In-flight antenna calibration for Direction-Finding with STEREO/Waves

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Direction-Finding with STEREO/Waves

- STEREO/Waves: 3 antennas, 2 channels
- DF data samples: DF0, DF1 and DF2
  - DF0: 2 antennas [1 instantaneous measurement]
    (2 auto+1 complex cross = 4 measurements)
  - DF1: 3 antennas [2 successive measurements with antenna switching]
    (3 auto+2 complex cross = 7 measurements)
  - DF2: 3 antenna [3 successive measurements with antenna switching]
    (3 auto+3 complex cross = 9 measurements) → Full information
- DF = computing instantaneous source parameters
  S, Q, U, V, θ, φ (and possibly γ, source size) : 6 (7) unknowns
- available: instantaneous analytical DF inversions for unresolved sources
  (or γ>5°)
  with DF0 or DF1 or DF2 measurements.
- DF inversion with γ as an output in preparation.
STEREO/Waves VS Cassini/RPWS/HFR

- Cassini/RPWS/HFR: DF0 and DF1 but no DF2
- Cassini: main source of noise: 8 bits data coding (~20 dB noise !)
- STEREO: 12 bits data coding. Noise = 1/16 of Cassini.

DF accuracy on Cassini:
- only direction (1 probe)
- 1° on directions, 10% on polarization degrees and 1db on flux
  IF: SNR>30dB and angular selection $\beta>20^\circ$
  (with $\beta$ = elevation over the antenna planes)

- Excepted accuracy on STEREO: at least identical.
  - with digitalization noise 16 times lower.
  - complete data set on DF2 mode.
  - position (stereo observation)
  - extended sources: enough measurements to obtain typical size of the radio source.
In-Flight Antenna System Calibration

- In-Flight Antenna calibration necessary to do accurate DF:
  - *calibration of direction and relative length:*
    Short dipole approximation:
    DF inversions are supposing that the antenna is a electric dipole.
    \( \text{ok if } L \ll \lambda \ (f < 1.5 \text{ MHz}). \)

  calibration is the determination of the effective electrical dipole equivalent to the monopole+satellite system.

  Reference radio source with known properties (AKR ? SURA ?).
  SURA calibration : \( f \sim 8-9\text{MHz} \) (not good for short dipole approximation)
  *Calibration at \( f < 1.5 \text{ MHz} \) is only possible with AKR, but only if distance STEREO/Earth > 120 \( R_E \)*

- *absolute antenna gain calibration:*

  Reference radio source (Galactic background ? SURA ? Sun (with joint observations)?)

  antenna/base capacitance and absolute effective length must be evaluated through in-flight calibration for absolute flux measurements [necessary for multi S/C analysis]

  *(accuracy depending on the accuracy of the determination of the reference source.)*
DF before in-flight antenna calibration?

- Use antenna calibration obtained through wire-grid simulation [Rucker et al.]
- on Cassini: $\Delta \theta = 7-8^\circ$ from physical to calibrated effective antenna length ratio: +20%
- Rucker et al. *Adv. Space Res.* 2005: $\Delta \theta$ for STEREO/Waves antenna as computed through wire-grid simulation is ~10-30°!

**In-flight calibration is necessary !!! but S/C rolls @ >120 RE needed !**

### STEREO/Waves antenna wire-grid simulation

![STEREO/Waves antenna wire-grid simulation](image)

### Cassini/RPWS/HFR antennas

<table>
<thead>
<tr>
<th></th>
<th>$u$ Antenna</th>
<th>$v$ Antenna</th>
<th>$w$ Antenna</th>
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<tbody>
<tr>
<td><strong>Physical directions</strong></td>
<td></td>
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<td></td>
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<tr>
<td>$h/h_w$</td>
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<td>1.0</td>
<td>1.0</td>
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<tr>
<td>$\theta$</td>
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<td>107.5°</td>
<td>37.0°</td>
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<td>$\varphi$</td>
<td>24.8°</td>
<td>155.2°</td>
<td>90°</td>
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<td><strong>wire-grid simulation (ASAP)</strong></td>
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<tr>
<td>$h/h_w$</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>$\theta$</td>
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<tr>
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<td><strong>In-Flight Antenna Calibration</strong></td>
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<tr>
<td>$h/h_w$</td>
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<td>1.19</td>
<td>1.0</td>
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<td>29.3°</td>
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<tr>
<td>$\varphi$</td>
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