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Spacecraft Observations of Quasi-Electrostatic Chorus Waves: Effective Length of a Receiving Antenna

Evgenii Shirokov (1), Andrei Demekhov (1,2), Yury Chugunov (1,3), and Alexey Larchenko (2)

(1) Institute of Applied Physics RAS, Nizhny Novgorod, Russia, (2) Polar Geophysical Institute, Apatity, Russia, (3) Deceased 24 August 2016

Whistler-mode chorus is a typical example of very low frequency electromagnetic emission in the Earth's and planetary magnetospheres. Chorus emissions typically propagate quasi-parallel to the ambient magnetic field in their source region but can also propagate in the quasi-electrostatic mode close to the lower oblique resonance cone.

However, the quasi-electrostatic wave field measurements by electric receiving antennas in a magnetoplasma are nontrivial. Indeed, the incident wave electric field amplitude E should be obtained from voltage $U = El_{\mathrm{eff}}$ induced on the receiving antenna, where l_{eff} is the so-called antenna effective length. The value of l_{eff} can be greater and even much greater than the antenna geometric length l_{geom} in case of the short (as compared to the electromagnetic wavelength in a plasma) antennas. This is because such antennas effectively re-radiate quasi-electrostatic waves in plasmas. Length l_{eff} should be calculated considering the plasma and wave characteristics, and, in general, this is quite a difficult problem.

In this work, we propose a method of calculating the effective length of a short receiving antenna for the case of spacecraft observations of quasi-electrostatic chorus emissions, and an analytical expression for this parameter is obtained. This method is based on the reciprocity theorem for quasi-electrostatic waves, which is also correct in gyrotropic and dispersive media such as magnetoplasmas, and requires an appropriate choice of the radiation source model. Such a choice is possible on the basis of the measured emission parameters if a quasi-monochromatic wave packet with wave normal angles near the resonance cone is detected.

We calculate the receiver effective length for some measurements of chorus wave quasi-electrostatic fields onboard THEMIS spacecraft using the proposed method. The emission parameters such as the wave normal angle have been found using the singular value decomposition method applied to the magnetic field waveforms. The electric field waveforms have not been used for this purpose because the effective length is unknown *a priori*. The effective length dependency on the dipole orientation has also been studied. The calculation results have shown that ratio $l_{\mathrm{eff}}/l_{\mathrm{geom}}$ is typically larger than one and can go up to 30 which means the effective re-radiation of the incident waves. In the case, where the incident wave electric field is quasi-orthogonal to the dipole, $l_{\mathrm{eff}}/l_{\mathrm{geom}} \lesssim 1$. This is because the electric current is induced inefficiently on the receiver and, hence, the wave re-radiation is weak.

Our results show that care should be taken when interpreting spacecraft data on wave electric fields if the waves propagate in the quasi-electrostatic mode. Since $l_{\mathrm{eff}}/l_{\mathrm{geom}} > 1$ in many cases, the electric field value can actually be less and even much less than value U/l_{geom}, which is conventionally used as the measured electric field in the satellite data analysis. In particular, this can be important for the estimates of electron energization by quasi-electrostatic chorus waves.