RPWS Electrical Antenna Calibration
Saturn Inbound Update

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August 9, 2005; v1.4

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The purpose of an electrical antenna calibration is to find the electrical equivalent dipole of the system composed of the antenna (a monopole in the case of the Cassini/RPWS antenna system) and the spacecraft. The Cassini/RPWS antenna system has been calibrated during the Jupiter flyby [Vogl et al., JGR, 2004]. This calibration has been achieved using 2 different methods: (a) a least square minimization (using a Powell algorithm) and (b) a analytical direction inversion (detailed in Cecconi and Zarka [Radio Sci., 2005]). Both of them gave the same result within 1–2º for the electrical antenna direction and 1% for the antenna relative lengths. The final calibrated antenna parameters derived in the Vogl et al. [JGR, 2004] paper are shown in *Table 1*. These results have been derived using the jovian HOM radio emission. The studied frequency range was thus 600-1350 kHz (which is exclusively in the HF1 band). Furthermore, the dipole antenna mode (the *u* and *v* antennas are used together to form a X-axis dipole, called *x*) has not been calibrated at that time.

Using data during the Saturn inbound period, we have calibrated the whole antenna system (*u*, *v*, *w* and *x*) using the SKR measurements in the ABC and HF1 bands.

We have been using the following time period: 2004152 (may 31, 3004) – 2004165 (june 4, 2004). On day 2004165, a 3 R_S distance at Saturn is

	u antenna	*v* antenna	*w* antenna
h/h_w	1.21	1.19	1.00
θ	108.3º	107.8º	29.3º
φ	17.0º	163.8º	90.6º

Table 1. Relative length, colatitude and azimuth of the RPWS antennas to be used as operational values for the RPWS Direction-Finding until Huygens Probe is released (see [Vogl et al., JGR 2004]).

seen with a 1º angular separation by Cassini. We then suppose that before day 2004165 the position of the SKR sources can be merged with the Saturn position, and it is actually the last opportunity to do this approximation. The selected time period is then also the most favorable period to do an antenna calibration in terms of SNR. Furthermore both dipole mode and Direction-Finding mode (during days 2004152, 156 and 157) were programmed, so that we were able to derive all the antenna parameters.

We used the analytical direct inversion presented in Cecconi and Zarka [Radio Sci., 2005]. With this inversion, we use 2–antenna data-sets — i.e. the 4 instantaneous measurements (2 autos and 1 complex cross) using the current selected pair of antenna (*u*, *v* or *x* on one input channel, *w* on the second one). The data has been carefully selected. Extended graphs and selection boundaries are given in appendix. The results are shown in *Table 2*. We have separated the ABC and HF1/2 bands for the antenna relative lengths as they give significantly different results. The angular results are the same on the to bands.

antenna pair (*i*,*w*)	(*x*,*w*)	(*u*,*w*)	(*v*,*w*)
h_i/h_w [ABC]	2.00 ± 0.16	1.08 ± 0.10	1.10 ± 0.11
h_i/h_w [HF1/2]	2.45 ± 0.28	1.19 ± 0.09	1.22 ± 0.18
θ_i	89.3 ± 2.4	109.6 ± 4.2	111.0 ± 5.0
φ_i	–0.7 ± 2.5	17.2 ± 2.6	163.0 ± 3.2
θ_w	29.6 ± 4.9	28.9 ± 8.9	29.4 ± 9.7
φ_w	87.9 ± 5.0	89.1 ± 7.6	91.1 ± 4.9

Table 2. Relative lengths, colatitude and azimuth of the RPWS antennas as calibrated during the Saturn Inbound phase. Each column corresponds to one calibration, using the corresponding (*i*,*w*) pair of antenna (*i* = *u*, *v* or *x*). The given uncertainties are the FWHM of the corresponding histograms.

The results are consistent with the Jupiter flyby calibration [Vogl et al., JGR, 2004]. The largest discrepancy is for the θ_V value which is 3.2º off the Jupiter calibration value (but it is consistent when we consider the error bar of ±5.0º). Regarding the large errors bars for the *w* antenna parameters, one shall note that the antenna system geometrical configuration was not favorable to the *w* antenna calibration during this period (see Cecconi and Zarka [Radio Sci., 2005] for further explanations on this particular point).

We then suggest that:

I. *monopole modes* – we keep the Jupiter flyby calibration values for the antenna angular parameters and for the antenna length ratios in the HF1/HF2 bands,
II. *monopole modes* – we use the new antenna length ratios in the ABC bands.
III. *dipole modes* – we use the new antenna parameters.

Note that another antenna calibration should be carried out after the Huygens probe release as it may change the equivalent antenna parameters by changing the shape of the spacecraft body.

This latter calibration might be more difficult to carry out than the former ones. In all calibrations made until now, we have assumed that the position of the radio source was know at a ~1º accuracy. The data sets and calibration periods were chosen to keep this hypothesis valid. Now that the Huygens probe as been released, a new calibration is necessary but we are too close to Saturn to neglect the angular distance between the center of Saturn and the SKR sources. As our calibration scheme needs to impose a known source position, we will need to specify very carefully the source position (which will vary with frequency) for any post-probe release calibration.

Appendix. Graphs and data selection

As explained by Cecconi and Zarka [Radio Sci., 2005], the relevant data selection criteria depends on the antenna parameter which is being calibrated:

- *antenna length ratio* – both antenna shall not point to the source; the SNR have to be high on both antenna.
- *antenna direction* – the calibrated antenna direction shall be close to the source direction; the SNR on the other antenna has to be high.

