SOLAR ORBITER RPW Antenna System Analysis, Science and Calibration

Oswald, T.H, H.O. Rucker, G. Mann, W. Macher

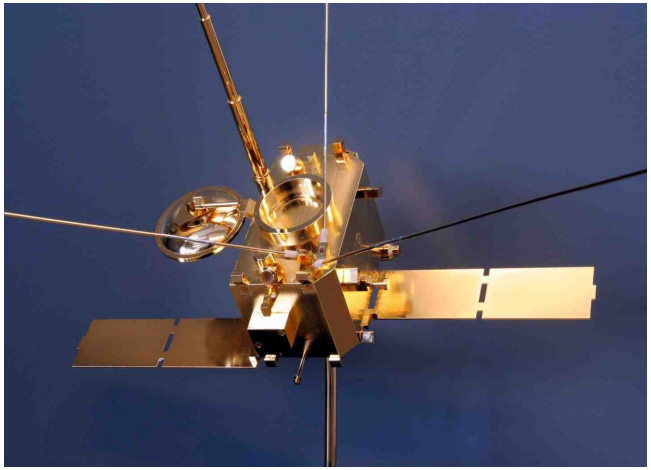
SOLAR ORBITER RPW antennas

Overview

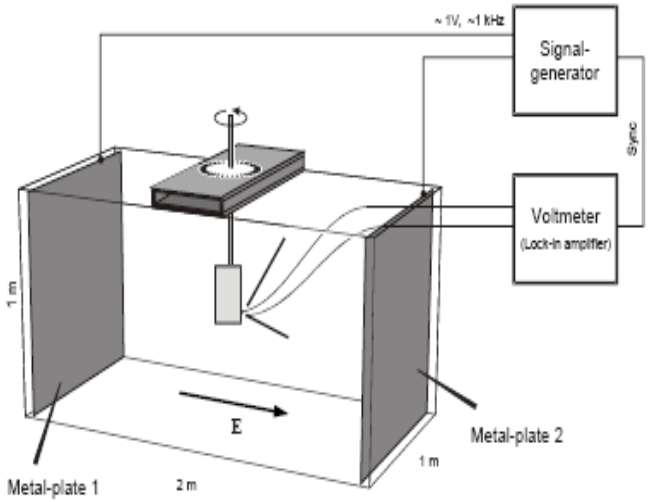
- The goal: correct data interpretation
- Effective length vectors, impedance/ admittance matrices, field patterns
- Numerical and experimental analysis:
  - Wire/Patchgrid modeling
  - Rheometry
  - Anechoic chamber
  - Inflight calibration

SOLAR ORBITER RPW antennas

Rheometry



Example: STEREO spacecraft

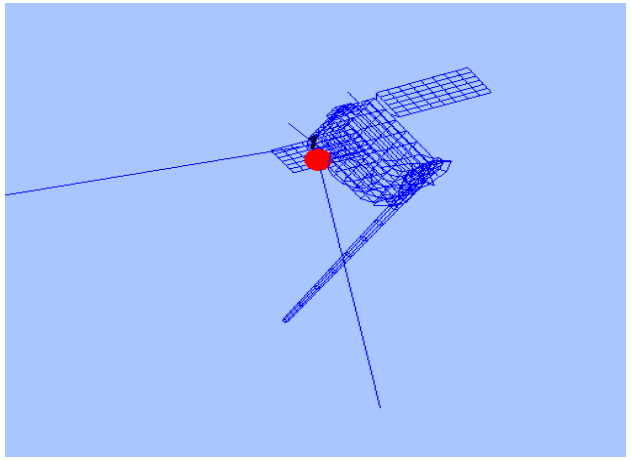


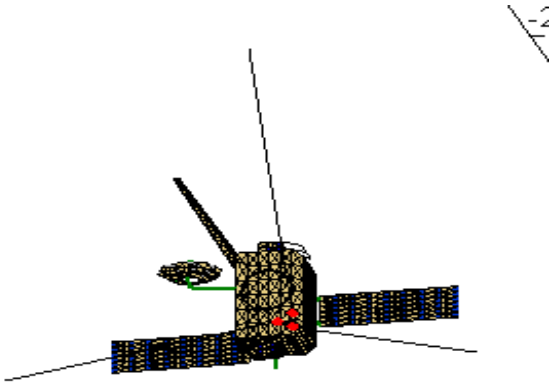
- A gold-plated model of the spacecraft is submerged into a water tank
- A low-frequency electric field is applied
- The response (induced voltage) of the antennas is measured as a function of spacecraft orientation
- The effective length vectors and the antenna impedances can be computed from the data
- Rheometry is only applicable to the quasi-static limit

