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

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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 power line emission (PLE) increases with the harmonic order, so they are well observed by ground-based EM sensors. However 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.

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. 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).

Microsatellite Chibis-M was launched on January 24, 2012, at 23:18:30 UTC from the cargo ship "Progress M-13M" to circular orbit with altitude $\sim$500 km and inclination $\sim$52°. Chibis-M mass is about 40 kg where one third is a scientific instrumentation. The dimensions of the microsatellite case are 0.26x0.26x0.54 m with the outside mounted solar panels, service and scientific instrumentation. The main scientific objective of Chibis-M is the theoretical model verification for the atmospheric gamma-ray bursts. It requires the study of the accompanying EM processes such as the plasma waves produced by the lightning discharges in the VLF band. Chibis-M decayed on 15 October 2014.

The Chibis-M electric sensor has a small 0.42 m tip-to-tip base and was developed in Lviv Centre of Institute for Space Research, Ukraine. The sensor provides the measurement of one electric field component, which is perpendicular to the orbital plane, in the frequency range of 0.1-40,000 Hz with the noise spectral density 0.8-0.04 (μV/m)/Hz$^{0.5}$ (in the band 1-100 Hz the noise is 0.2-0.04 (μV/m)/Hz$^{0.5}$).

We present the space distribution of the observed PLE and SR harmonics in the latitude range $\pm 52^{o}$ and connection of the PLE sources with the high-voltage overhead power lines. The electric field data have been analyzed for all Chibis-M operating time ($\sim$ 2.5 years). The fact of PLE and SR detection by LEO satellites C/NOFS and Chibis-M suggests that the model of the transionospheric ELF EM field propagation should be refined.