPI commands. The resulting software has the ability to remotely drive many instruments synchronically, reducing the number of experienced people needed to complete the measurement process.

Keywords: Antenna Gain, Antenna Under Test, Graphical User Interface, Measurement Instruments, Modular Antenna, Remote Access, RF Generator, SCPI Standard, Spectrum Analyzer, VISA Standard

1. Introduction

Working in an antenna laboratory requires conducting several tests to verify the specifications of the manufactured antenna (stable wave ratio, frequency range, radiation pattern, antenna gain.). These tests require the use of a combination of special equipment, such as an anechoic chamber, antenna feed cables, radio RF generators, and measuring instruments. Antenna gain measurement is a process that requires additional effort and time, especially for wide-band antennas, where it is necessary to measure the gain at a number of frequencies that cover the entire frequency band, and it also requires a modular antenna or several modular antennas that cover the entire frequency band. One of the issues that make this type of test more complex is that it requires tuning several measuring instruments (RF signal generator, spectrum analyzer) and also requires a distance between these instruments; therefore, we need more than one person experienced in using measurement instruments [1]. So, it is necessary to work on automating this process in order to save time and effort and reduce the number of experienced people needed to complete the measurement process.

The new automated measurement system presented in this paper improves the gain measurement process in two aspects. First, it simplifies the driving process of the needed instruments, and second, it reduces the complexity of the measurement mechanism.

Traditionally, for the driving process, some instrument manufacturers have provided the ability to control measurement instruments remotely by supporting the instruments with remote access technology and providing the required driving software for them. This requires purchasing of off-the-shelf software and licenses, which increases cost [2], [3]. However, this software may not support some functions that are appropriate for the type of test we want. Manufacturers of measurement instruments have developed the concept of programmed control of measurement instruments by supporting these instruments with “Standard Commands for Programmable Instrumentation” SCPI standard and “Virtual Instrument Software Architecture” VISA standard [4], [5], so the user can design a graphical user interface using one of the programming languages (C#, Python, Matlab, Labview) through which he can control the measurement instruments to suit his requirements [6], [7], [8]. However, this method requires drivers for the instruments used, and the measurement instruments must be equipped with the required interface outputs LAN, USB, and GPIB [9]. This paper presents a proposed structure of the measurement software to solve the problem of the need to have drivers for the used measurement instruments. The proposed structure of the measurement software is achieved by mixing the operational instructions of the instrument with the direct SCPI commands of that instrument so that the instrument can be connected directly via the RS232 serial port.

Traditionally, a wide-band antenna gain measurement mechanism requires the use of a modular antenna or many modular antennas that cover the entire frequency band of the antenna under test (AUT), which is not always available in the antenna lab. Our new automated measurement system modifies the measurement mechanism by eliminating the need for a modular antenna so that any two identical antennas can be used.

As a result, a new automated measurement system has been built that remotely drives two measurement instruments (RF generator and spectrum analyzer) synchronically and performs the wide-band antenna gain measurement over its entire frequency band. Then, the results were stored and calculated to compare them with the theoretical values on which the antenna was designed based. The new automated measurement system saves time and effort and avoids increasing costs by using relatively old measurement instruments available in the laboratory and only equipped with an RS232 serial port. Also, this proposed system reduces the number of experts needed to achieve the measurement process.

Sections of this paper are organized as follows. In Section 2, the methodology of finding antenna gain and the required equations are discussed. In Section 3, the proposed structure of the new software is presented. In Section 4, the experiments and results are demonstrated and presented. Finally, we present a conclusion in section 5.

2. Methodology

Wide-band antenna gain measurement requires a modular antenna with the same frequency band as the antenna under test (AUT). Fig. 1 shows the scenario of antenna gain measurement based on a modular antenna [1].

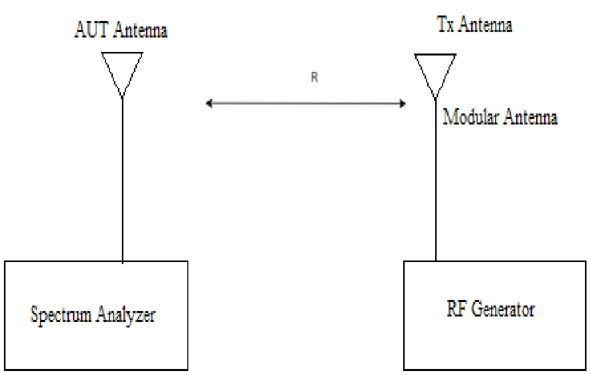

Figure 1. Scenario of antenna gain measurement based on a modular antenna.

