Power line emission 50/60 Hz and Schumann resonances observed by microsatellite Chibis-M in the Earth's ionosphere

Denys Dudkin[1], Vyacheslav Pilipenko[2], Fedir Dudkin[1], Vira Pronenko[1] and Stanislav Klimov[2]

[1] Lviv Centre of Institute for Space Research, Ukraine (dd@isr.lviv.ua); [2] Space Research Institute, Moscow, Russia (sklimov@iki.rssi.ru)

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Outstanding Student Poster Contest

1. Introduction

The fundamental frequency 50/60 Hz of power line emission (PLE) and the Schumann resonance (SR) harmonics were detected by use of very short electrical field sensor of 0.42 m length during the low Earth orbit microsatellite Chibis-M mission in the years 2012-2014. The initial orbit of Chibis-M was almost circular about 500 km height and 52º inclination. We present the space distribution of observed events and connections of PLE with the possible ground sources. PLE has been recorded both in the shadow and sunlit parts of the orbits as oppose to SR which have been recorded only in the shadow zones.

2. Basics

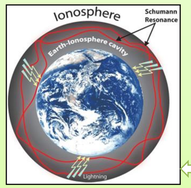
Power line emission (PLE)

- The overhead power lines are the sources of intense wideband electromagnetic (EM) emission, especially in ELF-VLF range, because of significant length (up to a few thousand kilometers) and strong 50/60 Hz currents with noticeable distortion.
- The radiation efficiency of the PLE increases with the harmonic order, so they are well observed by ground-based EM sensors.
- Their observations by low orbiting satellites (LEO) are very rare, particularly at basic harmonic 50/60 Hz, because of the ionospheric plasma opacity in ELF band.

From this follows, that **PLE and SR can hardly ever be detected by LEO satellites, i.e. above the F-layer of ionosphere.** In spite of this fact, these emissions were recently observed with use of the electric field antennas placed on the satellites C/NOFS (USA) and Chibis-M (Russia).

Schumann resonance (SR)

- The Schumann resonance (SR) is the narrow-band EM noise that occurs due to the global thunderstorm activity in the Earth-ionosphere cavity.
- The first five eigenmodes of the SR are **7.8, 14.3, 20.8, 27.3** and **33.8 Hz** and, thus, SR harmonics are also strongly absorbed by the Earth ionosphere.
- The published numerical simulations show that the penetration depth of such an ELF emission into the Earth's ionosphere is limited to 50-70 km for electric field and 120-240 km for magnetic field.



Electromagnetic source: mainly lightning
Boundaries: ground surface = perfect reflector ionosphere is dynamic and non-ideal reflector (?)

http://holographicarchetypes.weebly.com/schumann-resonance.html

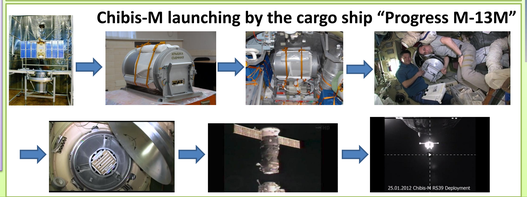
The ionospheric boundary of Schumann cavity has turned out to be very leaky!?

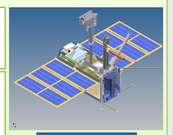
3. Chibis-M

Launch date: 2012-01-24
Decay date: 2014-10-15
Total mass: 40 kg
Altitude: ~500 km
Inclination: 52°
Orbit period: ~94.6 min
Mission: simultaneous monitoring of lightning discharges in radio, optical and gamma bands with very high time resolution (~sub-μsec).

The microsatellite (MS) Chibis-M (chibis.cosmos.ru), was designed by the Space Research Institute (Moscow) in cooperation with other Russian, Ukrainian and Hungarian space centers (Zelenyi et al., 2014).

Chibis-M launching by the cargo ship "Progress M-13M"





A = 0.60 m, B = 0.38 m, C = 0.25 m, D = 0.30 m.

4. Electric field sensor

The Chibis-M EM field sensor was developed and designed in Lviv Centre of Institute for Space Research, Ukraine (Korepanov et al., 2014).

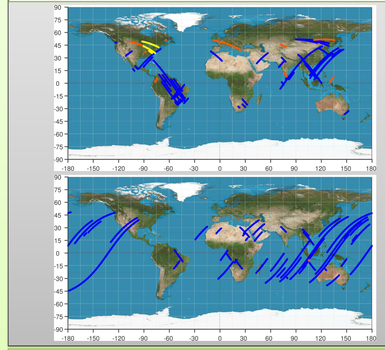
Dipole effective length: 0.42 m
Frequency range: 0.1 - 140 Hz
Sensitivity: ~4.24·10^{-6} V/(μV/m)
Input noise level:
in (μV/m)/Hz$^{1/2}$
0.8-0.04 at f = 0.1 Hz - 40 kHz
0.2-0.04 at f = 1 - 100 Hz

The electric sensor electrodes were placed on the center cases of two combined wave probes.

