Measurement of Radio Array Antenna Patterns Using Unmanned Aerial Vehicles and Software Defined Radios

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***Abstract*—Antenna pattern measurement often necessitates placing systems within an anechoic chamber. These measurements can be costly for sensor development and can place the antennas in an artificial scenario which may not be a realistic operational situation. Nevertheless, antenna pattern information is required to confirm that the sensor will operate as intended. Recently, a confluence in the development of two technologies, software defined radios (SDRs) and unmanned aerial vehicles (UAVs), have brought about a less expensive solution for this type of measurement.**

MIT Haystack Observatory has developed a method to measure an antenna pattern using a combination UAV and SDR technique. This method will be used in the near future for testing of a new geoscience array radar being built at the Observatory, and will allow researchers to confirm simulations of antenna patterns in the field. The UAV carries an SDR and a small computer to record RF data along with metadata for the position and velocity of the platform. Data is then processed to determine the antenna pattern using the required near-field to far-field transformations.

We will describe the data acquisition and processing, including hardware, software and algorithms. The acquisition and processing has been developed from readily available open source software. We intend to make this package available as well to the open source community in a timely manner. We will also present final analysis results of this pattern measurement method using a number of different antennas to demonstrate its validity. Results will also include statistical uncertainties of the measurements derived from first principle signal processing and electro-magnetics.

I. Introduction

Estimating the gain pattern of an antenna, $G_T(\theta_T)$, as a function of angle off from bore site of emitter, θ_T, to a receiver can be done in a number of ways. One way to do this is have the antenna under test (AUT) rotate in place surrounded by stationary antennas [1]. Another method could have the AUT stationary as the testing antenna moves around the emitter. Researchers have started to use unmanned aerial vehicles (UAVs) to do this measurement [4], [3]. This methodology shows promise for doing low cost antenna pattern measurement without the use of an anechoic chamber and can show the actual performance of an antenna in its actual operating environment.

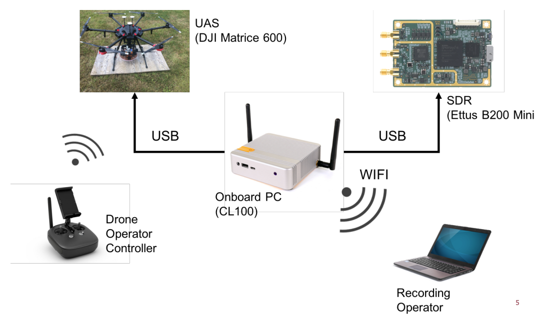

Fig. 1. Diagram of the overall UAS collection system with SDR,

The amount of power from an emitter to a receiver, P_r, is encapsulated in a modified version of the Friis Equation,

$$P_r = \frac{P_T G_T(\theta_T) G_R(\theta_R) \lambda^2 L}{(4\pi)^2 R^2}, \quad (1)$$

where λ is the wavelength of the emitter, P_T is the transmit power from the emitter, $G_R(\theta_R)$ is the gain of the receive antenna, R is the range between the two antennas and L are any losses not stated.

II. Measurement Methodology

A. Data Acquisition System

The overall data acquisition system can be seen in Figure 1. It is made up of commercial off the shelf sub systems which include the UAV with controller, SDR, and controlling PC. The operator at the laptop can send commands via wifi to fly the UAV to specific locations and task the SDR to record the RF signals from the AUT. The SDR is using a circular antenna that has been characterized in FEKO to receive.