SOLAR ORBITER RPW antennas

The numerical method

- The spacecraft is modeled as a grid of wires or patches
- Then the currents as a response of a 1V excitation along these wires/patches are computed
- This calculation is done with ASAP (wires), CONCEPT II (wires and patches) and NEC 4 in preparation
- On basis of the current distribution, all other antenna properties (effective length vectors, impedances) can be calculated with MATLAB routines

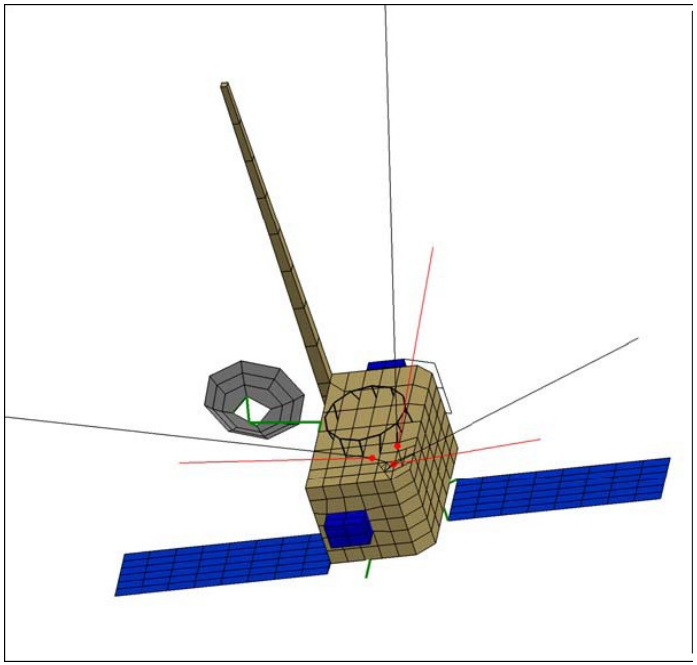




SOLAR ORBITER RPW antennas

The numerical method

- The equation governing the current distribution is the electric field integral equation (EFIE. CONCEPT, NEC), or the reaction integral equation (RIE, ASAP)
- For patches, the magnetic field integral equation (MFIE, CONCEPT) is used
- The antenna is excited at the feed
- Due to reciprocity, the receiving antenna results in the same current distribution as the transmitting (postulating vacuum)



SOLAR ORBITER RPW antennas

Including the effect of space plasma

- Antenna behavior is influenced by the surrounding space plasma.
- The influence is highest near the plasma resonance frequencies but also noticeable at the higher parts of the typical radio experiment frequency range.
- Due to the trajectory it could be important for the SOLAR ORBITER RPW antenna calibration.
- A dielectric model of the space plasma can be incorporated in the numerical antenna calibration.

- The effect of plasma is encapsulated in the Green's tensor, which shape depends on the plasma model used.

$$\mathbf{E}(\mathbf{r},\omega) = \int_{V'} \mathbf{G}(\mathbf{r},\mathbf{r}')\, \mathbf{j}_{ant}(\mathbf{r}',\omega) dV'$$

