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On the Influence of the Antenna RPW/Solar Orbiter Tilt Angle and Thermal Bending to the Radio Direction Finding Capabilities

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Abstract

Solar Orbiter is a future spacecraft dedicated to solar and heliospheric physics scheduled for launch in October 2018. The Radio Plasma Waves (RPW) instrument will measure electric fields at high time resolution using three electric antennas mounted on booms in a perpendicular plane to the spacecraft-Sun axis. Effective antenna lengths and directions will be different from the physical ones due to their thermal bending and coupling with the spacecraft body. This paper discusses the variations of the RPW's direction finding capability for interplanetary solar radio emissions as a function of the distance from the Sun.

1 Introduction

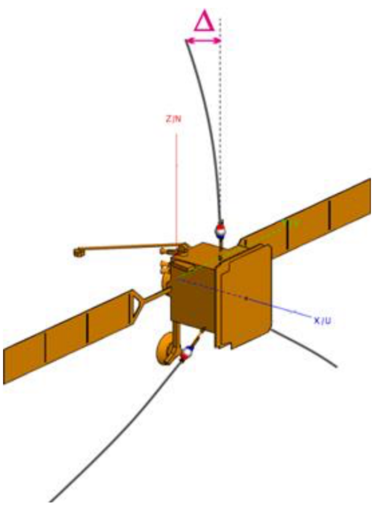

Figure 1. The Solar Orbiter model with thermal bended antennas.

Solar Orbiter is an M-class mission in the ESA Science Programme Cosmic Vision 2015 – 2025, which will have a highly elliptic orbit ranging from 0.9 au at aphelion to 0.28 au at perihelion [1]. The Radio Plasma Waves (RPW) instrument aboard will provide new insights into the microscale phenomenon, the propagation modes of the radio waves, and the localization of their source regions. Due to high requirements on the low frequency electric field measurements demanding equal illuminations of the three antennas (each ~ 6 m), the latter will be coplanar, limiting thus the possibilities of the direction finding analysis. Computer simulations suggest that the electric coupling with the spacecraft body will result in tilted effective antenna directions of 12° towards the Sun, which would be sufficient for a precise direction finding analysis of interplanetary solar radio emissions. However, the influence of thermal bending will be in the opposite direction (Figure 1). This effect will results in the antenna tip offset away from the Sun ranging between 0.5 m and 1.5 m at aphelion and perihelion, respectively (Figure 2). The radio direction finding analysis will be thus more inaccurate for closer distances from the Sun. Here, we provide estimates on the wave direction error with respect to the distance from the Sun and an uncertainty on the receiver gain.

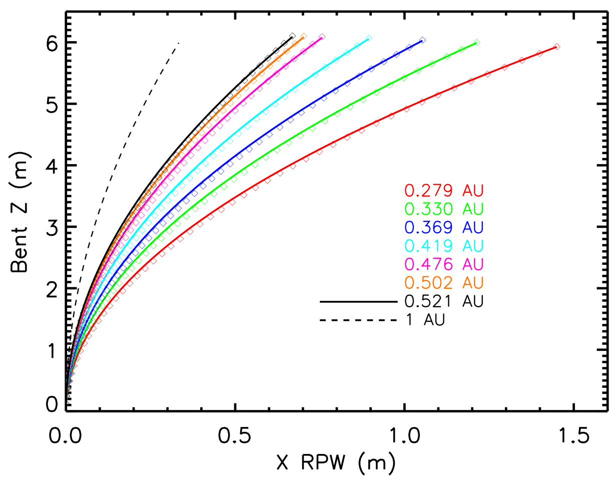

Figure 2. Estimated thermal antenna bending as a function of distance from the Sun.

2 Discussion and Results

To study a possible accuracy of the Solar Orbiter/RPW's direction finding capability we use a relation between measured auto and cross-correlations of signal from three monopole antennas (P_{ij}) and properties of an incident electromagnetic wave derived by *Ladreiter et al.* [2]:

$$P_{ij} = \frac{Z_0 G h_i h_j S_0}{2}[(1+Q)A_iA_j - U(A_iB_j + A_jB_i) + (1-Q)B_iB_j + \imath V(-A_iB_j + A_jB_i)], \quad (1)$$

$$A_k = -\sin\theta_k \cos\theta \cos(\phi - \phi_k) + \cos\theta_k \sin\theta, \quad (2)$$

$$B_k = -\sin\theta_k \sin(\phi - \phi_k). \quad (3)$$

The right hand side of equation (1) contains the impedance of free space (Z_0); the parameters of the electrical antennas: effective lengths (h_k), directions (θ_k and ϕ_k in spherical coordinates) and gain (G); and incident wave properties: the wave vector directions (θ and ϕ in spherical coordinates), the Stokes parameters: the energy flux S_0, the linear polarization degrees Q and U, and the circular polarization degree V. A_k and B_k represent projections of the effective antenna vector on the wave plane axes.

