

A COST-EFFECTIVE ANTENNA POSITIONING SYSTEM FOR MODERN RADIO-FREQUENCY (RF) AND MICROWAVE ANTENNA MEASUREMENTS

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INTRODUCTION

Recently, the microwave test equipment in the Electrical and Computer Engineering Department (ECE) at North Dakota State University (NDSU) was significantly upgraded. A new Agilent E5071C 8.5 GHz ENA series network analyzer and an anechoic chamber were two major pieces added to the lab. This upgrade required the development of an antenna measurement system (AMS) that could be used to measure the far-field behavior (i.e., field patterns) of an antenna. To develop an AMS a team consisting of ECE seniors was assembled. This team designed an AMS system that uses LabView to interface with the Agilent network analyzer and a structure that rotates the antenna in both the E- and H-planes. The computer running LabView interfaces with the network analyzer using the Ethernet and interfaces with the rotating structure using an infrared (IR) port. By correlating the S_{12} data from a network analyzer to the angle of rotation of the structure, a complete far-field pattern of the antenna can be measured. This paper will summarize the design and operation of the AMS along with the total cost. The cost of the AMS is about 10% of the cost of commercially available systems, thus making the system attractive to programs with a limited budget.

MOTIVATION FOR AN ANTENNA MEASUREMENT SYSTEM

Wireless communications is being studied extensively and has attracted the attention of many researchers throughout the world. A major component in all wireless systems is the antenna. These antennas mainly consist of three-dimensional antennas (Balanis, 2005) and planar antennas (Waterhouse, 2007). Therefore, when a novel antenna is developed, a system of testing the performance of this antenna is required. One method of testing a newly developed antenna is to use an AMS.

An AMS measures two main properties of an antenna: radiation pattern and input impedance. By measuring the radiation pattern of an antenna, a designer is able to determine the performance of the antenna in the space surrounding the antenna (this space is usually air). From this information, the direction the antenna is radiating the most power can be determined as well as how much power is actually radiated by the antenna (i.e., gain) and how much is being lost in the material used to construct the antenna. The AMS can also be used to measure the input

impedance of the antenna. If done correctly, this measurement results in a value representing the input impedance of the isolated antenna element and does not include the influence of the antenna feeding network. This value is useful for proper design of efficient power delivery to the antenna by a transmitter or efficient power delivery by the antenna to a receiver.

TOPOLOGY OF THE ANTENNA MEASUREMENT SYSTEM

The AMS consists of three major components: 1) antenna positioner, 2) network analyzer and 3) computer. The topology of the entire system is shown in Fig. 1. The following sections describe the operation of each major component.

Antenna Positioner

The antenna positioner rotates the antenna under test 180 degrees in both the x-z and y-z planes. Photographs of the antenna positioner are shown in Fig. 2. The step size of the positioner is defined by the user on the computer using the LabView software. Two servo motors control the antenna positioner. One servo motor rotates the antenna mast from 0 to 180 degrees (illustrated in Fig. 2 by the white arrows) at defined step sizes and the second servo rotates the plate at the top of the antenna mast from 0 degrees to 90 degrees in one step. In summary, the motions of the antenna positioner during a measurement are as follows: 1) the bottom servo rotates the mast from 0 degrees to 180 degrees at step sizes defined by the user; 2) when the mast is rotated to 180 degrees, the second servo rotates the antenna plate at the top of the mast 90 degrees in one step; 3) then the servo at the bottom of the mast rotates the mast back from 180 degrees to 0 degrees at the step sizes defined by the user. It should also be noted that the user can define a specific time delay between each step taken by the servo motor. This allows the mast to settle before measurements are taken by the network analyzer.

