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XXXIV Cycle

UAV-based Near Field Antenna Measurements

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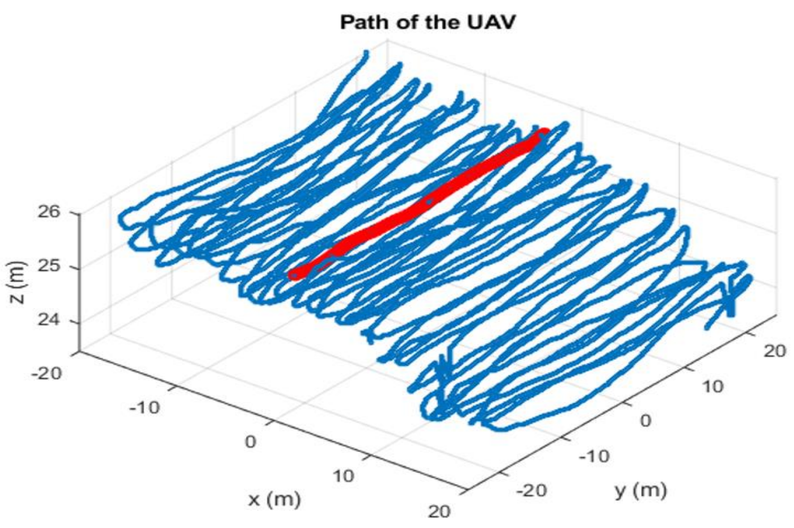
Research context and motivation

An Unmanned Aerial Vehicle (UAV) is a versatile tool to perform electromagnetic characterization of an antenna under test (AUT). In particular, UAVs can be used for those situations when the AUT, due to its large size, can not be placed in anechoic chamber and in-situ measurements have to be done. Large arrays of antennas fall into this situation. The UAV, equipped with an RF source, flies over the array while, at each antenna port, voltage is acquired.

The Square Kilometre Array (SKA) is a radio telescope under construction in Australia and South Africa. It will consist of thousands of elements placed in a random configuration over a physical area of several square kilometres. Due to its large size, it will have 50 times more sensitivity than any other radio instrument and the highest resolution images in all astronomy. The Low-Frequency Aperture Array (LFAA) covers the lowest frequency band for the SKA, from 50MHz up to 350MHz.

Addressed research questions/problems

1. The Fraunhofer distance $2D^2/\lambda$, due to the large diameter D of the array and the wavelenth λ, can not be reached by the UAV (regulation altitude limit = 120 m, technical altitude limit = 240 m). For example at 300 MHz, the diameter $D = 35$ m of AAVS1 (a sub-array of LFAA) corresponds to a Fraunhofer distance of around 2500 m. Then, the UAV flies in the near field zone of the AUT.
2. The UAV can not perform regular scans (e.g., planar or spherical) then standard near-to-far field transforms are hardly applicable. In the figure below there is shown an example of UAV trajectory. The programmed flight was actually set as a regular planar raster with a constant height of 25 m and constant line spacing.



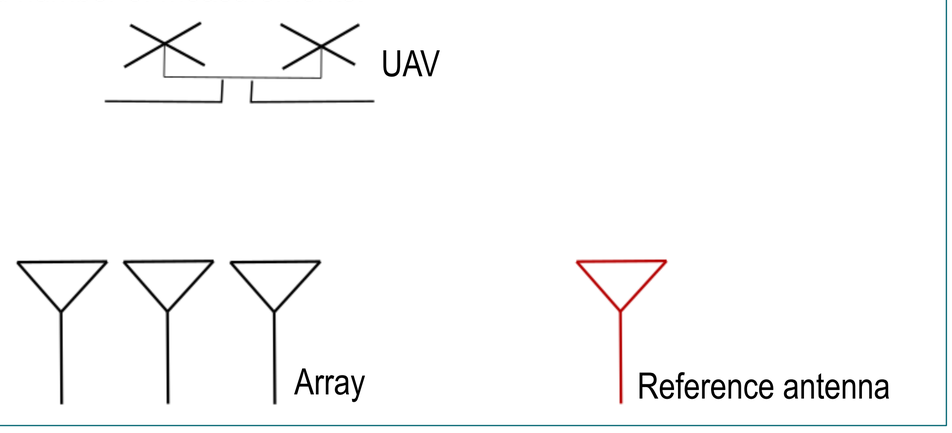
3. The UAV equipped with the trasmitting antenna is obviously not an ideal probe, then in order to retrieve the actual field of the AUT, probe correction has to be applied.
4. Because there are no links between the UAV and the ground, the source is not phase-locked to the RF receiver local oscillator/clock. Then, the phase information has to be retrieved.
5. UAV has a maximum flight time of around ten minutes, a capacity to lift weights of few kilos and, using a differential Global Navigation Satellite System (GNSS), an accuracy of centimeters on its position.

