

Effect of Conductive Propellers on VHF UAV-based Antenna Measurements: Experimental Results

Original

Effect of Conductive Propellers on VHF UAV-based Antenna Measurements: Experimental Results / Virone, Giuseppe; Paonessa, Fabio; Ciorba, Lorenzo; Lumia, Mauro; Addamo, Giuseppe; Peverini, Oscar Antonio; Bolli, Pietro. - ELETTRONICO. - (2021), pp. 46-47. (2021 IEEE Conference on Antenna Measurements & Applications (CAMA) Antibes Juan-les-Pins, France 15-17 Nov. 2021) [10.1109/CAMA49227.2021.9703392].

Availability:

This version is available at: 11583/2959500 since: 2022-03-30T13:37:29Z

Publisher:

IEEE

Published

DOI:10.1109/CAMA49227.2021.9703392

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

IEEE postprint/Author's Accepted Manuscript

©2021 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collecting works, for resale or lists, or reuse of any copyrighted component of this work in other works.

(Article begins on next page)

Effect of Conductive Propellers on VHF UAV-based Antenna Measurements: Measured Results

Giuseppe Virone, Fabio Paonessa, Lorenzo Ciorba, Mauro Lumia,
Giuseppe Addamo, Oscar Antonio Peverini
*Istituto di Elettronica e di Ingegneria dell'Informazione e delle
Telecomunicazioni (IEIIT)*
Consiglio Nazionale delle Ricerche (CNR)
Turin, Italy
giuseppe.virone@ieit.cnr.it

Pietro Bolli
Osservatorio Astronomico di Arcetri
Istituto Nazionale di AstroFisica (INAF)
Florence, Italy
pbolli@arcetri.inaf.it

Abstract— Professional Unmanned Aerial Vehicles (UAVs) are generally equipped with carbon fiber propellers. Their conductivity and significant size can potentially increase both noise and systematics of UAV-based antenna measurement systems operating in the VHF band. A set of alternative fiberglass propellers has been manufactured and tested. This paper present measured results on the signal stability achieved with both fiberglass and carbon-fiber propellers at 175 MHz.

Keywords— Unmanned Aerial Vehicles, Drones, Propellers, In-situ Antenna Measurement, Carbon Fiber

I. INTRODUCTION

UAV-based antenna measurements are recently exploited for in-situ verification of RF systems [1]-[5], with particular reference to large arrays for radio-astronomy [6]-[10]. The need of long flight duration and lift capabilities (for more RF functionalities of the payload) lead to exploitation of more powerful UAVs with respect to small prototypes used in [9],[10]. The standard propeller material for heavy-lift UAVs is carbon fiber owing to its stiffness and low-weight. Unfortunately, its conductivity can affect the stability of transmitted/received signals with a statistic that is related to the four (or more) counter-rotating propellers.

The impact of conductive propellers has been studied in [11] and [12] for Radar Cross Section and UAV-ground communication channel modelling, respectively. The effect of conductive propellers in the framework of antenna measurements has been investigated in [13] with simulations only. Experimental results on two sets of conductive (carbon fiber) and non-conductive (glass fiber) propellers are reported in this work.

II. EXPERIMENTAL RESULTS

The experimental setup consists of a UAV equipped with an RF synthesizer and a dipole [7]. The UAV is programmed to hover above a log-periodic antenna placed on the ground (pointed towards the zenith) at an altitude satisfying the far-field condition. The log-periodic is connected to a spectrum analyser configured to operate as a receiver i.e. span zero mode, sample detector, 1 MHz of both resolution and video bandwidths. The center frequency has been set to 175 MHz because it was expected to be a worst case [13]. At this frequency the dipole length is similar to the UAV frame one,