The gain of the antenna under test is calculated according to (1).

$$G_{t,dB} + G_{r,dB} = 20\log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10\log_{10}\left(\frac{p_r}{P_t}\right) \quad (1)$$

where:

$G_{t,dB}$: is the gain of the transmitting antenna.
$G_{r,dB}$: is the gain of the receiving antenna.
P_r: is the received power.
P_t: is the transmitted power.
R: is the distance between the transmitting and receiving antennas.
λ: is the wavelength of the radio signal.

Due to the difficulty of having a modular antenna that covers the entire frequency range of the wide-band AUT, we will present a method to measure the antenna gain in the absence of a modular antenna.

2.1. Proposed Approach for Gain Measurement

This approach requires two stages to find the antenna gain. In the first stage, we use two identical antennas operating on the same frequency range as the antenna under test. One antenna is used at the transmitting end, connected with the RF generator, and fed with a specific power P_t. The other antenna is used at the receiving end and connected with the spectrum analyzer, the received power P_r. Because of the correspondence between the two antennas, we accept that the gain of the transmitting antenna is equal to the gain of the receiving antenna, so the Friiss equation becomes (2).

$$G_{dB} = \frac{1}{2}\left[20\log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10\log_{10}\left(\frac{p_r}{P_t}\right)\right] \quad (2)$$

Fig. 2 shows using of two identical antennas.

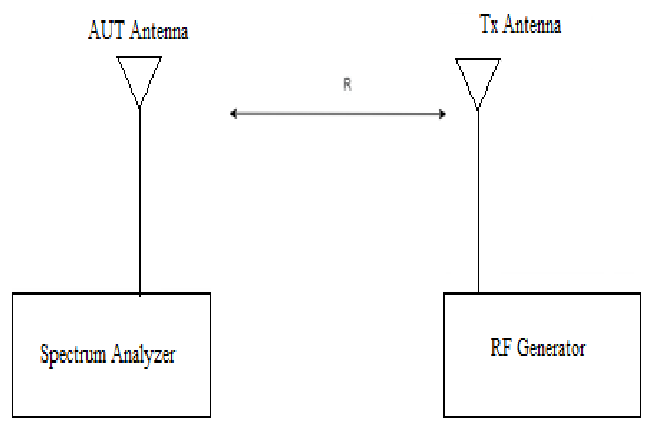

Figure 2. Using of two identical antennas.

At this point, an antenna of known gain has been obtained to be used as a reference antenna. Then, in the second stage, the experiment is repeated. The antenna under test is fixed at the reception end, and one of the two identical antennas is fixed at the transmission end. Then, the scenario in the previous paragraph is applied. We note that this method requires re-experimenting twice, and each time, we must scan all the required points within the frequency range of the antenna. This process consumes a lot of time and effort because of the need for more than one person who has experience in working on measurement instruments. We will automate this process by designing a graphical user interface through which both the RF generator and the spectrum analyzer are synchronically controlled remotely, and the whole test is done automatically.

2.2. Proposed Structure of the Measurement Software

SCPI is a standard programming language designed specifically for controlling instruments from an external computer. SCPI allows building a control application using a high-level programming language [10], [11], [12].

Programming languages support measurement instrument's control through the use of VISA libraries that encapsulate SCPI commands and send them to the connected instrument with the computer through various communication ports such as LAN, GPIB, USB, and RS-232. However, this method requires having the VISA libraries and installing the drivers for the used instrumentation [13], [14], [15]. Fig. 3 shows the structure of the traditional software.

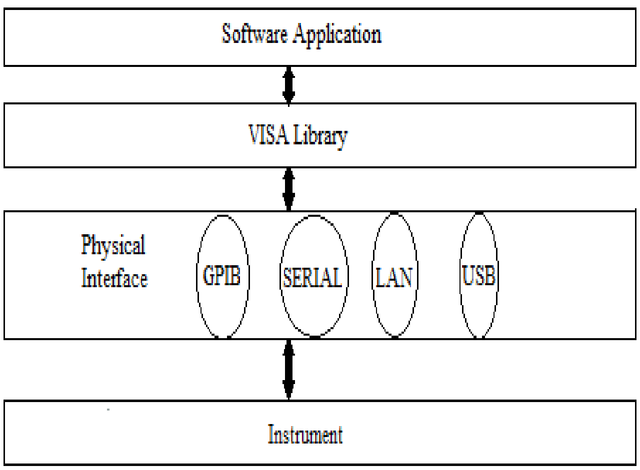

Figure 3. Structure of the traditional software.