- The general form of the response tensor is

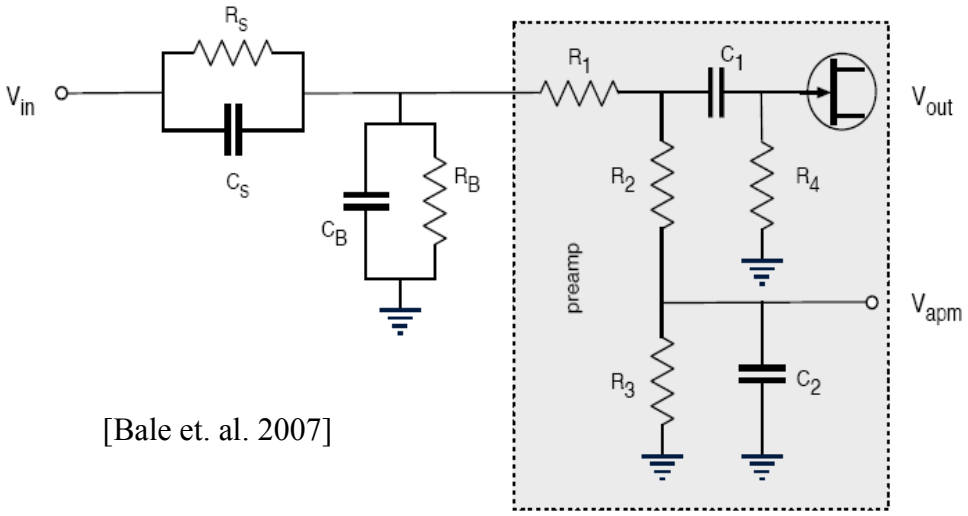
$$\mathbf{G}(\mathbf{r},\mathbf{r}') = \frac{\mu_0 \imath\omega}{(2\pi)^3} \int_{-\infty}^{\infty} \frac{adj(\lambda)}{\det(\lambda)} e^{\imath(k\cdot(\mathbf{r}-\mathbf{r}'))} d\mathbf{k}$$

- The resulting tensor can be incorporated into the electric field integral equation.

SOLAR ORBITER RPW antennas

Including the plasma sheath

- Spacecraft antennas are usually coupled to the surrounding space plasma.
- The electromagnetic coupling can be modeled by a system of a resistance and a capacitance.
- In rarefied plasma the coupling can not take place without photoelectrons.
- The sheath thickness must not be larger than the antennas.

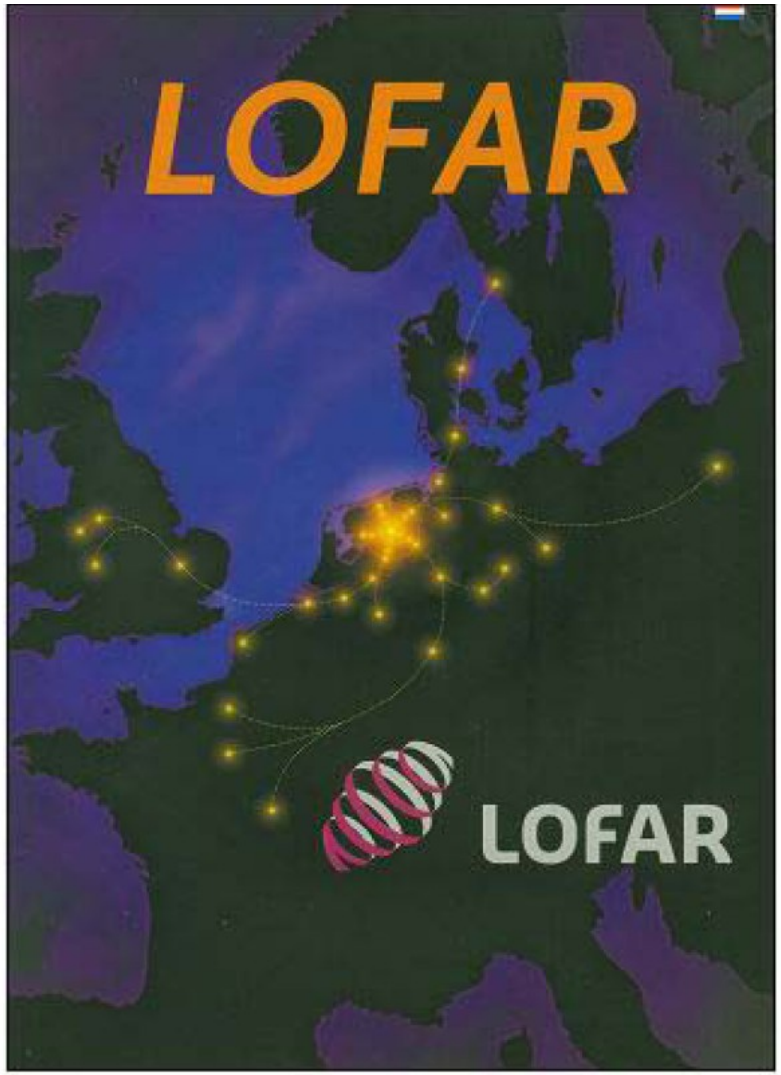


[Bale et. al. 2007]

