Effect of the UAV Orientation in Antenna Pattern Measurements

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***Abstract*— A novel radiation pattern measurement system for VHF and UHF antennas has been recently developed using the Unmanned Aerial Vehicle (UAV) technology. This paper discusses the effect of the UAV orientation and the applicable corrections on the pattern extraction procedure, in order to increase the accuracy and repeatability of the measurements.**

***Index Terms*—antenna radiation pattern, VHF antennas, UAV.**

I. Introduction

The *UAV antenna verification system* [1] exploits a flying far-field test source to characterize the Antenna Under Test (AUT) in its operative conditions (over the soil, as array element, etc.), which is a very important task in the development of the new-generation arrays for radio astronomy e.g. the low-frequency instrument of the Square Kilometer Array (SKA). The source is on a hexacopter which is able to perform GPS-guided, constant-height flights above the AUT [2]. As shown in Fig. 1, such a micro Unmanned Aerial Vehicle (UAV) is equipped with a continuous-wave RF transmitter and a dipole antenna.

This paper describes the effects of the UAV orientation on the extracted AUT pattern. Two experimental cases obtained with a reference antenna at 250 MHz are presented.

II. Source Pattern Contribution

As discussed in [3], the AUT pattern is extracted from the measured RF power at the AUT port by removing the simulated contributions of the source gain, the path loss and the remaining constant contributions. In particular,

$$g_{AUT}(\hat{r})M(\hat{r},\alpha,\beta,\gamma) = \frac{P_R(\underline{r})}{P_S \cdot g_S(\hat{r},\alpha,\beta,\gamma) \cdot G_R}(4\pi R/\lambda)^2 \qquad (1)$$

where g_{AUT} is the gain of the AUT, the unit vector $\hat{r}$ identifies a specific observation direction in the AUT spherical reference system, M is the polarization mismatch, P_R is the measured received power at AUT port, $\underline{r} = R\hat{r}$ is the distance vector from the AUT to the test source, λ is the wavelength, G_R contains both the LNA gain and the cable losses. P_S and g_S are the source power and its radiation pattern, respectively.

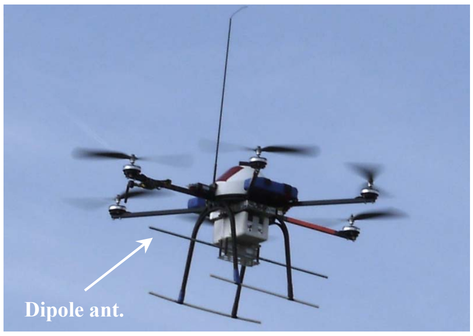

Fig. 1. UAV equipped with the RF transmitter and the dipole antenna.

The Euler angles α (bearing), β (pitch) and γ (roll) describe the orientation of the test source measured by the onboard Inertial Measurement Unit (IMU). During a quasi-rectilinear scan over the AUT, the value of pitch and roll should be nominally zero (hexacopter arms parallel to the ground), whereas the bearing (compass) should be either 0° or 90° for co- or cross-polar measurements, respectively. However, the measured Euler angles along a real flight with moderate wind speed could vary up to ten degrees from the nominal condition.

The effect of these angles is kept into account in the actual contribution $g_S(\hat{r},\alpha,\beta,\gamma)$ of (1), which is computed applying the corresponding rotation to the nominal source pattern g_S.

Rigorously speaking, the orientation angles also affect the polarization mismatch *M*. However, such an effect is negligible as far as the co-polar measurements presented in this work are concerned.

III. Experimentals Results

The effect of the UAV orientation is shown on two different co-polar measurements (identified as A and B), performed along the *E*-plane of a log-periodic reference antenna at 250 MHz. Measurement A has been performed with moderate wind (about 4-5 m/s), whereas a more calm condition has been exploited for measurement B (less than 1 m/s).

As shown in Fig. 2a, the pitch value for the whole flight A is about –5°. As a consequence, the actual source contribution $g_S(\hat{r},\alpha,\beta,\gamma)$ along the path (Fig. 2b, solid line) turns out to be

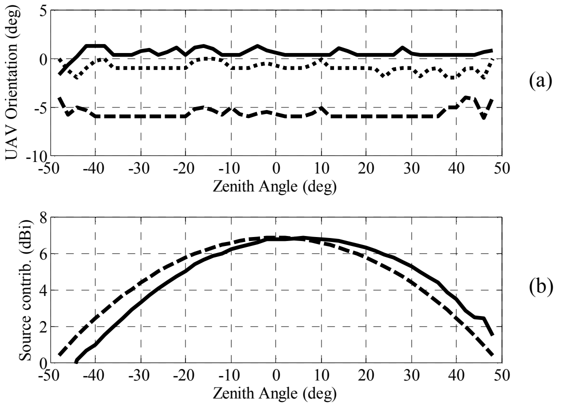

Fig. 2. (a) UAV orientation along flight A: bearing (solid), pitch (dashed), roll (dotted). (b) Source gain contribution for flight A: nominal (dashed), actual (solid).