In this paper, we present a proposed structure of the measurement software to solve the problem of the need to have drivers for the used measurement instruments. The proposed structure mixes the operational instructions of the instrument with the direct SCPI commands of that instrument, connecting it directly via the RS232 serial port without the need for VISA libraries and the instrument's drivers. Fig. 4 shows the structure of the proposed software.

From the figure, we can see that the need for VISA libraries and instrument drivers has been eliminated, and direct access to the instrument has been achieved.

3. Proposed Architecture of the Automated Measurement System

The proposed system consists of an RF generator connected to the transmitting antenna and a spectrum analyzer connected to the antenna under test. Both devices are connected separately to the laptop via an RS-to-USB converter connection. Fig. 5 shows the scheme of the automated system.

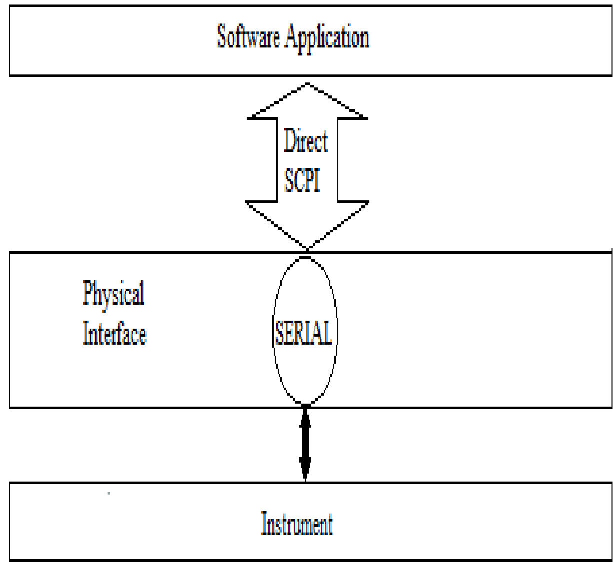

Figure 4. Structure of the proposed software (Mixed "direct SCPI" & "operational instructions").

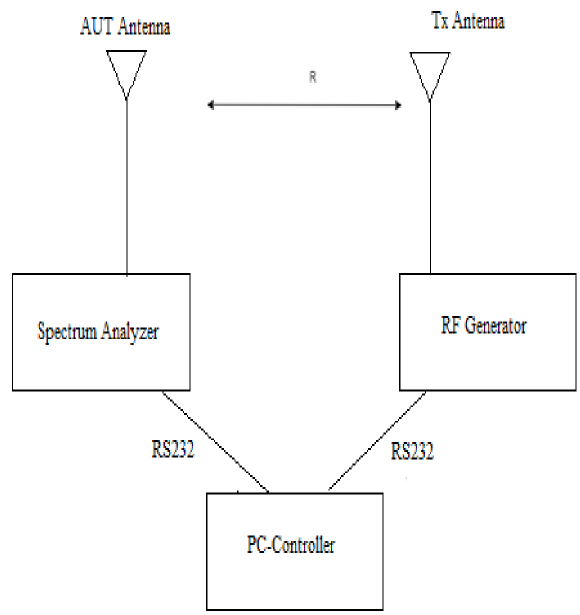

Figure 5. Scheme of the proposed automated system.

The instruments used in this system are relatively old devices, and it is difficult to get the drivers for them. They are equipped only with an RS-232 serial port interface. This reduces cost in terms of the possibility of building an automated system without the need to purchase modern instruments or even get driver files for them.

The frequency range and the points required to calculate the gain are determined through the GUI within the computer, and then the program automatically calculates the gain over the entire frequency range without the need for more than one person. It also does not require that the person making the test be experienced in using measurement instruments. Thus, the effort and time are greatly reduced.

3.1. Software Design for the Proposed System

The GUI is designed using C# programming language, through which both the RF generator and the spectrum analyzer are controlled after connecting each of them to the computer via the RS232 serial port. After designing the GUI, it can be installed on any computer, where the program sends SCPI commands directly to the connected devices without the need to download any drivers or any of the VISA libraries of these instruments and thus the design of the program is simplified.

