Lightning-related VLF emissions in the magnetosphere – satellite observations and numerical modeling

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Of the several natural sources of VLF waves in the magnetosphere, lightning strokes are the most familiar. The investigation of ionospheric and magnetospheric wave phenomena related to lightning strokes began from classical research by Eckersley (1935) and Storey (1953a) among others, and it has continued up to the present. A key finding in the investigation of nonducted whistler-mode waves belongs to Kimura (1966) who has demonstrated an unexpected possibility for whistler-wave reflection when the ions are taken into account in the dispersion relation. In a sense, this finding predicted magnetospherically reflected whistlers, which were found in the spectrograms of wave data from OGO 1 and 3 (Smith and Angerami, 1968). Magnetospheric reflection occurs when the waves reach some point where their frequency is less than the local lower-hybrid-resonance (LHR) frequency, so it is also referred to as *LHR reflection*.

VLF spectrograms from the MAGION 4 and MAGION 5 satellites contain most of the known types of VLF emissions, as well as new ones not discussed previously. Recently, numerical modeling of VLF spectrograms related to nonducted lightning-induced emissions became a new line of investigations. The spectrograms observed by a satellite in the magnetosphere depend on several factors: the properties of the source, wave propagation features, which in turn depend on the geomagnetic field structure and cold plasma distribution, and the evolution of emissions in the magnetosphere caused by wave resonant interactions with energetic particles. Therefore, numerical modeling of spectrograms and comparing them with real ones may serve as an indirect tool of investigation of the mentioned above factors and processes that affect the spectrograms. This tool is especially effective when the source of emission is known, in particular, in the case of lightning induced emissions. Main aspects of a new method in numerical modeling of spectrograms include:

a) wave-field presentation in the form of wave packets treatable in the frame of geometrical optics;
b) construction a frequency-time plot basing on the notion of a group front;
c) calculation of the variation of the ray-tube cross-section, then translation of the energy in each wave packet, of a certain bandwidth, into spectral intensity displayed on a spectrogram, using energy conservation and Parseval's relation.

A discussion of these and related questions, as well as the results obtained, and comparing them with the observations from MAGION 4 and MAGION 5 is the subject of the report.

References

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