As the calibration shall be carried out on the SKR emission, we also

	V	SNR[*i*]	SNR[*w*]	α_i	α_w
dipole mode (i = x)					
h_x/h_w	>0.2	>33dB	>33dB	>π/6	>π/6
θ_x and φ_x	>0.2	>5dB	>33dB	<π/6	—
θ_w and φ_w	>0.2	>33dB	>5dB	—	<π/6
monopole mode (i = u or v)					
h_i/h_w	>0.2	>20dB	>20dB	>π/6	>π/6
θ_i and φ_i	>0.2	>5dB	>20dB	<π/6	—
θ_w and φ_w	>0.2	>20dB	>5dB	—	<π/3

Table 3. Data selection criteria used for the Saturn Inbound Calibration Update.

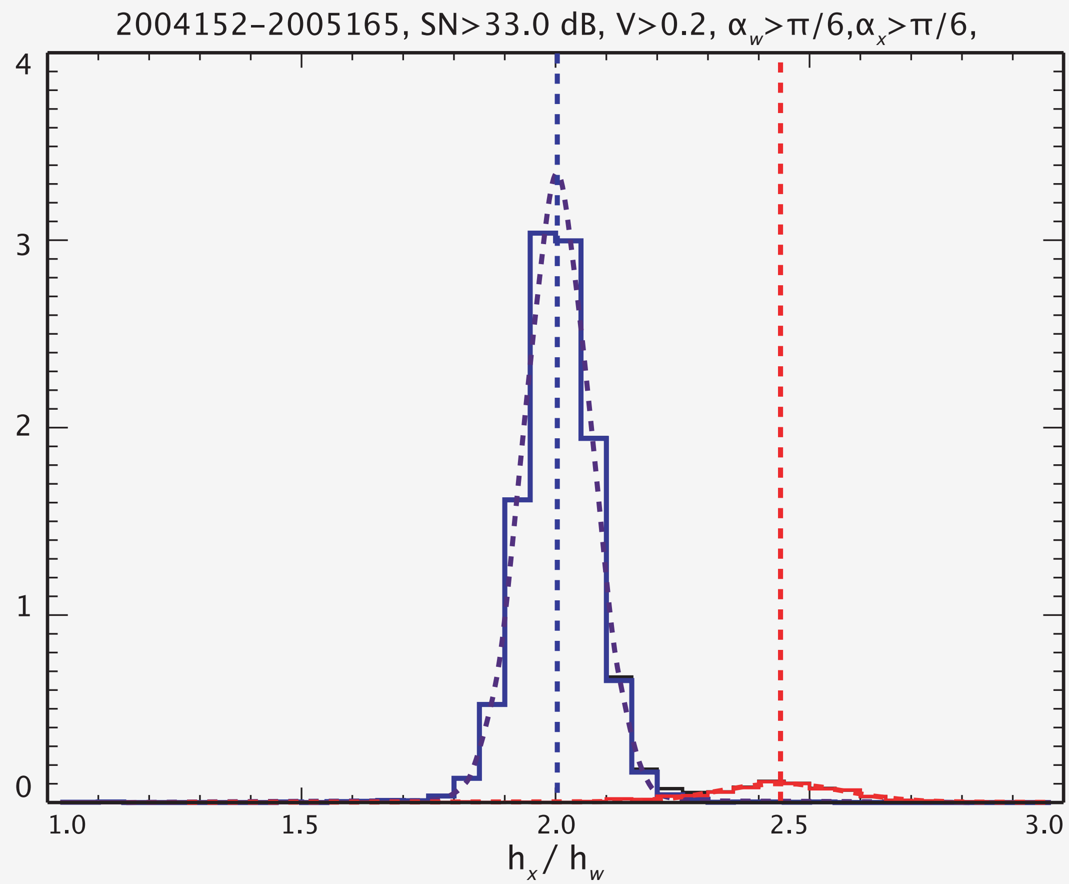

Figure 1. Histogram of the *x* antenna length ratio for the given data selection. Blue curves are for the ABC bands (frequency < 320 kHz) and the red ones for the HF1/HF2 bands (frequency > 320 kHz). The vertical dashed lines corresponds to the calibrated valued which is resulting from a gaussian fit on the histograms. The corresponding gaussian fits are in dashed blue and red respectively for ABC and HF1/HF2 bands.

impose a selection on the circular polarization degree V. The polarization selection removes non polarized emission such as Solar emissions. *Table 3* shows the data selection criteria used for this calibration. Figure 1 shows the *x* antenna length ratio histograms and their gaussian fits used to compute the calibration results.

The selection has been chosen to get comparable results throughout the different calibrations. It is however to get more accurate results by using more severe data selection in some cases. For instance, moving the minimum circular polarization threshold to V>0.5 will improve the *u* and *v* antenna colatitudes which are then: θ_u = 109.2º ± 2.9º and θ_v = 110.2º ± 3.7º. This more strict data selection can not be applied to all antenna parameters because it would result in empty selected data sets.

References.

- D. Vogl, **B. Cecconi**, W. Macher, P. Zarka, H. P. Ladreiter, P. Fédou, A. Lecacheux, T. Averkamp, G. Fischer, H. O. Rucker, D. A. Gurnett, W. S. Kurth, G. B. Hospodarsky : *In-flight calibration of the Cassini-RPWS Antenna System for Direction-Finding and Polarization Measurements*, J. Geophys. Res, 109, A09S17, doi:10.1029/2003JA010261, **2004**.
- **B. Cecconi**, P. Zarka : *Direction finding and antenna calibration through analytical inversion of radio measurements performed using a system of 2 or 3 electric dipole antennas*, Radio Science, 40, RS3003, doi: 10.1029/2004RS003070, **2005**.