3.2. Program Flow Chart

A graphical user interface "GUI" based on C# programming language is built. The GUI controls two instruments (spectrum analyzer - RF generator). Fig. 6 shows the Flowchart of the designed program.

The process of conducting the measurement requires the control of the (RF Generator & Spectrum Analyzer) at the same time, which necessitates attention to the synchronization between these devices to ensure that the measurement result at each point of the experiment is correct.

In this program, the use of fixed delays to generate time delays is avoided. Instead, time delays are generated by examining the status registers in each instrument using each of the instructions (*OPC?, *OPC, *WAI). In this way, we can reach the synchronization points at which the instruments are synchronized. Fig. 7 shows the synchronization diagram of the designed program.

4. Test and Results

In this section, the proposed automated system is used to measure the gain of a printed antenna (antenna under test) operating in the frequency range [2.6, 3.3] GHz. The antenna gain is measured in two stages: in the first stage, two identical horn antennas operating at a frequency range [2, 3.3] GHz are used, and its gain is obtained based on (2).

Then, in the second stage, the printed antenna (antenna under test) is used, where the measurements are taken, and its gain is calculated using the designed software.

Using the designed GUI, the user can configure each of the RF generators and spectrum analyzer remotely, then measure the received power from the antenna and separately apply (1) and (2) for each stage to calculate the antenna gain.

For the first stage, the power is plotted on the right side (dBm) of the GUI, as shown in Fig. 8. Then gain values are calculated and plotted on the left side (dB) of the GUI, as shown in Fig. 9. The program also saves these values in an Excel file so that the user can view the results at a later time. The results are shown in Table 1.

For the second stage, it measures the received power from the antenna under test and applies equation (1) to calculate the gain of the antenna under test at each point within the specified frequency range and draw these values. Fig. 10 shows the graph of the received power from both the horn antenna (first stage) and the antenna under test (printed antenna).

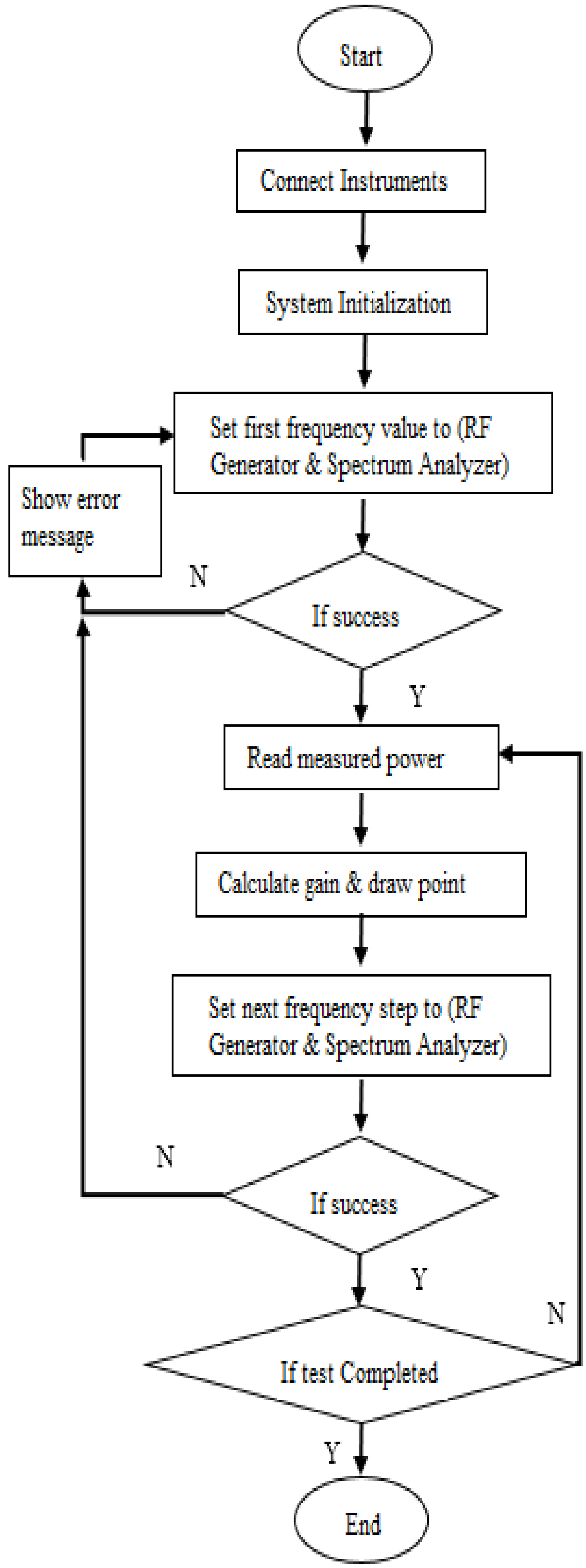

Figure 6. Flowchart of the designed program.