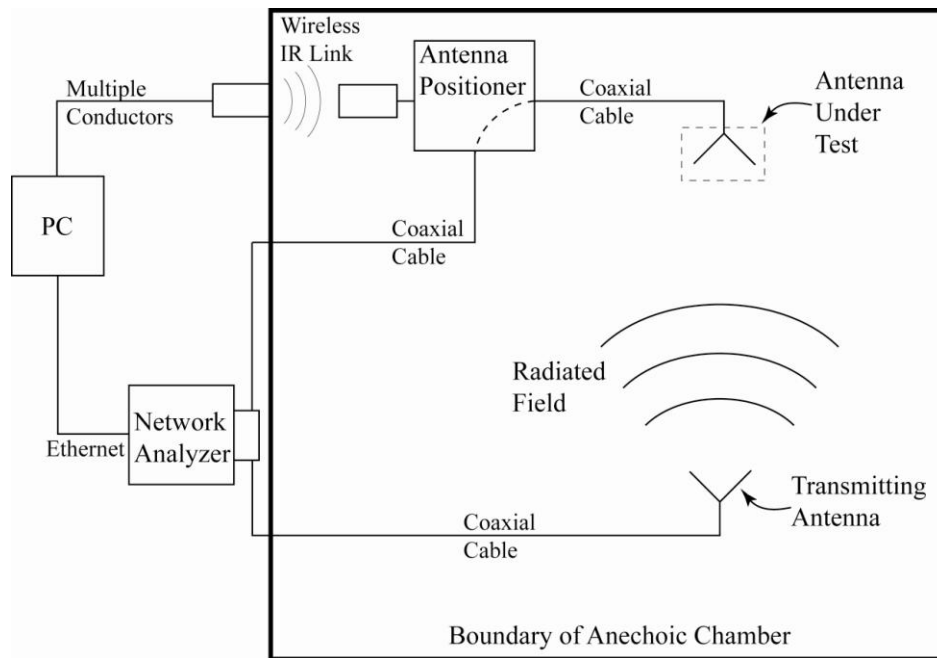


Fig. 1. The topology of the antenna measurement system.

