Open-Source Antenna Pattern Validation using FEKO

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***Abstract*—An open-source antenna pattern measurement system comprised of software-defined radios (SDRs), standard PVC tubing, and 3-D printer components measures the radiation patterns of student-built prototype antennas. Position control is realized using an Arduino microcontroller. Measured principal plane gain patterns for two antenna prototypes are compared to (FEKO) simulated results. The low-cost, open-source nature of the measurement system is ideal for undergraduate-level investigation of antenna theory and measurement.**

Keywords*—*Antenna measurements, antenna radiation patterns, microcontrollers, software-defined radios.

I. Description of System

An antenna pattern measurement system developed at Weber State University (WSU) was inspired by the published work of Picco and Martin [1]. Their practical system utilized commercially-available 2.4 GHz Wi-Fi routers to transmit and receive a single-frequency wireless signal. Open-source firmware accessed the received signal strength indicator (RSSI). Antenna position control, RF signal measurement, and write-to-file functions were realized using National Instruments LabVIEW.

The WSU prototype shown in Fig. 1 utilizes two GNU Radio Companion driven software-defined radios (SDRs) for the link between the source antenna and antenna-under-test (AUT). The AUT position control is achieved using an Arduino microcontroller with open-source software (GRBL) developed for 3-D printer systems. Low-cost, commercially-available three-dimensional printer hardware (e.g., gears, synchronous belts) and software are utilized for position-control.

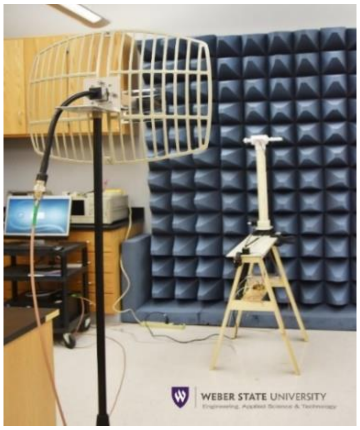

Fig. 1. Principal plane pattern measurement setup for the Yagi-Uda prototype.

II. Antenna Pattern Validation

Complete developments of pattern, directivity, and gain discussed are available in numerous texts. Two popular examples include [2] and [3]. An approximation of the gain from the measured pattern of a lossless antenna may be determined by scaling the measured data to a calculated gain. FEKO is used to model the prototype and calculated maximum gain values. Comparisons of measured pattern data are straightforward once the measured pattern data is normalized and scaled to the maximum calculated gain. The method described is limited to a qualitative check, but it is a highly relevant demonstration of validation in an educational setting.

It is anticipated the majority of future student-built prototypes will be designed for Wi-Fi band ($f \approx 2.4$ *GHz*) with a free-space wavelength of approximately $\lambda \approx 12.5$*cm*. Prototypes of three Wi-Fi band antennas were constructed to evaluate an antenna design and development process for undergraduate students. Comparisons of measured versus theoretical results are shown for the quarter-wave monopole and Yagi prototypes.

A. Quarter-Wave Monopole on Finite Ground Plane

A monopole above a $D=1\lambda$ ground plane shown in Fig. 2 was simulated for comparison to a physical prototype. Fig. 3 is a principal plane pattern comparison for one monopole prototype. The symmetry and close agreement above the ground plane are evident. Some deformation on the right-side behind the ground plane is due to the presence of the antenna feed.

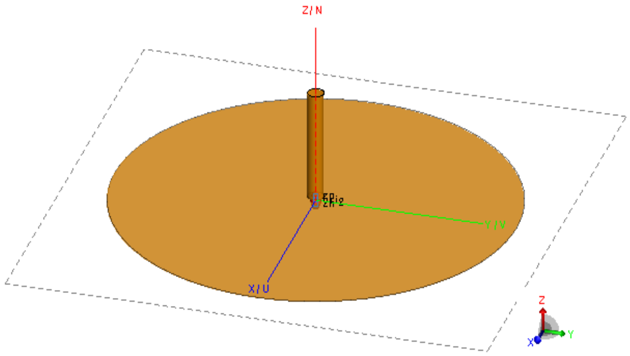

Fig. 2. CAD rendering of quarter-wave monopole prototype over finite ground plane.