We modeled the auto and cross-correlations P_{ij} between three monopole antennas using equations (1 – 3), which represent an unpolarized wave (Stokes parameters: $Q = 0$, $U = 0$, and $V = 0$) propagating from a point source located on the Sun (a wave vector direction: $\theta = 90°$, and $\phi = 0°$), that correspond to properties of interplanetary solar radio emissions. Effective antenna parameters for various distances from the Sun have been estimated by computer simulations.We have performed simulations for each set of parameters considering an uncertainty on the receiver gain between 0.1 and 1 dB by applying the Gaussian noise on the final auto/cross-correlation products (normal distributions of the uncertainties in dB centered at 0 dB). The wave vector directions have been then calculated using the Singular Value Decomposition (SVD) method [3, 4]. This way we have simulated an angle difference between an input wave vector direction and an output one obtained by SVD.

Figures 3 and 4 display a mean difference in estimation of the wave vector directions (*i.e.* deviations from the Sun direction) as a function of an uncertainty on the receiver gain and the antenna tip offset, respectively. We expect that the reasonable experimental uncertainty of RPW will be between 0.3 dB and 0.5 dB. We thus conclude that the direction finding accuracy for radio emissions will be between 1° and 2° at aphelion, and between 2° and 5° at perihelion. Although RPW antenna configuration is not suitable for the direction finding analysis of interplanetary solar radio emissions, computer simulations suggest that it will be possible.

3 Acknowledgements

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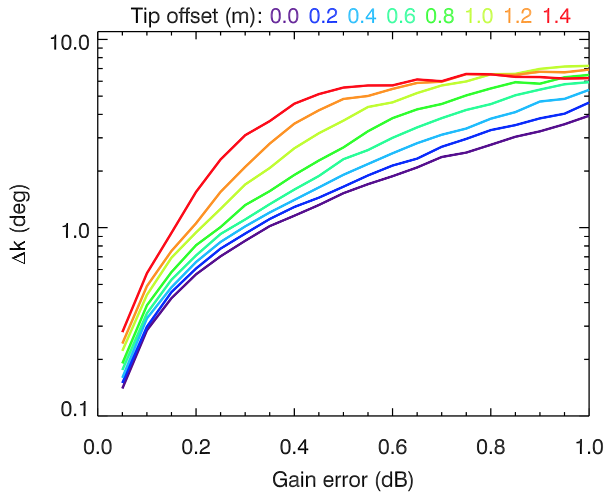

Figure 3. The simulated difference between input and output wave vector direction as a function of an uncertainty on the receiver gain for 8 values of the tip offset (in color).

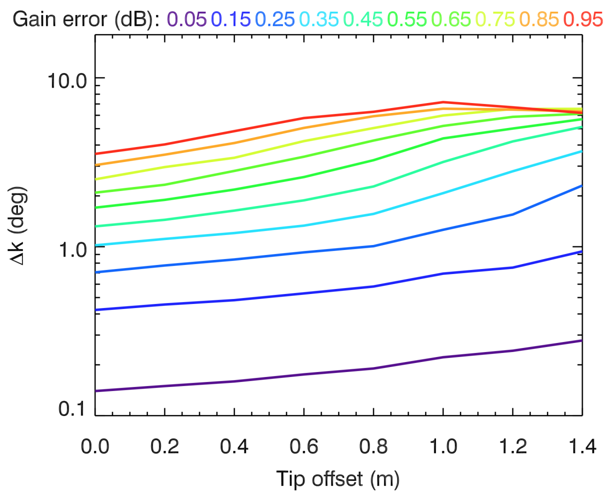

Figure 4. The simulated difference between input and output wave vector direction as a function of the tip offset gain for 10 values of an uncertainty on the receiver (in color).

References

[1] Müller, D., Marsden, R.G., St. Cyr, O.C., and The Solar Orbiter Team., "Solar Orbiter Exploring the Sun–Heliosphere Connection," *Solar Physics*, **285**, 25, 2013, doi: 10.1007/s11207-012-0085-7.

[2] Ladreiter, H. P., P. Zarka, A. Lecacheux, W. Macher, H. O. Rucker, R. Manning, D. A. Gurnett, and W. S. Kurth, "Analysis of electromagnetic wave direction finding performed by spaceborne antennas using singular-value decomposition techniques," *Radio Science*, **30**, 1699, 1995, doi:10.1029/95RS02479.

[3] Krupar, V., Santolik, O., Cecconi, B., Maksimovic, M., Bonnin, X., Panchenko, M., Zaslavsky, A., "Goniopolarimetric inversion using SVD: An application to type III radio bursts observed by STEREO," *J. Geophys. Res.*, **117**, 6101, 2012, doi: 10.1029/2011JA017333.

[4] Santolik, O., Parrot, M., Lefeuvre, F., "Singular value decomposition methods for wave propagation analysis," *Radio Science*, **38**, 1010, 2003, doi: 10.1029/2000RS002523.