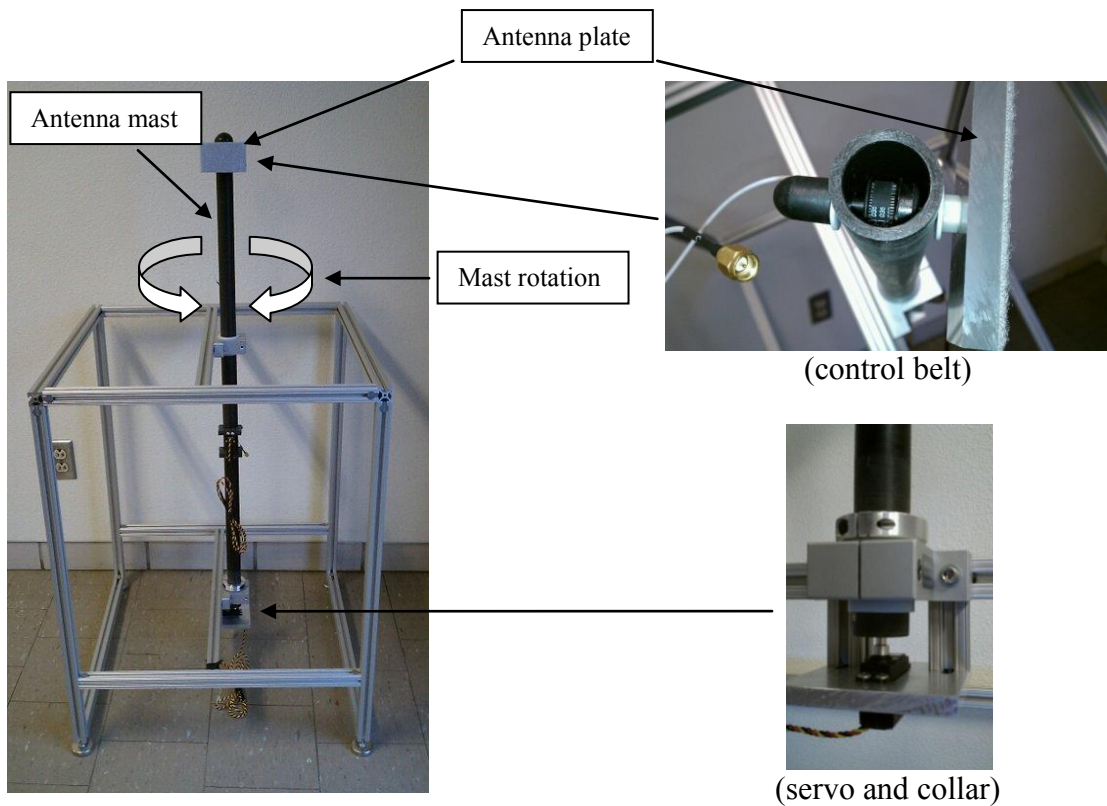


Fig. 2. Antenna positioner.

Network Analyzer

The network analyzer is the piece of equipment that takes the actual field measurements. This is done by attaching an antenna to port 1 and the antenna under test (AUT) to port 2 (as shown in Fig. 1), both with coaxial cables, and placing both antennas in an anechoic chamber. An image of the network analyzer and the anechoic chamber is shown in Figs. 3 and 4, respectively. The network analyzer provides measurement results in the form of the scattering matrix. These measurements determine how well the AUT is receiving power and how well the two antennas are linked in the chamber. The measurements on how well the antennas are linked provide the necessary information about the antenna as to how well the AUT is radiating into the region around itself.

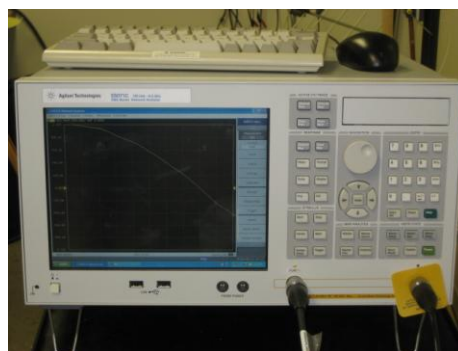


Fig. 3. Agilent Technologies network analyzer.



Fig. 4. Anechoic chamber.

Computer

For correct operation of the system, it is essential that the PC must manage the timing and information between the network analyzer and the antenna positioner. The PC is connected to the network analyzer through the Ethernet port and connected to the antenna positioner through an infrared (IR) port. An image of the IR port and controlling circuitry is shown in Figs. 5 – 7 (schematics for these boards are shown in the Appendix). The PC controls the system with a single user interface written in LabView. A screen-shot of the LabView interface is shown in Fig. 8.

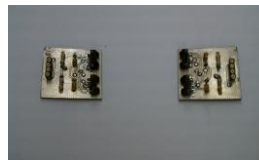


Fig. 5. IR boards used to communicate between the PC and the antenna positioner



Fig. 6. PC board used to send data from the PC to the antenna positioner to control the servos.



Fig. 7. PC board used on the antenna positioner to receive data from the PC to control the servos.