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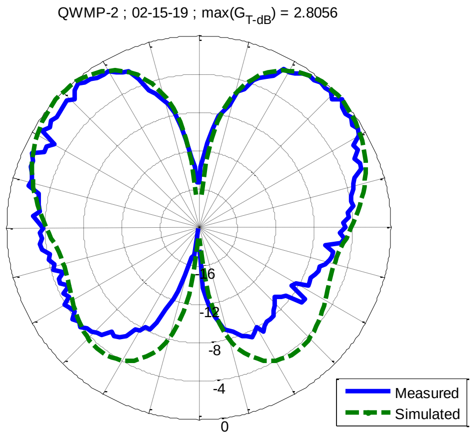

Fig. 3. Measured versus simulated results for principal plane pattern of λ/4 monopole over finite ground plane.

B. Yagi Antenna

Fig. 4 is a CAD rendering of the Yagi-Uda antenna model generated for comparison to constructed prototypes. Fig. 5 plots the scaled measured pattern to the simulated pattern. Front lobe agreement was observed for both prototypes. Feed interference seen previously with the monopole is also apparent with the Yagi-Uda measured pattern. Sidelobe levels behind boresight are 10 dB below the main beam levels and may be investigated when additional absorber is available.

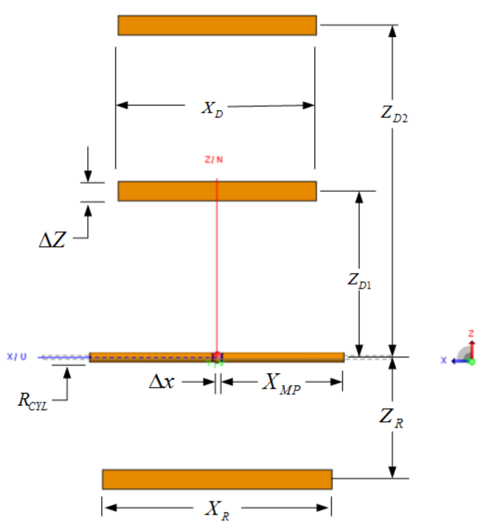

Fig. 4. CAD rendering of Yagi-Uda prototype.

III. Conclusions and Future Work

An antenna pattern measurement system based upon the Picco and Martin concept was modified to incorporate software-defined radios and commercially-available 3-D printer hardware. Examples of commercially-available hardware include low-cost synchronous gears and matching belts. Additional components were constructed using 3-D printer technology. Examples include both the base and head connecting the PVC mast to the azimuth and elevation synchronous gears.

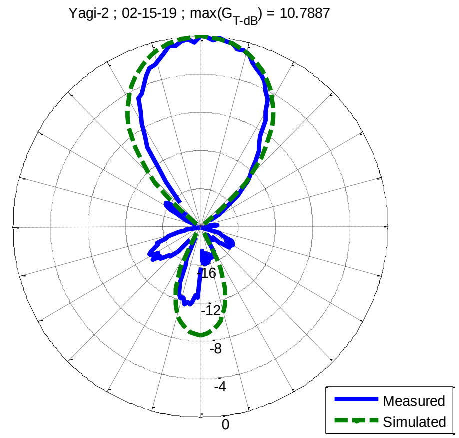

Fig. 5. Measured versus simulated results for principal plane pattern of the Yagi antenna prototype.

Comparisons of simulated and measured gain patterns for the two antenna prototypes shown indicate the measurement system will be a valuable resource for laboratory exercises and student projects.

The current measurement system employs a 'noise subtraction' method at each sample point. An ambient noise measurement is taken before the transmitter signal is applied. A second receiver measurement of the transmitted signal plus noise is recorded. At each position, the ambient noise signal is subtracted from the transmitted signal measurement to obtain a pattern signal amplitude.

Future research with the pattern measurement system will incorporate modulation methods with noise-mitigation characteristics. Open-source SDRs permit the investigation of cellular phone signal processing techniques developed to mitigate noise, multipath and fading. Examples include analog Frequency Modulation and coherent amplitude demodulation to potentially improve pattern measurements made in non-anechoic environments. Narrow and Wide Band noise interferers will be introduced to evaluate measurement fidelity for different modulation techniques.

References

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