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Energetic electron precipitations associated with ULF Pc5 modulations during substorms using LF/VLF standard radio waves

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Periodic electron precipitations into the lower ionosphere are often observed by ground-based riometers as cosmic noise absorption [1]. The period of the variations is from a few seconds to several minutes associated with ultra low frequency (ULF) magnetic pulsations [2]. The possible mechanism is that the ULF waves in the magnetosphere modulate the precipitations of energetic electrons [3], which means the electron precipitations and the ULF waves have same periods. In the ULF waves, Pc5 (150-600 s) pulsations and electron precipitations are simultaneously observed in the morning sector (6-12 MLT) at the auroral latitudes [4]. In this study, we investigate the precipitations of energetic electrons into the lower ionosphere during substorms of 27 April, 2017 and 7-8 September, 2017, using a network of very low frequency (VLF)/low frequency (LF) subionospheric transmitter signals.

As for the substorm of 27 April, 2017, the transmitters are NAA (USA, 24.0 kHz, L = 2.88), NLK (USA, 24.8 kHz, L = 2.88), NDK (USA, 25.2 kHz, L = 2.98) and WWVB (USA, 60.0 kHz, L = 2.26), while the receivers are ATH (Athabasca, L = 4.31) and PKR (Poker Flat, L = 5.95). As for the substorm of 7-8 September, 2017, the transmitters are NRK (Iceland, 37.5 kHz, L = 4.05) and NPM (Hawaii, 21.4kHz, L = 1.15), while the receivers are NYA (Ny-Ålesund, L=17.2) and PKR. The substorm occurred at 05:35 UT (around midnight in American sector), 27 April, 2017. Based on the wavelet analysis, we found that the LF/VLF intensities for the NDK-ATH, WWVB-ATH, and NLK-ATH paths show oscillations with a period of 4-6 minutes during the substorm growth phase (05:00-06:00 UT). Magnetic field variations at ATH also show the same period, indicating that the radio intensity variations with the period of 4-6 minutes would be caused by ULF Pc5 modulations.

We also analyzed the substorm occurred at 19:40 UT on 7 September, 2017. Variations in the radio intensities (3-4 dB) for NRK-NYA, NRK-PKR and NPM-NYA paths due to precipitations were seen during 23:20 UT, 7 September - 01:00 UT, 8 September, 2017. Based on the wavelet analysis, the radio intensities for above 3 paths show oscillations with periods of 30-40 minutes. Magnetic field variations along the subionospheric propagation paths, the IMF Bz, and AE index also showed the same periods of 30-40 minutes, which could be caused by the occurrence of the substorm injection itself. In the presentation, we will discuss the cause of these radio variations in detail.

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