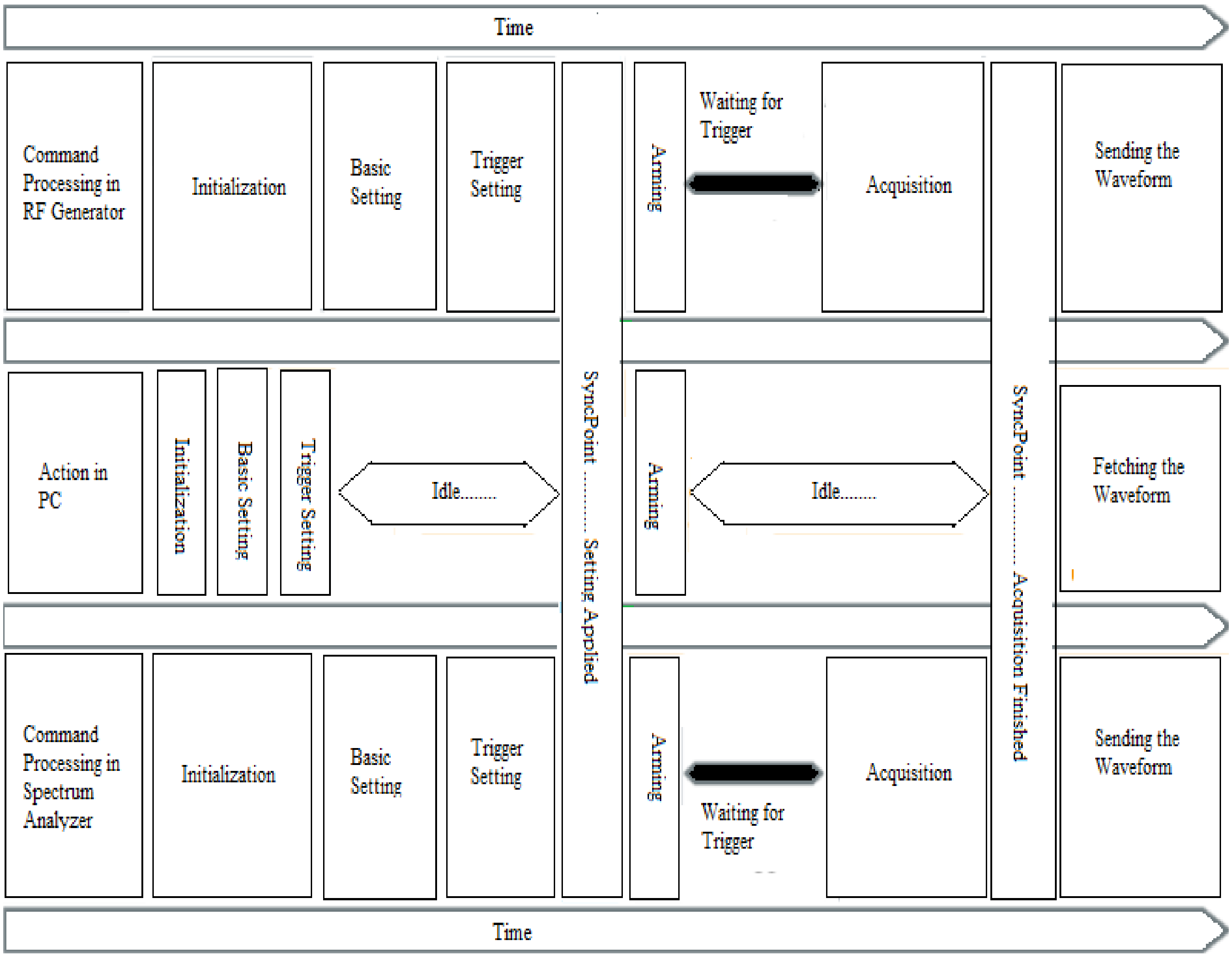

Figure 7. Synchronization diagram of the designed program.

