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Calibration of antenna systems: The effective antenna vector and its implications on spacecraft design and radio data analysis

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Abstract

Non-thermal radio emission, as generated by solar plasma or planetary magnetospheric processes, is measured by either spacecraft or ground-based antenna systems, both defined by reception properties which are strongly dependent on their structure and the design of adjacent conducting features. The incoming electric field of radio waves induces currents on the adjacent antenna system structures (e.g. masts of ground-based telescopes or spacecraft hull) which generate significant changes in the reception properties of the respective antenna systems. The representation of this change of reception property is defined by the so-called « effective antenna vector » (h_eff), physically representing the electric antenna, which in most cases deviates from the physical antenna rod. It will be shown how this calibration procedure can be performed, i.e. how the h_eff can be determined and how this knowledge can be used to improve any design of antenna systems, and specifically how the validity of corresponding radio data analysis can be enhanced.

1. Introduction

Knowledge on the effective antenna vectors h_eff can be provided by different methods:

(a) Rheometry, putting a scaled model into a water tank with a homogeneous quasi-static electric field and measuring the electric response at the model antenna rods. The underlying relation combines the induced voltage at the open antenna terminals of the model with the inner vector product of h_eff with the incident wave electric field: V = vec(h_eff) . vec(E)

(b) Numerical computer simulations, where a wiregrid or patchgrid of the spacecraft hull including the antenna system is established. The underlying relation determines the h_eff by integrating over all induced currents on the spacecraft structure (Fig. 1):

$$\vec{h}_{eff} = \frac{1}{I_a} \int \vec{J}(\vec{r}') e^{j\vec{k}\cdot\vec{r}} dV'$$

The flexibility of this sort of numerical calibration method, e.g. changing the mechanical design of antenna footpoints and rod directions, enables an optimum radio wave reception or, in case of strong design constraints, a proper optimization of h_eff directions of independent antenna rods (two rods in a rotating spacecraft, three rods in a 3-axes stabilized spacecraft) in order to enable direction finding, the determination of the full set of Stokes parameters and the direction of the incoming radio waves.

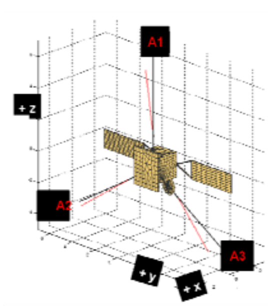

Fig. 1: Patchgrid model of (presumable) Solar Orbiter structure with the physical antenna rods A1, A2, and A3, and the calculated effective antenna vectors (red).

(c) In-flight calibration, using real (observed) data of radio emission (Fig. 2) and determining

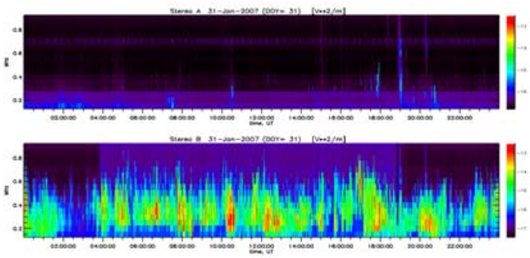

Fig. 2: AKR observation by the WAVES experiment of STEREO-B during a roll maneuver Jan 31, 2007 (bottom panel).

h_eff by the analytic signals of the voltages of each receiver input (preferably during a spacecraft roll maneuver) and finally

(d) Anechoic chamber measurements, where ultra high frequency waves will be beamed on a spacecraft model within a shielded “anechoic” chamber to avoid electromagnetic interferences.

The combination of these techniques, where applicable resp. possible, enable the determination of the reception properties of an antenna system over a wide frequency range, from a few kHz up to tens of MHz, with a rather high accuracy. This knowledge definitely improves the radio data analysis which will be shown by some examples.