Disturbances on space borne accelerometers and the behavior of metal shields in a dilute plasma

Anja Schlicht
Forschungseinrichtung Satellitengeodäsie, TU München

Introduction

On electrostatic accelerometers of the gravity field missions CHAMP, GRACE and GOCE many high frequency, and on GOCE also broad band noise, can be seen. Some are analyzed already: the heater switching spikes on GRACE (Flury et al. 2008), the magnetic torquer switching on GRACE (Petersen et al. 2012) and so called twangs (Petersen 2014). We now show the correlation of one type of twangs with the troposphere and the excitation of whistler waves (in VLF very low frequency range) injected by lightning strokes in the troposphere and propagating in the ionosphere-Earth waveguide as sferics and leaking into the ionosphere.

As it is not possible to explain all the observed similarities between twangs and whistlers as secondary effects (accelerations or magnetic disturbances) we hypothesize, that the accelerometer itself is sensitive to VLF and worked out two special frequencies which cause the problems, the lower-hybrid resonance and the ion cyclotron resonance. We classify the disturbances, show the correlation of whistlers and twangs and present the hypothesis.

Classification of disturbances

First class: Internal short pulsed disturbances
In this class belong all switching processes on the spacecraft, like heater switching, torque switching and discharging events (twangs type I and II)

Second class: Internal continuous disturbances
In GOCE accelerometer it is the first time that we see continuous disturbances. In all 6 accelerometers in axis a white noise structure is seen, which correlate between the two accelerometers of all axis. Correlated to this noise is a permanent quadratic factor at least shown for the y-direction of accelerometer 2 and 5 (Siemes 2017)

Third class: External short pulsed disturbances
The type III twangs belong in this class. These signatures correlate with sferics caused by lightning strokes and high wind speed.

Twangs have varying shapes. In most cases they consist of double or triple peaks but more peaks can be observed. A following oscillation is as common as a precursor peak or even precursor oscillation.

Tropospheric twangs

These twangs correlate with the cloud coverage and with strong winds in the troposphere. They have a seasonal variability, a day and night asymmetry, and separate bands for first peak positive and negative. As figure 3 shows they have multiple shapes, but can be divided into a multiple peak and a following oscillation. They are dominantly observed in the radial direction of the accelerometer.

Sferics and Whistler-sferics

Sferics are injected short electromagnetic pulses in the Earth-ionosphere waveguide by lightning strokes in the troposphere. While propagating in this waveguide they disperse and when reflected at the ionosphere fractions of the energy can penetrate into the ionosphere and travel as whistler-sferics to the top of the ionosphere and into the magnetosphere. Their propagation direction is perpendicular to the Earth surface. As whistler-sferics travel oblique to the magnetic field the electric field is tilted in the direction of propagation. So the electric field has a great component into the direction of propagation. Their frequency is in the order of some kHz.

Hypothesis

As other mechanisms causing this correlation can be excluded (magnetic shielded, mass movement small electric fields) we propose that accelerometers are sensitive to VLF.

1. Excitation of resonance frequency in the satellite-plasma tube
2. Metal cannot shield
3. Absorption in metal proof-mass enhanced by potential stabilization
4. Change in equilibrium position of the proof-mass causing a quadratic factor
5. Force on proof-mass due to potential drop

Disturbances on the read-out side: The excitation of resonances in the proof-mass causes a shift in the equilibrium position of the proof-mass. This causes a quadratic factor. In GOCE permanent due to high frequent heater switching?

Disturbance on the force side: The voltage drop (direction of the electric field of the disturbance) leads to a force enhanced by the potential stabilization at the gold wire contact.

Acknowledgement

The author thanks the Deutsche Forschungsgemeinschaft for funding this project under grant AOBJ:612582.

EGU-General Assembly 2017, 23 - 28 April in Vienna, Austria