A Cost-Effective Far-Field Antenna Pattern Measurement System

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***Abstract*—A low-cost far-field antenna measurement solution is developed and presented. In an increasingly wireless society, it is important to be able to characterize antennas. Unfortunately, determining antenna radiation pattern characteristics is an involved and often expensive process. The presented system provides a complete combination of hardware and software that can be used for far-field pattern measurements of an antenna operating in the 700 MHz to 18 GHz range. This would allow institutions and groups with few resources to be able to characterize the radiation pattern of antennas for many emerging applications.**

Keywords*—*Anechoic chamber, antenna pattern measurement, far-field measurement, low cost.

I. INTRODUCTION

Antennas are typically characterized by their impedance bandwidth and their radiation qualities. The impedance bandwidth is easily determined through a one-port measurement with a VNA, however, the radiation qualities of an antenna require specialized ranges to ascertain [1-2]. These ranges typically consist of a standard antenna that is used to determine the radiation parameters of an unknown antenna. The distance between the two antenna must meet the far-field criteria for accurate measurements [3].

There are many types of such far-field ranges, however, the one this paper focuses on is an implementation of a system that works within an anechoic chamber.

The proposed system consists of electrical hardware, mechanical fixtures, and in-house software as explained in the following sections. The far-field measurement is conducted by analyzing S21 data taken using a Keysight VNA connected to a source fixture and an antenna-under-test (AUT) fixture spaced approximately three meters apart. There is one rotary table for the source antenna, typically a horn, and two rotary tables for the AUT. These rotary tables allow the system to perform S21 measurements as a function of multiple angles and frequencies. An example dipole antenna pattern measurement with this system can be seen in Fig. 1. The pattern is asymmetrical because the measurement was conducted without calibration or absorbers lining the anechoic chamber at the time of this writing.

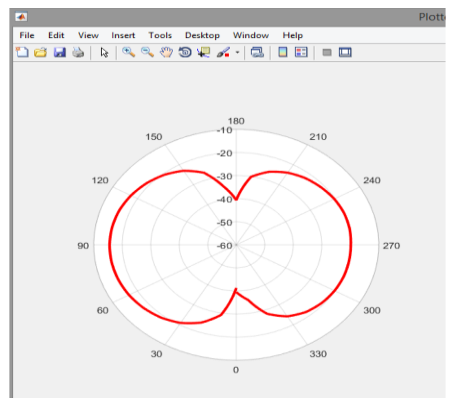

Fig. 1. The measured y-z plane pattern cut of a z-directed half-wavelength dipole antenna [4].

II. ELECTRONIC HARDWARE

Several pieces of equipment facilitate the measurement process. The system components are shown in Fig. 2. There are two LNAs, one at the output of port 1 and one at the input of port 2. The software automatically powers the LNAs through a programmable BK-Precision power supply. Three Velmex rotary tables are used, one on the source side, and two on the AUT side. These rotary tables allow for two axes of rotations at the AUT and one axis of rotation at the source antenna. There are also two Pololu linear actuators that allow for horizontal and vertical alignment of the source antenna with the AUT.

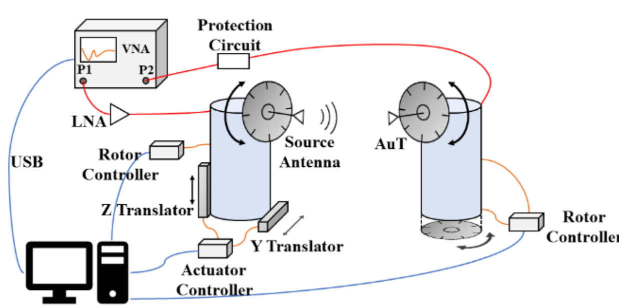

Fig. 2. Schematic for the designed antenna pattern measurement system [4].

