Directional pattern measurement of the BRAMS beacon antenna system

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The typical methods for measuring antenna characteristics are mostly based on the use of remote transmitters or receivers. For antennas used in radio communications, calibrations are usually done on an antenna test stand using transmitters with known power output. In order to minimize the ground effects while performing measurements, it is necessary to place the transmitter or receiver high above ground with the aid of aircrafts. It is, however, necessary to determine precisely the coordinates of the airborne devices as well as to maintain high stability. This used to be excessively difficult to carry out, but recent advances in Unmanned Aerial Vehicle (UAV) technologies have brought a feasible option. In this paper, the results of using a low-cost system for measuring the directional pattern of BRAMS beacon antenna system based on an UAV are presented.

1 Introduction

BRAMS is a project coordinated by BISA under the frame of the Solar–Terrestrial Centre of Excellence (STCE) that, based on *forward-scattering* techniques, aims to study the meteoroid population. BRAMS comprises a series of radio receiver stations mostly hosted by Belgian radio amateurs or groups of amateur astronomers, and a dedicated beacon located at Dourbes Geophysical Centre (Southern Belgium) emits a pure sinusoidal wave with a constant power of 150 W at 49.97 MHz (Calders and Lamy, 2012).

The typical methods for measuring antenna characteristics are mostly based on the use of remote transmitters or receivers. For antennas used in radio communications, calibrations are usually done on an antenna test stand using transmitters with known power output. Such transmitters must be situated in the far field, (Bansal, 1999) if easily interpretable results are to be obtained. For large scale antenna and radio telescopes, this can be an issue as the far field region will be, physically, challenging to reach. Thus, in radio astronomy it is very common to use natural transmitters (galactic or extra galactic) as far field sources.

In order to minimize the ground effects while performing measurements on large antennas, it is possible to place the transmitter or receiver high above ground with the aid of aircrafts. It is, however, necessary to determine precisely the coordinates of the airborne devices as well as to maintain high stability. This used to be excessively difficult to carry out, but recent advances in Unmanned Aerial Vehicle (UAV) technologies have brought a feasible option (Virone et al., 2014; Chang et al., 2015). In this paper, a low cost system for measuring directional patterns based on an UAV-based solution and preliminary results on measuring the antenna system of the BRAMS beacon are presented.

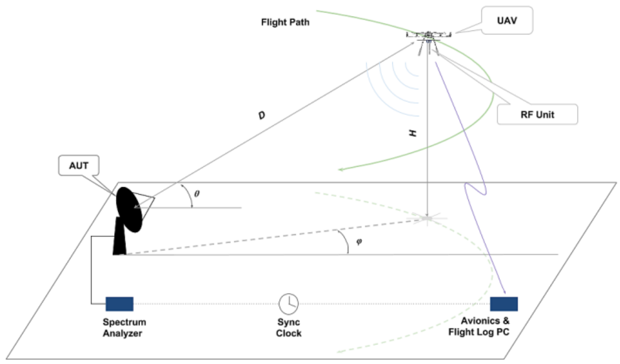

Figure 1 – General RAMON diagram with the components of the measurement system setup.

2 Description of the system

The Radio Antenna Measurement Onsite (RAMON) solution is composed of several parts. *Figure 1* shows a simplified diagram of the whole setup needed to measure the pattern of any Antenna Under Test (AUT). The separate components are described below.

UAV

The chosen aircraft –an OktoXL ARF-Mikrokopter (HiSystems GmbH, 2013) – is shown in *Figure 2*. Its electronic boards (FlightCtrl V2.1, NaviCtrl V2.0 and MKGPS V2.1) and a software interface allow for loading arbitrary GPS-controlled autonomous flight with a stable orientation of the aircraft during the overall flight. One fully charged LiPo battery offers a maximum autonomy of 15 minutes.