B. Signal Processing

For the tests the AUT outputs a simple sinusoidal tone. Assuming that the carrier frequency is perfectly removed the down converted version can be represented as the following,

$$x(t) = Ae^{-j(2\pi f_o t + \phi)} \quad (2)$$

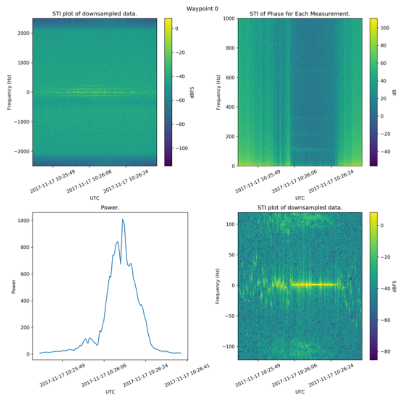

Fig. 2. Spectrograms of recorded data from a pass over the AUT.

where f_o is the frequency offset from the carrier, ϕ is the phase offset from the emitter, and A is the amplitude of the sinusoid, for this case $A^2 = P_r$, see Equation 1. To process this and get a measurement of the power an Fast Fourier Transform (FFT) can be used to concentrate the energy of the sinusoid. If the frequency is chosen properly all of the energy will be placed in a single frequency bin. Overall this will add a SNR gain of M number of samples taken for the FFT. The final output of this processing will yield a spectra with a single frequency point.

III. Initial Results

A number of flights have been made using the Square Kilometer Array Low-frequency Antenna (SKALA) [2]. This specific model of antenna was chosen due to its known performance characteristics.

The results from a single pass of the UAV over the AUT, the SKALA, will be shown. The UAV was flown along the E-Plane of the AUT at an altitude of 20 meters above the ground. The AUT was emitting a 440 MHz sinusoidal tone which was down converted using the SDR and saved to disk.

In Figure 2 spectrograms, along with a power vs. time plot of recorded data can been seen from the UAV pass. The spectrograms show the general outline of an antenna pattern during the leg of the drone flight.

A "quicklook" of the same pass as in Figure 2 can be seen in Figure 3. The quicklook has plots of the received antenna power along E and H planes, labeled as y and x respectively, and along Θ along with a range corrected antenna pattern. The range corrected antenna pattern, at the bottom left hand corner seems to suggest the antenna is squinted off borsight, which was not the case. This is likely due to improper characterization of the antenna on the UAV or GPS measurement error from the UAV.

IV. Conclusions

We have shown a method to measure an antenna pattern from a UAV using software defined radios. Initial results were shown and although there are errors in the pattern this method shows promise.

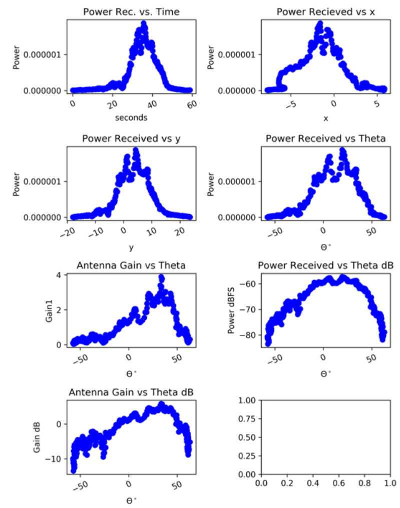

Fig. 3. Quicklook of received data from AUT.

References

[1] C. A. Balanis, *Antenna Theory: Analysis and Design*. Hoboken NJ: Wiley-Interscience, 2005.

[2] E. de Lera Acedo, N. Drought, B. Wakley, and A. Faulkner, "Evolution of SKALA (SKALA-2), the log-periodic array antenna for the SKA-low instrument," in *2015 International Conference on Electromagnetics in Advanced Applications (ICEAA)*. IEEE, 2015, pp. 839–843.

[3] F. Paonessa, G. Virone, E. Capello, G. Addamo, O. A. Peverini, R. Tascone, P. Bolli, G. Pupillo, J. Monari, M. Schiaffino, F. Perini, S. Rusticelli, A. M. Lingua, M. Piras, I. Aicardi, and P. Maschio, "Vhf/uhf antenna pattern measurement with unmanned aerial vehicles," in *2016 IEEE Metrology for Aerospace (MetroAeroSpace)*, June 2016, pp. 87–91.

[4] F. stner, E. Aydemir, E. Gle, M. larslan, M. elebi, and E. Demirel, "Antenna radiation pattern measurement using an unmanned aerial vehicle (uav)," in *2014 XXXIth URSI General Assembly and Scientific Symposium (URSI GASS)*, Aug 2014, pp. 1–4.