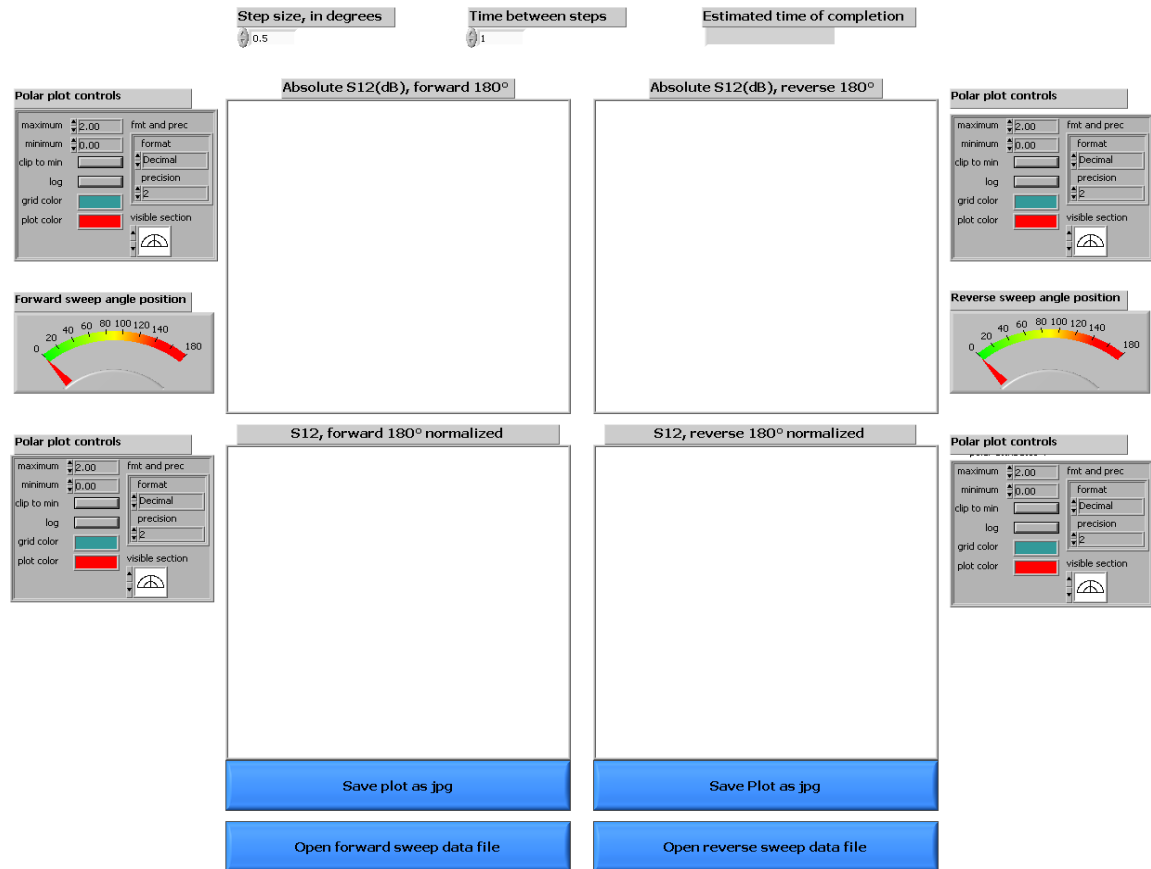


Fig. 8. LabView Interface.

DESCRIPTION OF THE ANTENNA MEASUREMENT SYSTEM

When a measurement is underway, the following sequence of events occurs:

- 1) When the system is setup and initialized (i.e., angle = 0 degrees), the PC records the first values from the network analyzer.
- 2) When this value is recorded the PC communicates with the antenna positioner and rotates the mast from 0 degrees to $0 + \Delta$ degrees where Δ is the user-defined angle step size in LabView.
- 3) After a short wait time, the new value measured by the network analyzer is recorded by the PC and stored in a manner related to the angle of the mast (i.e., each measurement corresponds to an angle of the antenna positioner).
- 4) After this value is recorded by the PC, the PC rotates the antenna positioner to $0 + 2\Delta$ degrees.
- 5) The PC then waits a short time and records the new measurement in the same manner as in step 3).
- 6) Steps 4) and 5) are repeated until the antenna positioner reaches a mast angle of 180 degrees. At that point the antenna plate rotates 90 degrees and the measurement process is repeated from 180 degrees back down to 0 degrees.
- 7) The result from this measurement is a matrix that contains measurement values from the network analyzer and corresponding antenna positioner angles.
- 8) LabView draws a polar plot of the measurement values and corresponding angles.

COST

The AMS system developed at NDSU has shown to be a reliable and accurate system. The budget for the entire project was \$750. This low cost places the AMS system in reach of many smaller ECE programs.

