Study on the noise reduction technique for VLF emissions by audio signal processing

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VLF emissions are common phenomena in the magnetosphere. The VLF emissions greatly contribute to pitch angle scattering for the generation of pulsating aurora (tens of keV ~ 100 keV electrons) and acceleration for MeV electrons in the radiation belts. We have been conducting the ground-based observations of the VLF emissions (100 Hz ~ tens of kHz) at Athabasca (L = 4.3) in Canada. Ground-based observations can continuously observe the VLF emissions having propagated along the geomagnetic field line from the magnetospheric source region at a fixed L with a high time resolution. However, there is a disadvantage that the noise received along the by propagation path is included in the observed waveforms.
In this study, we have studied a noise reduction technique by using audio signal processing techniques. Observation data include stationary noises (white noise and line noise etc.) and pulse noises (atmospheric noise and artificial clock noise etc.). To remove the stationary noises, two audio noise reduction techniques are evaluated for the VLF emissions with added noise components. One is spectral subtraction (SS) and other is modulation frequency analysis (MFA). SS uses an average noise spectrum from the noisy data to remove noise components in the frequency domain. In this study, to estimate the average noise spectrum, spectral entropy method is used for classifying the signals and the noises. On the other hand, MFA does not require an average noise spectrum from the observation data. Time variations of the amplitude spectrum are calculated in MFA. The stationary noises concentrate around the DC component in the time variations of the amplitude spectrum. By removing the DC component, the stationary noise can be removed in MFA. Chirp signals (2 ~ 4 kHz) (simulated chorus waves) with added stationary noises are evaluated by using the two methods. Both methods show that the SNR is improved from 0 dB to 10 dB.
Both noise reduction techniques are used in the actually observed data including the chorus waves. The analyzed data show that the stationary noise is removed. However, the observed signals including hiss waves are also removed. Because the hiss wave is similar to the thermal noise spectrum, the noise reduction techniques cannot effectively remove only the noise components if the hiss exists. To classify the noise and the hiss waves, we make use of the polarization characteristics. Hiss and chorus waves have a right-handed polarization. As a result, both noise reduction techniques can effectively reduce only the noise for chorus and hiss events.
In this presentation, we will discuss our noise reduction techniques for the VLF emissions in detail. We believe that this study can significantly contribute to reduction in the cost and time for a conventional EMC test.

Keywords: VLF emission, Noise reduction, Audio signal processing

