Research on impacts of power line harmonic radiation on ionospheric parameters

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Introduction: Power line harmonic radiation (PLHR) refers to a kind of electromagnetic wave phenomena at harmonic frequencies of 50 or 60 Hz, which are the working frequencies of terrestrial power systems. Since the 1970s, PLHR events have been detected with several magnetically conjugate pairs of receivers and different satellites [1, 2, 3]. With the increase of global power consumption, PLHR has become more serious. Already, many scientific satellites have observed such anthropogenic electromagnetic waves in the ionosphere, and some possible typical impacts of those waves on the ionosphere have been reported [4]. However, reaching a final conclusion as to the impacts has been proven to be a difficult task. To further understand PLHR and its impacts, we utilize the data of three scientific payloads of DEMETER satellite collected with the Langmuir probe (ISL), thermal plasma analyzer (IAP), and energetic particle detector (IDP) to study the variation of ionospheric parameters due to the occurrence of PLHR.

Analytical Methods: DEMETER is a French seismo-electromagnetic microsatellite that was in operation from June 29, 2004 to December 9, 2010. The ISL onboard measured the electron density (N_e), electron temperature (T_e), and ion density (N_i). The IAP measured the density of H^+ (N_{H+}), He^+ (N_{He+}), O^+ (N_{O+}), and ion temperature (T_i). The IDP measured the electron fluxes in the range from 70 keV to 2.5 MeV. The variations of ionospheric parameters are affected by many factors, including latitude, longitude, altitude, daytime or nighttime, season, and solar activity. To minimize these impacts, we proposed an approach that compares the data from the PLHR-orbit and quiet-period orbit ($AE \leqq 50$ nT, AE is an index to evaluate the level of geomagnetic activity).

Among the 133 PLHR events detected by Wu et al. [5] when DEMETER flew over China, one quiet-period orbit, covering most of China's latitudes, was found for each year (2004-2010) according to AE index. In each PLHR-orbit, three-segment dataset were obtained: 30s before, at, and 30s after the occurrence region of PLHR event. By subtracting data of quiet-period orbit with corresponding latitudes from each-segment data of PLHR-orbit, we statistically analyzed the variation trend of ionospheric parameter in each PLHR-orbit due to PLHR.

Results & Discussion: With ISL and IAP data, it was found that both N_e and T_e were at a low level, N_{H+} was at a high level, and N_{O+} was at a low level when PLHR occurred. These results were generally helpful for understanding the formation behaviors of PLHR and were consistent with the theoretical results. From the analysis of IDP data, obvious variations of pitch angles before and after PLHR were occasionally observed to occur, and the variation did not exceed 10°. Its corresponding equatorial pitch-angle may not have fallen into a loss-cone, so the variation tendency of the electron flux did not have a definite connection with the pitch angle. The statistical results indicate that when PLHR occurs, the electron flux in the high-band (>1 MeV) tends to decrease and the decremental magnitude is very large, while the electron flux in the middle-band tends to increase and the incremental magnitude is relatively large.

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