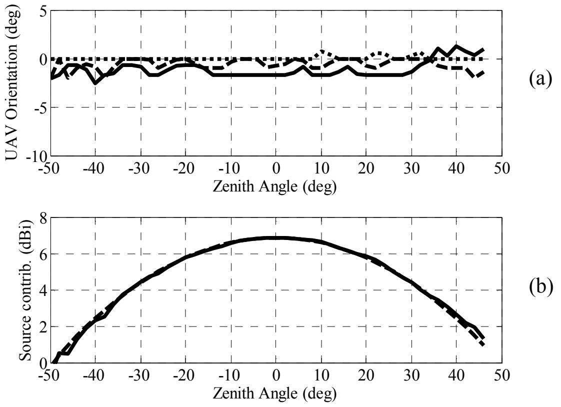

Fig. 3. (a) UAV orientation along flight B: bearing (solid), pitch (dashed), roll (dotted). (b) Source gain contribution for flight B: nominal (dashed), actual (solid).

significantly different with respect to the nominal one (dashed line). On the contrary, Fig. 3a shows small angle values (pitch angle is about $-1°$) for the flight B. In this case, the orientation effect on the source contribution is negligible (Fig. 3b).

The AUT patterns extracted from measurements A and B are compared to full-wave simulation in Figs. 4 and 5. The results in Fig. 4 have been obtained using nominal source patterns, whereas the actual data have been used in Fig. 5.

As expected, the agreement between measurement B (circles) and simulation (dashed line) is good in both figures. On the contrary, a significant discrepancy can be observed for the uncorrected measurement A (triangles) in Fig. 4. Such a deviation is instead properly corrected in Fig. 5. The agreement between the two measurements also highlights a good repeatability.

IV. CONCLUSION

The effect of a nonideal UAV orientation on the measured AUT pattern is significant. The source gain contribution should be computed according to the measured orientation angles in order to increase both the accuracy and the repeatability between different measurements performed with moderate wind. The results obtained for a log-periodic reference antenna at 250 MHz show discrepancies within 0.5 dB between measurements and simulation.

Finally, it should be pointed out that similar accuracy levels have been also obtained on a 3x3 array of Vivaldi antennas at 408 MHz [4].

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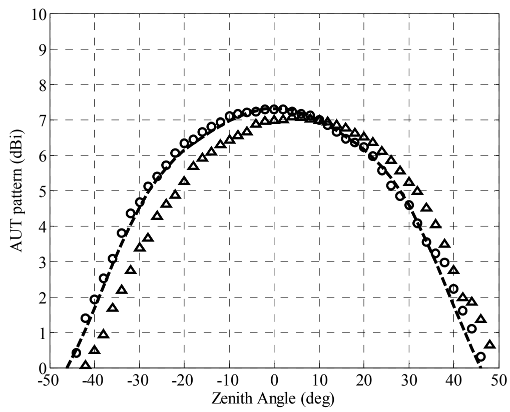

Fig. 4. Co-polar AUT pattern extracted with nominal orientation: measurement A (triangles) and B (circles); simulated AUT pattern (dashed line).

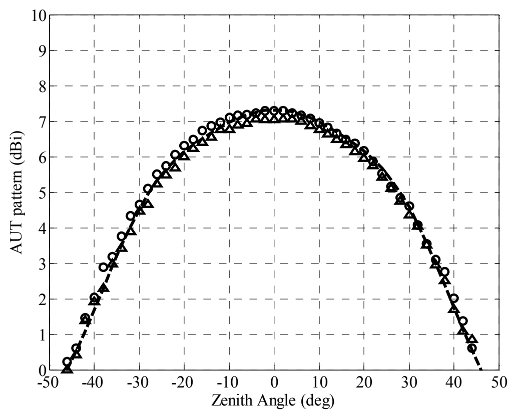

Fig. 5. Co-polar AUT pattern extracted with measured orientation: measurement A (triangles) and B (circles); simulated AUT pattern (dashed line).