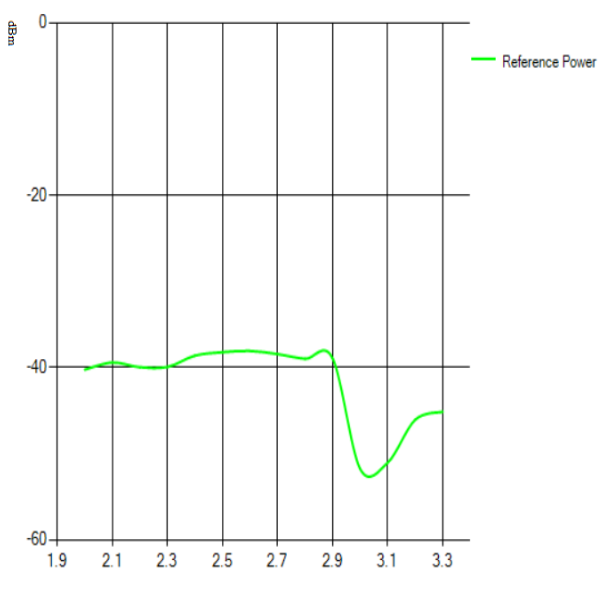

Figure 8. The received power in first stage of the experiment.

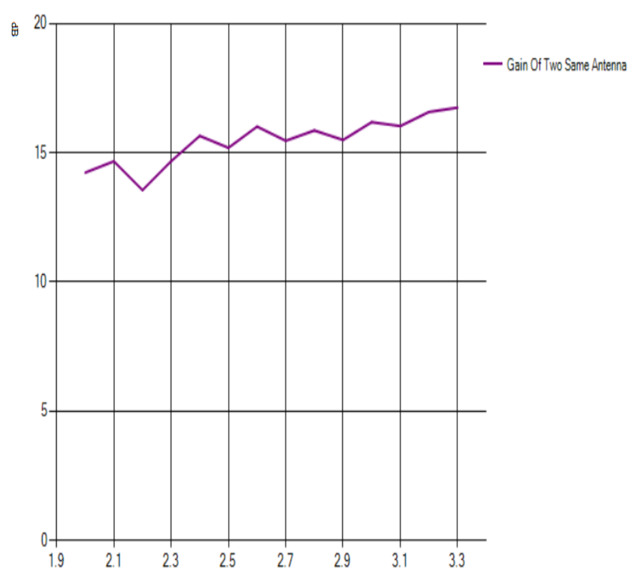

Figure 9. The calculated gain in first stage experiment.

The graph of the gain values for both antennas is shown on the left side of the GUI, as shown in Fig. 11. Its Excel file is shown in Table 2.

Table 1. Results of the first stage.

Frequency (GHz)	Received Power (DBM)	Antenna Gain (DB)
2	-40.2201767	14.225443
2.1	-39.39613342	14.66446355
2.2	-39.94549561	13.54927957
2.3	-39.91497803	14.6696559
2.4	-38.60260773	15.64801565
2.5	-38.20584869	15.18702341
2.6	-38.05324554	16.008065
2.7	-38.419487	15.45950673
2.8	-38.968853	15.85766757
2.9	-38.90781021	15.49131514
3	-51.72628403	16.179951
3.1	-51.0243187	16.02844346
3.2	-46.04953003	16.57422139
3.3	-45.103405	16.74212843

