Waveforms of Nighttime Atmospherics as a Measure of the Lower Ionospheric Electron Density Profiles over UK and France on August 31, 2008

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We use finite-difference time-domain (FDTD) modeling to perform time domain analysis of night time atmospherics observed near Bath UK on August 31st 2008. On that night the lightning activity was reported by the French lightning detection network Meteorage, that covered south-western Europe and the western Mediterranean Sea. The electromagnetic signals chosen for the present study were recorded with a wideband digital low-frequency radio receiver [Fullekrug, Measurement Science and Technology, 21, 015901, 1-9, 2010] located near Bath in Southwest England of the United Kingdom (51.3 N, 2.3 W). The electric field waveforms of negative cloud-to-ground lightning discharges (-CGs) located at 330±5 km and 530±5 km away from the radio receiver are averaged to produce one waveform for each distance that are subsequently used for comparison with FDTD modeling. The FDTD model is azimuthally symmetric electromagnetic model that describes propagation of atmospherics in the Earth-ionosphere waveguide for specified lower ionospheric electron density profile and source lightning current waveform. For the present work we utilize a lightning current with effective rise time τ_r=40 μs using model specified in [Cho and Rycroft, JASTP, 60, 871, 1998]. In the present study the non-linear dependence of electron conductivity on the magnitude of the applied electric field is not considered assuming that fields produced by studied -CG discharges are weak to produce any significant effects related to heating of ionospheric electrons. The lower ionospheric electron density profiles are modeled using classic Wait and Spies [Tech. Note 300, National B. Stand., Boulder, CO, 1964] representation that involves ionospheric height h' (km) and sharpness β (km^{-1}) parameters. We also utilize profiles obtained from International Reference Ionosphere (IRI) model [Bilitza, Radio Science, 36, 261, 2001]. Due to known uncertainties introduced by variability of lightning sources [e.g., Schonland et al., Proc. Royal Soc. London A, 176, 180, 1940] in our time domain analysis we ignore direct (ground) wave and the wave produced by the first ionospheric reflection and focus on accurate analysis of subsequent sky hop waves (up to nine) to derive information about parameters of the lower ionosphere. The results indicate that the observed averaged waveform at 530 km can be best represented by the electron density profile with h'=87 km and β=1 km^{-1}, consistent with previous reports of similarly steep profiles in [Shvets and Hayakawa, JASTP, 60, 461, 1998]. The FDTD modeling indicates that the analyzed atmospherics can not be reproduced using IRI model profiles. The observed atmospherics and model results are also compared with the ray theory developed by Schonland et al. [1940] demonstrating that observed atmospherics can be described by positioning the effective ionospheric reflection height between 88 and 89 km. In this talk we will also present frequency domain comparisons of observed and modeled atmospherics, and discuss issues related to calibration of lightning sources used in FDTD models and their relationship to radiation zone fields measured by VLF and LF receivers.

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