SOLAR ORBITER and LOFAR

LOFAR

- The LOw Frequency ARray Project consists of a network of a large number of radio stations in the Netherlands, as well as remote stations in other European countries.
- The main objective is research on extragalactic radio sources.
- A possible use for solar physics is obvious and planned.
- It is planned to use LOFAR in combination with solar observing spacecraft...like SOLAR ORBITER



SOLAR ORBITER and LOFAR

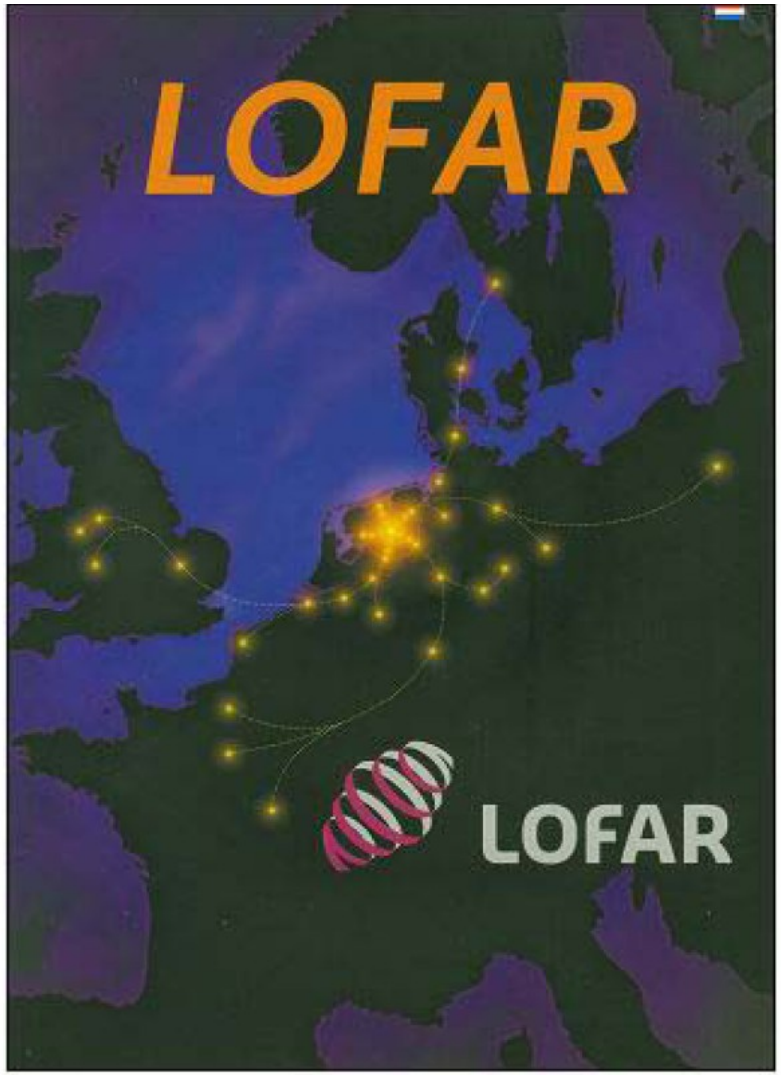
LOFAR

- Each station consists of two types of antennas:
  - ➔LBA = low-band-high antennas 30-80 MHz
  - ➔HBA = high-band antennas 120-240 MHz.
- The receivers also have an input channel for a third antenna family which is not yet implemented:
  - ➔VLBL = low-band-low antennas 10-30 MHz

- If VLBA would be implemented combined ground-based and space-based observations would be possible.

SOLAR ORBITER and LOFAR

- At the Space Research Institute, Graz we are in the planning stage to build a new LOFAR radio station.
- We also propose to implement the very-low-band functionality to make combined SOLAR ORBITER and LOFAR observations possible.



Conclusion:

We are ready for the SOLAR ORBITER RPW antenna calibration.

We propose the preparation of very-low-band antennas at the LOFAR radio stations.

The End

Thank You for Your attention !