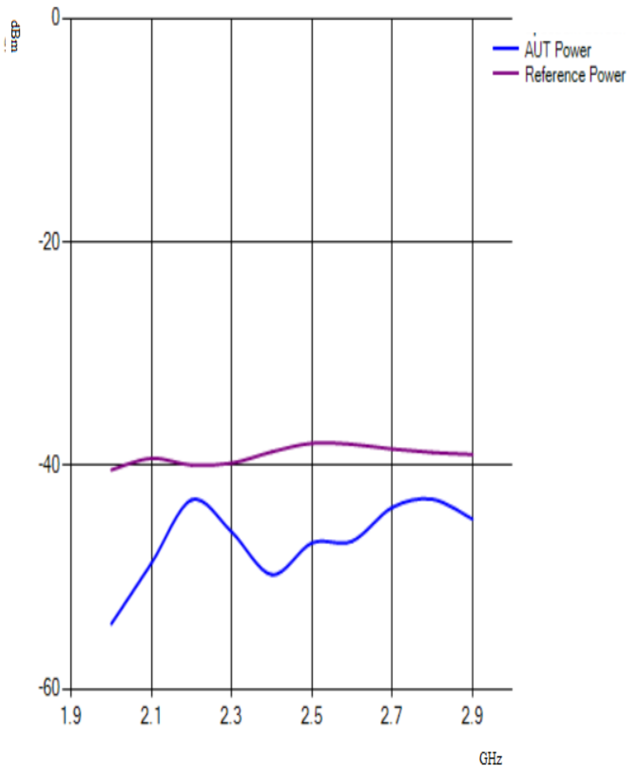

Figure 10. Received power from both the horn antenna (first stage) and the antenna under test (second stage).

The calculated values of antenna gain can be compared with the theoretical values that are exported from the CST program to determine the deviation of the manufactured antenna from the theoretical values for which it was designed.

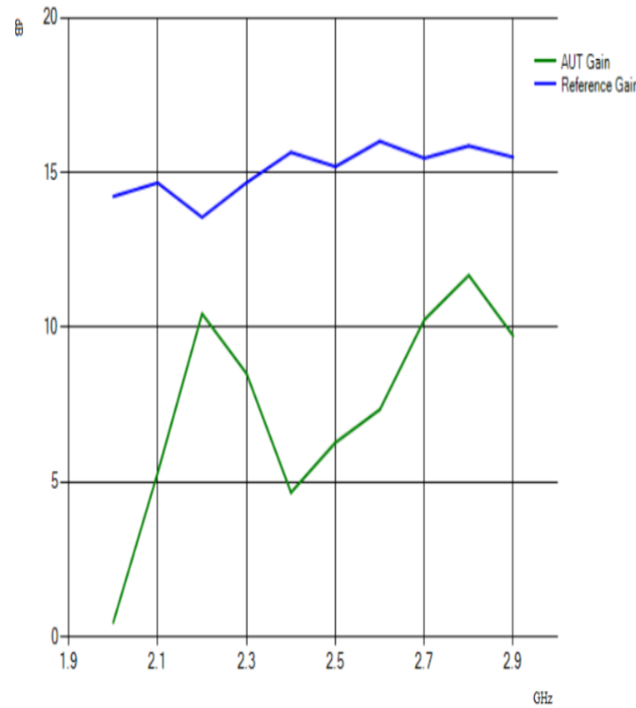

Figure 11. Calculated gain of both the horn antenna (first stage) and the antenna under test (second stage).

Table 2. Results of the second stage.

Frequency (GHz)	Received Power Form the Known Antenna (DBM)	Received Power from "Aut" (DBM)	Calculated Gain of the "Aut" (DB)
2	-40.37277985	-54.13737488	0.46084797
2.1	-39.33509445	-48.70478439	5.294773605
2.2	-39.94549561	-43.0585556	10.43621958
2.3	-39.76237488	-45.92744827	8.504582508
2.4	-38.75521088	-49.74246979	4.66075674
2.5	-37.99220657	-46.9040947	6.27513528
2.6	-38.08376694	-46.75149536	7.340336583
2.7	-38.51104736	-43.72999954	10.24055455
2	-40.37277985	-54.13737488	0.46084797
2.1	-39.33509445	-48.70478439	5.294773605
2.2	-39.94549561	-43.0585556	10.43621958
2.3	-39.76237488	-45.92744827	8.504582508
3.2	-46.04953003	16.57422139	
3.3	-45.103405	16.74212843	

5. Conclusion

The article discusses the challenges and complexities involved in measuring the specifications of manufactured antennas, particularly focusing on antenna gain measurement. It highlights the need for special equipment and expertise to conduct these tests effectively, especially for wide-band antennas. The proposed automated measurement system aims to simplify and streamline the gain measurement process by remotely driving the necessary instruments and reducing the complexity of the measurement mechanism.

Overall, the article presents a novel approach to antenna gain measurement, offering practical solutions to address the challenges posed by traditional measurement methods. The proposed system enhances efficiency, reduces complexity, and improves accuracy, making it a valuable tool for antenna testing in research and industry settings.

A graphical user interface "GUI" based on C# programming language is built to control two instruments (spectrum analyzer - RF generator). As a result, an automated system is built that performs antenna gain measurements over its entire frequency range. This system has the ability to store and calculate the results and then compare them with the theoretical values on which the antenna was designed. Finally, some experimental results on measuring the gain of some available antennas are presented.