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In this design, there is a novel protection mechanism that is optional to the base functionality of the system but adds to the robustness of the overall system. This protection circuit was added to protect the VNA receiver from damage due to high power levels which may occur with novice users. This circuit essentially consists of a limiter and detector diode. The detector diode serves to notify the software and operator that a hazardous condition has been reached and halts the measurement until it is reviewed. This equipment can be seen on the control table in Fig. 3.

Fig. 3. Control table featuring all necessary electronic hardware.

III. MECHANICAL FIXTURES

The fixtures shown in Fig. 4 that hold the source and AUT were designed using MDF plywood, which was chosen for its low cost, relative strength, and machining ease. Furthermore, MDF plywood would not reflect electromagnetic waves as much as metal materials such as aluminum, which would disturb the measurement results. The AUT fixture allows for different antenna to be easily mounted. The fixtures are also designed to be easily taken apart so that maintenance and inspection can be done in a short amount of time.

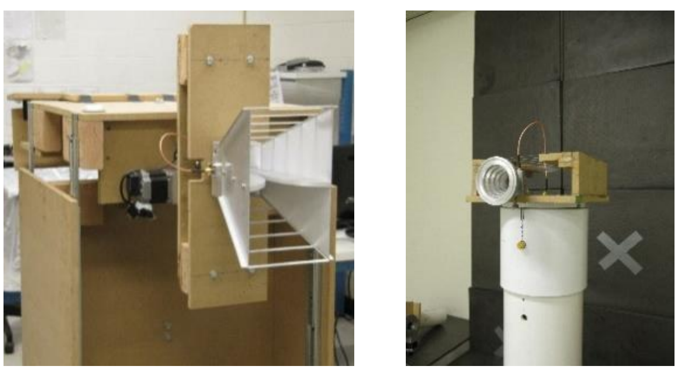

Fig. 4. Source fixture with source horn (left) and AUT fixture with mounted dipole antenna (right).

IV. SOFTWARE

The developed software consists of a main GUI written in MATLAB and custom C# drivers that communicate with SCPI-enabled programmable power supplies and Keysight ENA/ Fieldfox series VNAs [4]. This software allows for complete setup and control of the measurement. The software was designed to be modular so it could be easily upgraded and adapted to different equipment.

V. FUTURE ENHANCEMENT

Currently, the alignment of the source antenna with the AUT is done manually. An automated system for alignment utilizing lasers is in progress. Furthermore, the fixtures can be greatly improved by moving away from the MDF that was used and instead utilizing 3D printed plastics and belts to make them more compact, lightweight, and robust. Lastly, the linear actuators are to be replaced with geared stepper motors for better positional accuracy of the source fixture.

VI. PRECAUTIONS

Most groups who try to make their first antenna pattern measurement system will underestimate how important it is to have a defined and consistent antenna mounting scheme. There are many kinds of antennas which may potentially require measuring different planes, so it is important to always define measurement sweeps in a consistent manner for clarity of measurement results across operators and antennas. This is directly related to how each group decides to mount their rotary tables, as no single combination of rotary table placements is necessarily more correct over another especially when one is measuring many different types of antennas. Depending on where one chooses to locate their rotary tables, they may or may not get pure ϕ or θ plane cuts of their antenna, which is important to take into consideration when defining measurements and analyzing data.

VII. COST

The presented system provides antenna far-field measurement capability at low cost. The total costs is less than $10,000. A majority of this cost can be further reduced by utilizing less precise rotary tables for which the software and fixtures can easily be adapted to. This of course does not include the costs for a two port VNA and absorbers for the chamber, which are a significant cost of any antenna pattern measurement system. However, one may not need to buy an expensive VNA like the ones used in this system. Depending on the user's needs, one could opt for one of the growing consumer and affordable VNAs on the market, which would reduce entry costs significantly. These other VNAs can easily be adapted to the controller software due to its modularity.

VIII. CONCLUSION

Cost effective antenna measurement system is developed. Components, associated cost, and precautions in developing the system are presented.

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