Submitted and published works

- Ciorba, L. et al., "*Near Field Phase Reconstruction for UAV-based Antenna Measurements*", 13th European Conference on Antennas and Propagation (EuCAP), Krakow, Poland, 2019
- Ciorba L. et al., "Far Field Evaluation from Undersampled near Field Measurements Using Numerically Built Basis Functions", 13th European Conference on Antennas and Propagation (EuCAP), Krakow, Poland, 2019
- Paonessa, F. , Ciorba, L. et al. "Characterization of the Murchison Widefield Array Dipole with a UAV-mounted Test Source", 13th European Conference on Antennas and Propagation (EuCAP), Krakow, Poland, 2019
- Virone, G. , Paonessa, F., Ciorba, L. et al. "The SKA Aperture Array Verification System: Measured Digitally-Beam-Formed Radiation Patterns", IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, Atlanta, Georgia, U.S.A, 2019

Novel contributions

In order to solve problem (4), a reference antenna has been placed far from the array in order to recover the correct phase information. Instead, in current literature amplitude only acquisitions are preferred, with the disadvantage to deal with a non-linear minimization problem and a doubled number of measurements.

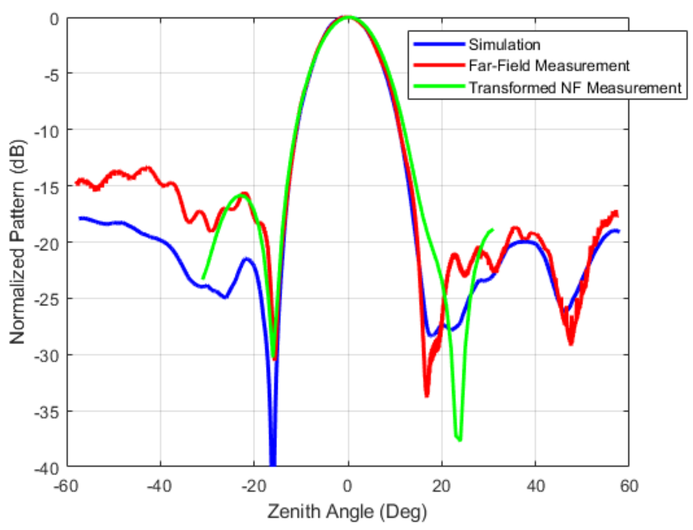


Adopted methodologies

An inverse source method is exploited to perform a near to far field transform to compute the array beam. Antennas are enclosed in a virtual closed surface where unknown electric $\boldsymbol{J}$ and magnetic $\boldsymbol{M}$ currents are placed. For the sake of brevity, here only $\boldsymbol{J}$ is considered. Current $\boldsymbol{J} = \sum_i \alpha_i \boldsymbol{f_i}$ is expanded as linear combination of basis functions $\{\boldsymbol{f_i}\}$. The unknown coefficients $\{\alpha_i\}$ are computed enforcing equality (in least squares sense) between the electric field $\boldsymbol{E}[\boldsymbol{J}]$ produced by $\boldsymbol{J}$ and the measured field $\boldsymbol{E}^{meas}$ over measurement points $\{\boldsymbol{r}_k\}$, i.e.

$$\min_{\{\alpha_i\}} \sum_k \left| \boldsymbol{E}^{meas}(\boldsymbol{r}_k) - \sum_i \alpha_i \boldsymbol{E}[\boldsymbol{f}_i](\boldsymbol{r}_k) \right|^2$$

Once obtained coefficients $\{\alpha_i\}$, the current $\boldsymbol{J}$ is known and its field $\boldsymbol{E}[\boldsymbol{J}]$, approximation of the real field, can be evaluated everywhere. The figure on the right shows a first preliminary result of a near to far field transform through inverse source applied on the Pre Aperture Array Verification System of SKA. Blue, red and green lines represent magnitude of the simulated, measured and reconstructed far field pattern, respectively.



Future work

- The method has still to include a full probe correction applicable over an arbitrary set of points in order to solve problems (2) and (3). Using knowledge on the UAV far-field pattern, the measurement has to be corrected to retrieve the actual field of the AUT. Due to the electrically large size of the array, the method has to be both accurate and fast.
- UAV is a powerful tool for indoor measurements too. Furthermore, in the latter situation there is less noise and more precise instruments (e.g, for tracking UAV position) can be used.
- Due to inaccuracies on the position of the UAV and radio frequency interference, it must be understood what limitations of the method are and what the reconstruction error on the field is.

List of attended classes

- 01MMRRV – Advanced computational electromagnetics for antenna analysis and design (February 2019, 20 hours)
- 01TCORV – Surrogate and compact modeling: theory for the user (March 2019, 20 hours)
- 01TBDRT – Asymptotic and computational analysis of waveguides (November 2018, 30 hours)
- European School of Antennas (ESoA) course: Compressive Sensing in Electromagnetics (March 2019, 30 hours)
- Emerald core transferable skills week (February 2019, 20 hours)

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