The position of the UAV during the flight is given by 5 or more GPS satellites, and the height of the UAV is controlled by a barometric altimeter. Those measurements are typically accurate to well within a meter. This data is logged in real time on a PC via a 2.4 GHz RF link using the hardware and software provided by the UAV manufacturer.

Figure 2 – UAV flying around the antenna beacon at Dourbes.

Although the aircraft is capable of flying up to 1000 m above ground level, the Belgian air regulation authority (BELCONTROL) granted a special permission for research purposes for flying up to 120 m above ground level, restricted to the registered radio astronomy sites.

RF Unit

A continuous-wave RF signal generator based on a phased-locked loop (PLL) (Anciaux, 2015)[1] has been adapted below the battery holder on the bottom of the UAV aluminum frame set. A 50 Ω short monopole antenna is connected to the RF generator, and oriented downward, towards the ground. The frequency of the RF signal can be controlled by an attached single-board computer (SBC) which allows switching or cycling through a series of pre-selected values if needed. An independent compact battery that powers the RF generator and the SBC completes the payload of the UAV. In order to reduce the EM influence of the aluminum UAV frame on the radiation pattern of the RF generator antenna, a metallic mesh has been inserted between the UAV and the payload. *Figure 3* shows a close-up of the RF unit.

The vertical radiation pattern of the RF unit including the UAV, measured though a calibrated antenna, showed an almost constant gain for every inclination angle.

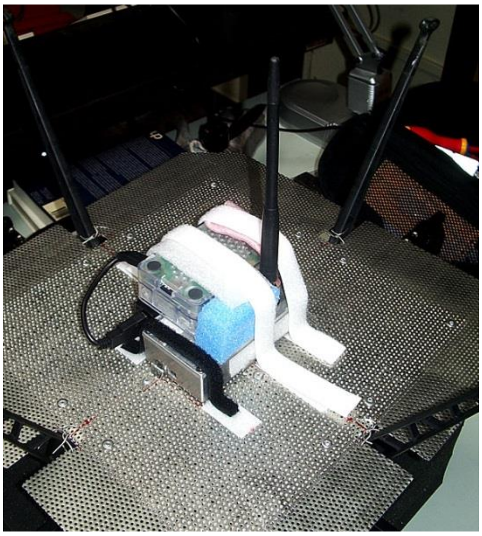

Figure 3 – RF Unit.

[1] http://brams.aeronomie.be/files/BRAMS_annualmeeting_2014_MichelAnciaux_calibrator.pdf

Receiver

An Agilent E4445A Spectrum Analyzer was used to measure the power of the received signal at the different preselected frequencies.

A PC, connected to the E4445A served as a data logger and ensured a correct time-stamping of the data. Good time accuracy is necessary to match the position of the UAV and the received power and derive the directional pattern of the antenna under test (AUT).

A reference power spectrum of the signal transmitted by the RF generator was obtained prior to each flight by connecting the RF unit directly to the E4445A.

3 Measurements

This set up is meant to calibrate the whole set of BRAMS antennae directly managed by BISA. As a proof of concept, a preliminary set of measurements was performed for the beacon antenna.

Description of the AUT

The radiating system of the Dourbes beacon consists of a turnstile antenna arranged in normal mode, with an 8 m × 8 m grid acting as reflector plane disposed between the antenna elements and the ground. The size of each aluminum element of the turnstile is 2.82 m, with 14 mm in diameter. The grid is made of stainless steel (SS). The AUT is shown in *Figure 2*.

Flight pattern

In order to obtain a full 3-D directional pattern, we decided to fly the UAV following successive horizontal circular paths (i.e. horizontal slices) at every 10º of elevation each, and centered over the AUT. Each flight-path waypoint was separated 10º in azimuth, where the UAV was stabilized at 0 m/s speed during 12 second-periods to get reliable data points for every position.

Data processing

In order to avoid variations of received power due to unwanted motions of the UAV, only those waypoints with no or minimal ground speeds were kept from the route file (a GPX markup standard file). The corresponding time intervals were used to select the data to be processed from the Spectrum Analyzer.

