Study on Dispersion Characteristics of Lightning Whistlers Observed by the Akebono Satellite

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It is well known that electron density profile in the geospace changes day by day and thus remote sensing techniques using electromagnetic waves are recently highlighted as a powerful tool, because they are useful for obtaining the global electron density profile in the earth's plasmasphere with high time resolution. We have been developing tomographic techniques using information of propagation time and direction of VLF waves such as Omega signals and lightning whistlers obtained by the Akebono satellite. As whistler mode wave originated from lightning discharge has a unique spectrum characterized by so-called "dispersion curve", we can estimate an electron density profile in the plasmasphere by solving the inverse problem from the trend of dispersion curve obtained along an trajectory of Akebono [1]. In the present paper, we introduce some features of dispersions of lightning whistlers observed in the plasmasphere along the trajectories of Akebono satellite.

In the analysis, we developed an automatic detection method of lightning whistlers from the wideband spectrum data obtained by the VLF instrument onboard Akebono. First, a smoothing in the frequency space and a simple noise filtering are carried out. Secondly, a template matching method is adopted in order to achieve a rapid and simple detection of lightning whistler. It is also noted that most whistlers observed in the plasmasphere are non-ducted and thus their dispersion curves are not represented by simple dispersion parameter. Therefore we propose an additional method in order to quantify the dispersion curves for non-ducted whistlers.

Finally we applied the developed method using the VLF spectrum observed by Akebono. The maximum frequency of the wideband spectrum is 20 kHz and the time and frequency resolution are 20msec and 50Hz, respectively. A series of lightning whistlers were successfully detected and the properties of their dispersion curves were estimated with high accuracy. We could also obtain high-dimensional properties of their dispersion curves properly by the proposed method. The results are satisfactory enough to analyze the trend of dispersion curve along the trajectory of the satellite. For example, lightning whistlers originated from northern hemisphere were continuously observed and the estimated dispersion of the whistlers became larger as the satellite moved from northern to southern hemisphere. In another case, lightning whistlers from both hemispheres were simultaneously observed.

Computation time for the analysis is several minutes for one-hour observational data using a PC workstation, which is practical for the application of the real-time operation. In other words, our proposed method can be applied to software receiver onboard future satellites so as to detect and estimate important properties of lightning whistlers automatically.

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References

[1] Y. Goto, Y. Kasahara, and T. Sato, An Inversion Technique of the Plasmaspheric Electron Density Estimation Based on Propagation Characteristics of Whistler Mode Wave, Proc. Int. Symp. on Antennas and Propagation, 1E2-2, pp.245-248, 2004.