Authors' Contributions: The methodology and supervision were done by Alaa Salman. Programming was done by Ali Ameen Mohammad. Analysis and simulation were done by Ali Ameen Mohammad and Bashar Alwannos. Discussion of results, typesetting, and approving the final manuscript were implemented by all authors.

Acknowledgments: The authors acknowledged the facilities provided by HIAST University.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

[1] K. K. Mistry, P. I. Lazaridis, Z. D. Zaharis, M. Akinsolu, B. Liu and T. Loh, "Accurate antenna gain estimation using the two-antenna method," *Antennas and Propagation Conference 2019 (APC-2019)*, Birmingham, UK, 2019, pp. 1-4.

[2] O. V. Drozd, P. A. Russkikh and D. V. Kapulin, "Special software for Automated Measuring Complex based on Rohde & Schwarz equipment," *2019 International Siberian Conference on Control and Communications (SIBCON)*, Tomsk, Russia, 2019, pp. 1-4.

[3] R. Martinek, M. Al-Wohaishi and J. ćídek, "Software based flexible measuring systems for analysis of digitally modulated systems," *9th RoEduNet IEEE International Conference*, Sibiu, Romania, 2010, pp. 397-402.

[4] B. A. Balaji, S. Sasikumar, and K. Ramesh, "SCPI based integrated test and measurement environment using LabVIEW," *IOP Conference Series: Materials Science and Engineering,* 2021, vol. 1045.

[5] M. Jurčević, H. Hegeduć and M. Golub, "Generic system for remote testing and calibration of measuring instruments: Security architecture", *Meas. Sci. Rev.*, vol. 10, no. 2, pp. 50-55, 2010.

[6] T. Shejbal, M. Petkov, T. Zalabsky, J. Pidanic, Z. Nemec, "Remote Control Software for Rohde & Schwarz Instruments," *International Journal of Computer and Information Engineering*," vol. 7, no. 10, 2013.

[7] R. Martinek, M. Al-Wohaishi and J. ćídek, "Software based flexible measuring systems for analysis of digitally modulated systems," *9th RoEduNet IEEE International Conference*, Sibiu, Romania, 2010, pp. 397-402.

[8] Z. Zeng, X. Zhu, S. Qi, X. Shen, and S. Cai, "Preliminary Exploration of Instrument Control Technology," *IOP Conf. Series: Materials Science and Engineering 394*, 2018.

[9] P. Sumathi and D. Peter, "Instrument Control through GPIB-USB Communication with LabVIEW," *2019 IEEE 28th International Symposium on Industrial Electronics (ISIE)*, Vancouver, BC, Canada, 2019, pp. 1583-1588.

[10] H. M. Hyman, "Philip B. Kurland and Ralph Lerner, eds., The Founders' Constitution, Chicago: University of Chicago Press, 1987. 5 vols. Pp. xiii, 3260. $300 (ISBN: 0-226-46387-7).," Law and History Review, vol. 5, no. 2, pp. 581–582, 1987.

[11] C. -C. Chang, Y. -T. Chiu and C. -C. Wei, "Design instrument control software interface based on SCPI commands to reduce development time," *2021 7th International Conference on Applied System Innovation (ICASI)*, Chiayi, Taiwan, 2021, pp. 97-100.

[12] R. & S. G. & C. KG, "Hints and Tricks for Remote Control of Spectrum and Network Analyzers." Accessed: Jul. 23, 2024. [Online]. Available: https://www.rohde-schwarz.com/us/applications/hints-and-tricks-for-remote-control-of-spectrum-and-network-analyzers-application-note_56280-15635.html

[13] R. & S. G. & C. KG, "How to use Rohde & Schwarz IVI.NET instrument drivers." https://www.rohde-schwarz.com/us/applications/how-to-use-rohde-schwarz-ivi.net-instrument-drivers-application-note_56280-143873.html (accessed Sep. 08, 2022).

[14] F. Alegria and H. G. Ramos, "A remote controlled automated measurement system," *IEEE Instrumentation and Measurement Technology Conference Sensing, Processing, Networking. IMTC Proceedings*, Ottawa, ON, Canada, 1997, pp. 1186-1189 vol.2.

[15] U. Tariq, "GUI Application for Measuring Instruments Noise Measurement System," Uppsala University, pp. 11–13, 2013.