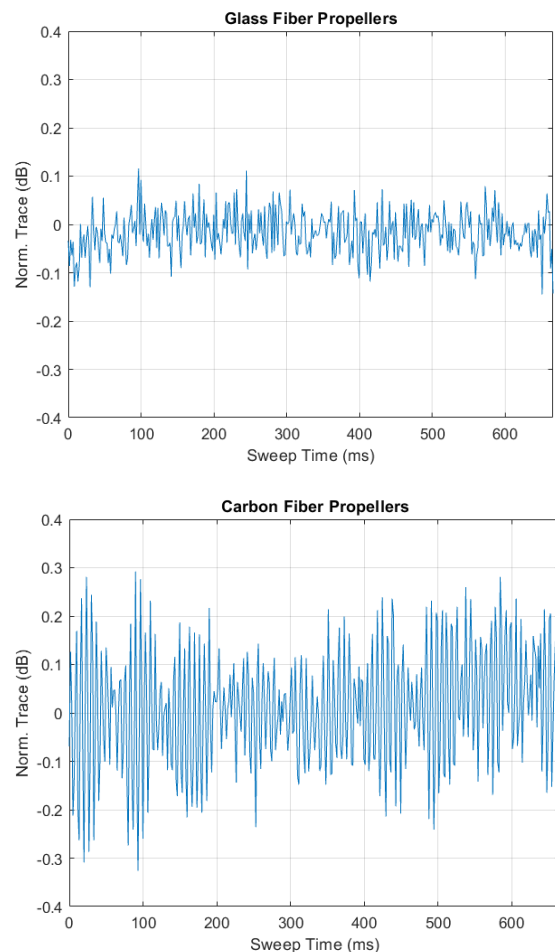


Figure 1. Received signal for Glass (top) and Carbon (bottom) Fiber propellers at 175 MHz.

therefore, directional resonance phenomena can occur [14].

Two hovering flights have been performed with custom-built glass-fiber propellers and commercial carbon-fiber ones, respectively. Two acquisitions of the received power (normalized) are shown in Fig. 1. The data with glass-fiber (top axes of Fig. 1) exhibits a variation which is consistent with trace noise of the instrument. On the contrary, a strong periodic behavior can be observed for the carbon-fiber ones (bottom of Fig. 1). The period of the signal is about 6 ms, this corresponds to a frequency of 167 Hz which is consistent to a propeller rotation speed of 10.000 RPM.

The peak-to-peak variation is in the order of 0.6 dB which is relevant for antenna measurement applications. In [13], the worst-case predicted ripple was in the order of +/- 2 dB. This can suggest that the simulation was too pessimistic, probably because the anisotropy of the carbon fiber propellers was not accounted for, their conductivity was not accurate or the predicted resonance effect were over estimated on the perfect conducting model of the UAV frame. However, it should be mentioned that the simulations in [13] were performed with the four propellers arranged in a symmetrical configuration to maximize their effect on the UAV radiation pattern. Such configurations are unlikely to happen in real experiments. Moreover, the sampling time for the data in Fig. 1 is about 1.66 ms (sweep time equal to 666 ms with 401 measurement points) which corresponds to a Nyquist frequency of 300 Hz i.e. 18.000 RPM. However, UAV motors can potentially go up to 40.000 RPM. Therefore, the discrepancy between simulation and measurements could be also due to under-sampling phenomena.

CONCLUSION

The effect of conductive propellers in the framework of VHF antenna measurements has been demonstrated with experimental results. The simulated data in [13] are more pessimistic than the measured ones. However, tests should be repeated with a higher sampling rate. The presented effect of conductive propellers does not totally impair the measurements (averaging could be exploited). However, it will be visible on digital back-ends with high data rate (such as the back-ends for low-frequency radioastronomy [6],[10]). Future studies are still required to determine the best trade-off between Carbon and Fiber Glass propellers.

