Modulation of the D-region ionosphere by Pc5 waves observed by VLF/LF standard radio waves

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Ionospheric modulation due to ultra low frequency (ULF) Pc5 waves have been observed by GPS-total electron content (TEC), high frequency (HF) Doppler sounders, and SuperDARN HF radars [e.g., Pilipenko et al., 2014; Belakhovsky et al., 2016]. However, there are few reports for the modulation of the lower ionospheric associated with the ULF Pc5 waves using VLF/LF transmitter signals. In this study, we investigate the D-region signatures of the modulation due to the ULF Pc5 waves using a network of very low frequency (VLF)/low frequency (LF) standard radio waves. We show oscillations in intensities of the VLF/LF waves with a period of 4-6 minutes during substorms on 27 April, 2017. The transmitter signals from 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) were observed by the receivers at ATH (Athabasca, L=4.31) and PKR (Poker Flat, L=5.95). The substorm occurred at 04:30 UT. Based on the wavelet analysis, we found that the intensities for the NDK-ATH and WWVB-ATH paths showed oscillations with a period of 4-6 minutes during the substorm growth phase (05:00-06:00 UT). Magnetic field variations observed by ground magnetometers around the NDK-ATH and WWVB-ATH paths also showed the same periodicity, which means that the variations in the VLF/LF intensities would be caused by Pc5 modulations. The magnetic field oscillations were observed in wide latitude range. The intensity of the oscillation was larger at high latitude magnetometers than those around the location of the NDK-ATH and WWVB-ATH path (mid-latitude). The Pc5 oscillations could be excited by solar wind because solar wind speed had similar period of the 4-6 minutes. In this presentation, we will discuss the cause of these VLF/LF oscillations.

Keywords: VLF/LF standard radio waves, Pc5, ULF