5. Results

The orbits of Chibis-M satellite where PLE (top) and SR eigenmodes (bottom) were detected

The shadow parts of MS orbit are marked by blue. The illuminated parts of MS orbit are marked by orange for MS over Earth's night side and by yellow for MS over Earth's day side.

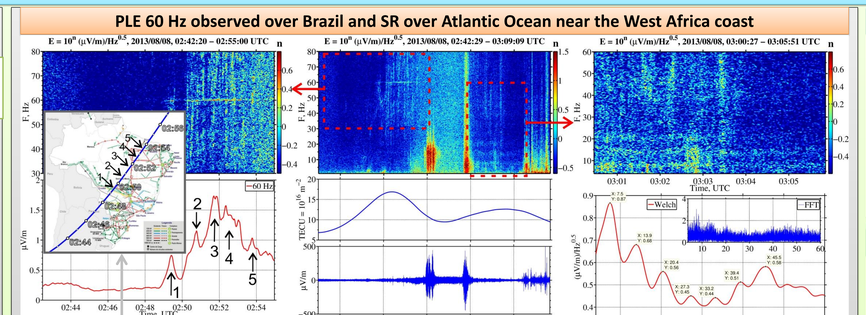


Data processing notes

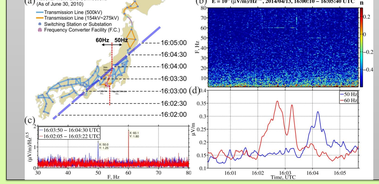
- Spectral smoothing of FFT spectrum has been done by Welch method. This method provides noise reduction at the expense of diminished frequency resolution (Barbé et al., 2010).
- The averaged absolute value of 50/60 Hz signals calculated by wave form filtration (Butterworth bandpass filter of 1st order, bandwidth 1 Hz).
- Total electron content (TEC) calculated by spline interpolation of "final ionospheric TEC grid" (accuracy 2-8 TECU, sample interval 2 hours, 5° (lon) x 2.5° (lat)) downloaded from International GNSS service (www.igs.org).

Barbé, K., R. Pintelon, and J. Schoukens (2010), Welch method revisited: nonparametric power spectrum estimation via circular overlap. IEEE Trans. Signal Process. 58(2), 553–565.

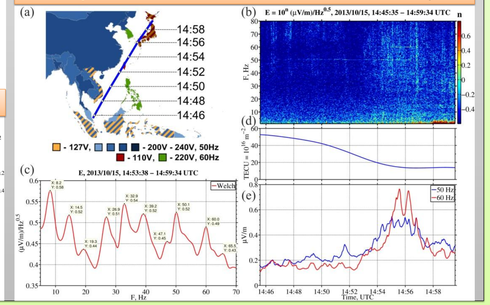
PLE 60 Hz observed over Brazil and SR over Atlantic Ocean near the West Africa coast



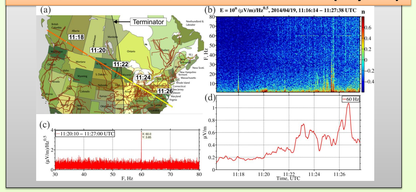
PLE 50/60 Hz observed over Japan



PLE 50/60 Hz and SR observed over China Sea and Japan

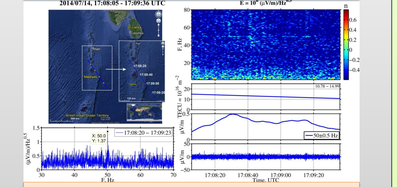


PLE 60 Hz observed over Canada and USA (dayside)

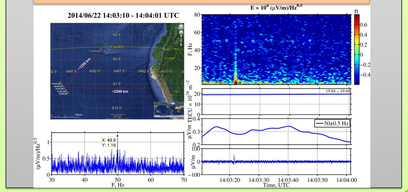


Very long distance PLE propagation?

PLE 50 Hz observed over Maldives



PLE 50 Hz observed over Pacific Ocean



6. Conclusions

Power line emission (PLE)

1) *Observation time:* local night and day time.
2) *Observation place:* near industrial regions, over the power lines.
3) *Observation distance:* 500-800 km (sometimes up 2,300 km?)
4) *Spectral density:* 0.6-18 (μV/m)/Hz$^{1/2}$.
5) *TEC range:* all.

Schumann resonance (SR)

1) *Observation time:* local night time.
2) *Observation place:* all parts of orbit (depended on TEC or unknown specific conditions).
3) *Eigenfrequencies:* coincide with the typical SR values with the accuracy of 1-9 %.
4) *Q-factor:* 3-11 for 1st – 3rd harmonics.
5) *Spectral density:* 0.20 – 0.45 (μV/m)/Hz$^{1/2}$.
6) *TEC range:* below ~30-40 TECU. However, sometimes it is no correlation between SR leakage absence and high TEC level.

- The fact of PLE and SR registration in the ionosphere suggests that the Earth-ionosphere waveguide should be described as a leaky cavity for ULF-ELF wave propagation.
- Nevertheless the electric field antenna of Chibis-M (0.42 m) is much shorter than C/NOFS antenna (20 m), PLE harmonics and SR modes were reliably detected, too.

7. References

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