From the AUT and UAV relative positions, inclination and azimuth angles (φ, θ) as well as the distance between them can be derived. Path losses can be calculated based on distances values.

4 Results and discussion

Figure 4 shows the directional pattern plots for the horizontal and vertical planes obtained from the preliminary measurements performed at 49.97 MHz over the BRAMS beacon antenna in Dourbes. For comparison purposes, data from numerical simulations is included in the plots (Martinez Picar et al., 2014).

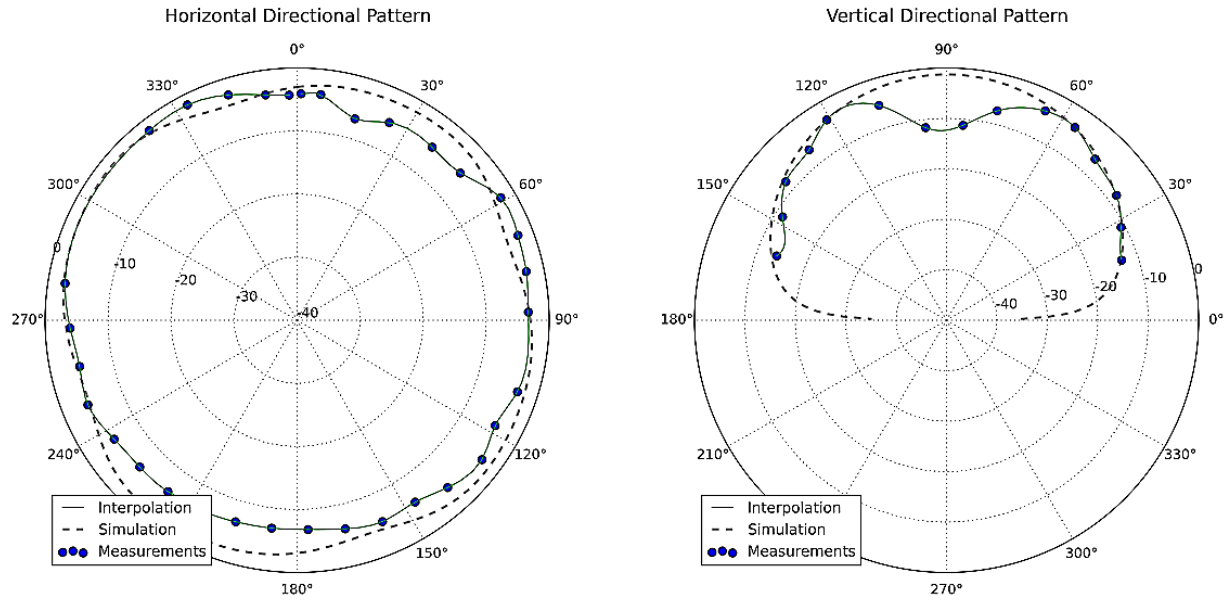

Figure 4 – Normalized directional patterns for the BRAMS beacon antenna system obtained from the measurements.

The plots show good agreement between the measurements and the expected values. The horizontal pattern (at 30º elevation) shows the approximate and expected round shape, however the zenithal "dip" feature visible on the vertical pattern must be revised and more measurements are mandatory to verify and validate this preliminary result.

The reliability of the results will rely on a statistical analysis over a relatively large set of measurements. This implies carrying out intensive measurements campaigns to collect enough information. This will allow reconstructing the antenna patterns under different environmental conditions.

Acknowledgment

We thank Juha Kallunki from the Metsähovi Radio Observatory for his technical assistance with the E4445A interface. We thank the electronic workshop of the Belgian Institute for Space Aeronomy for manufacturing the RF signal generator. We thank the technical group of the Solar Physics department of ROB for the assessment and manufacturing of all mechanical modifications performed to the UAV.

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