CONCLUSION

A simple cost-effective antenna measurement system has been presented. The topology of the system has been summarized and details of the three main components have been summarized. Furthermore, a detailed sequence of events involved with a typical measurement has been offered. This was then followed by a total cost summary of \$750 which makes this system affordable for many smaller ECE programs.

REFERENCES

Balanis, C. A. (2005). *Antenna Theory: Analysis and Design*, 3rd ed., Hoboken, NJ: John Wiley and Sons.

Waterhouse, R. (Ed.), (2007). *Printed Antennas for Wireless Communications*, Hoboken, NJ: John Wiley and Sons.

BIOGRAPHICAL INFORMATION

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APPENDIX

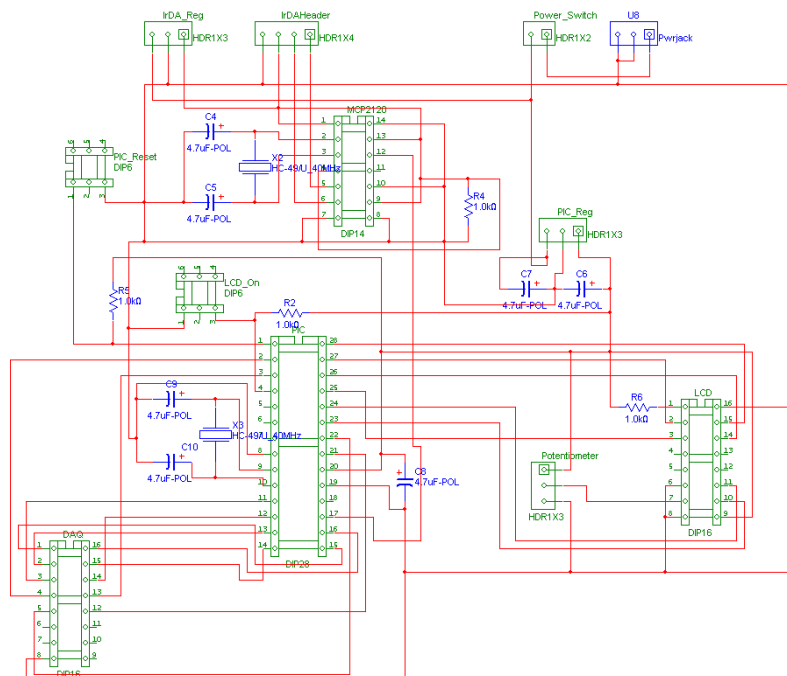


Fig. 9. Transmitter schematic.

Fig. 9 is an image of the Transmitter schematic. This circuit contains the following components:

- (2) LED indicators
- (7) 4.77 μ F capacitors
- (4) 1k Ω resistors
- (2) push button
- (1) MC33063A voltage regulator
- (1) MCP2120 IrDA driver
- (1) 10k Ω TrimPot
- (1) 100k Ω TrimPot
- (1) PIC18F242-I
- (2) 40MHz Crystals

This circuit contains a PIC that sends data to a MCP2120, which is the IrDA encoder/decoder. The MCP2120 then sends the data to the IrDA transceiver. There is a 1x4 header that connects to a 4 conductor ribbon cable from the IrDA PCB. There is also a 2x8 header that connects to a 16 conductor ribbon that runs to a backlit LCD screen. The various capacitors and resistors are used to reduce noise throughout the circuit. The two push buttons are to reset various devices.