REFERENCES

- [1] M. García-Fernández et al., "Antenna Diagnostics and Characterization Using Unmanned Aerial Vehicles," *IEEE Access*, vol. 5, pp. 23563-23575, 2017.
- [2] I. Farhat, D. Cutajar, M. Bezzina and K. Z. Adami, "Drone Characterization Approach for Radio Telescopes," in *2019 Photonics & Electromagnetics Research Symposium - Spring (PIERS-Spring)*, Rome, Italy, 2019, pp. 3016-3018
- [3] S. Duthoit et al., "A new approach for in-situ antenna characterization, radome inspection and radar calibration, using an Unmanned Aircraft System (UAS)," in *2017 IEEE Radar Conference (RadarConf)*, Seattle, WA, 2017, pp. 0669-0674
- [4] A. Y. Umeyama, J. L. Salazar-Cerreno and C. J. Fulton, "UAV-Based Far-Field Antenna Pattern Measurement Method for Polarimetric Weather Radars: Simulation and Error Analysis," in *IEEE Access*, vol. 8, pp. 191124-191137, 2020, doi: 10.1109/ACCESS.2020.3027790.
- [5] Paonessa, Fabio; Virone, Giuseppe; Addamo, Giuseppe; et al., "UAV-based pattern measurement of the SKALA", *IEEE International Symposium on Antennas and Propagation / USNC/URSI National North American Radio Science Meeting* Location: Vancouver, CANADA Date: JUL 19-24, 2015
- [6] E. de Lera Acedo et al., "SKA Aperture Array Verification System: Electromagnetic modeling and beam pattern measurements using a micro UAV", *Experimental Astronomy*, vol. 45, issue 1, pp. 1–20, Mar. 2018. DOI: 10.1007/s10686-017-9566-x
- [7] P. Bolli et al., "From MAD to SAD: the Italian experience for the Low Frequency Aperture Array of SKA1-LOW", *Radio Science*, vol. 51, issue 3, pp. 160–175, Mar. 2016. DOI: 10.1002/2015RS005922
- [8] G. Virone et al., "Strong Mutual Coupling Effects on LOFAR: Modeling and In Situ Validation," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 5, pp. 2581-2588, May 2018. DOI: 10.1109/TAP.2018.2816651
- [9] P. Bolli et al., "Near-Field Experimental Verification of the EM Models for the LOFAR Radio Telescope," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, issue 4, pp. 613–616, Apr. 2018. DOI: 10.1109/LAWP.2018.2859828
- [10] F. Paonessa, L. Ciorba, G. Virone, P. Bolli, A. Magro, A. McPhail, D. Minchin, and R. Bhushan, "SKA-low Prototypes Deployed in Australia: Synoptic of the UAV-based Experimental Results," *URSI RADIO SCIENCE LETTERS*, VOL. 2, 2020, DOI: 10.46620/20-0021
- [11] T. Pető, K. Marák, S. Bilicz and J. Pávó, "Experimental and numerical studies on scattering from multiple propellers of small UAVs," *12th European Conference on Antennas and Propagation (EuCAP 2018)*, London, 2018, pp. 1-4, doi: 10.1049/cp.2018.1081.
- [12] H. Hou and L. Wang, "Analysis on Time-Variant Air-to-Ground Radio Communication Channel for Rotary-Wing UAVs," *2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring)*, Kuala Lumpur, Malaysia, 2019, pp. 1-6, doi: 10.1109/VTCSpring.2019.8746377.
- [13] G. Virone et al., "Effect of Conductive Propellers on VHF UAV-based Antenna Measurements: Simulated Results," *2021 15th European Conference on Antennas and Propagation (EuCAP)*, 2021, pp. 1-4, doi: 10.23919/EuCAP51087.2021.9411266.
- [14] F. Paonessa, G. Virone, P. Bolli, G. Addamo, S. Matteoli and O. A. Peverini, "UAV-Based Antenna Measurements: Improvement of the Test Source Frequency Behavior," *2018 IEEE Conference on Antenna Measurements & Applications (CAMA)*, 2018, pp. 1-3, doi: 10.1109/CAMA.2018.8530506.