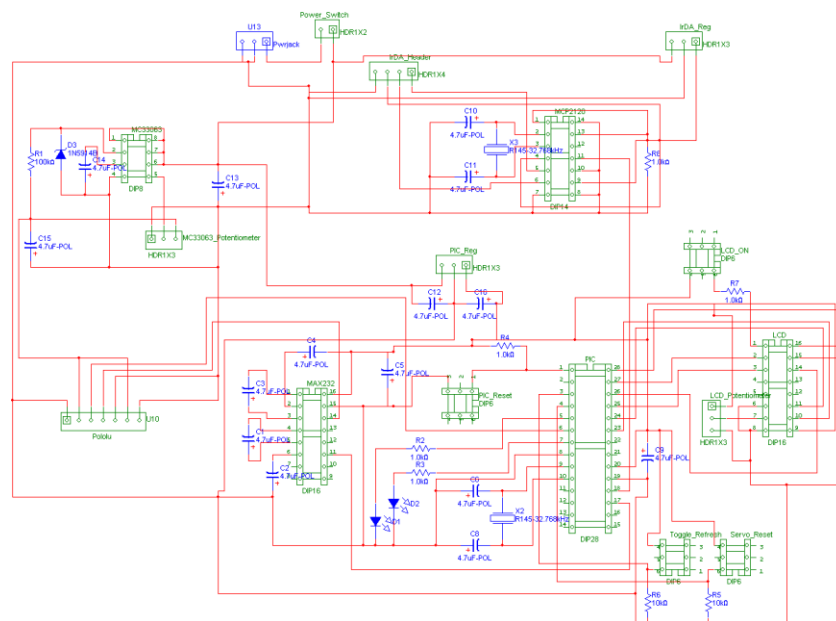


Fig. 10. Receiver schematic.

Fig. 10 is an image of the schematic for the Receiver PCB. This circuit contains:

- (2) LED indicators
- (14) 4.77 μ F capacitors
- (4) 1k Ω resistors
- (2) 10k Ω resistors
- (1) 100k Ω resistor
- (4) push button
- (1) MC33063A voltage regulator
- (1) MCP2120 IrDA driver
- (1) 10k Ω TrimPot
- (1) 100k Ω TrimPot
- (1) Pololu Micro-Controller SSC03A
- (1) MAX232A RS-232 driver
- (1) PIC18F242-I
- (2) 32.768kHz Crystals

This circuit contains a PIC that sends data to a MCP2120, which is the IrDA encoder/decoder. The MCP2120 then sends the data to the IrDA transceiver. There is a 1x4 header that connects to a 4 conductor ribbon cable from the IrDA PCB. There is also a 2x8 header that connects to a 16 conductor ribbon that runs to a backlit LCD screen. The various capacitors and resistors are to reduce noise throughout the circuit. The MAX232 is used to convert from UART to RS232 for the Pololu Micro-Controller. The four push buttons are used to reset various devices, and the MC33080 is for power regulation.

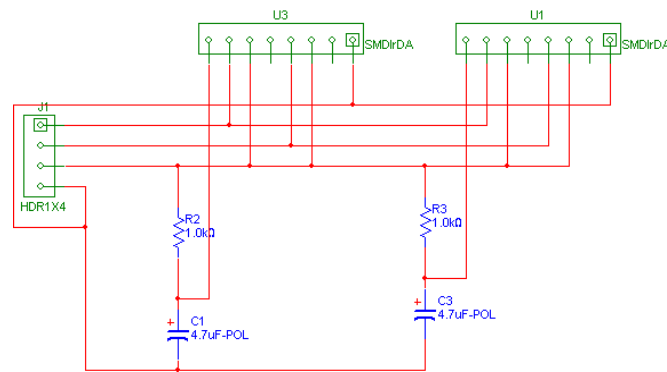


Fig. 11. IR board schematic.

Fig. 11 is an image of the schematic for the IR circuit. This board contains the following components:

- (2) 1kΩ resistors
- (2) 4.7μF capacitors
- (2) TFDU4101 Vishay Infrared Transceivers
- (1) 4 pin header to connect to transmitter or receiver

This circuit connects two IrDA transceivers in parallel to increase our transmission range. The 1x4 header connects by a 4 conductor ribbon cable to either the transmitter or receiver. The resistors and capacitors in the circuit are there to reduce noise throughout the circuit.