LWPC Analysis of Lightning 'Sferic ELF Propagation Velocity

Sandeep Sarker(1), Mark Golkowski (1), Chad Renick (1), Robert Moore(2) and Neal Dupree(2)

(1) Department of Electrical Engineering, University of Colorado Denver, Denver, CO, 80204,

(2) Department of Electrical and Computer Engineering University of Florida, Gainesville, FL, USA

The Long Wave Propagation Capability (LWPC) software package is a comprehensive simulation tool with a longstanding track record of simulating the propagation of very low frequency (VLF: 3-3- kHz) electromagnetic waves in the Earth-ionosphere waveguide. The code is able to simulate waves launched at any geographic location and takes into account effects of parameters that vary spatially around the world, such as the Earth's magnetic field, the ground conductivity, and the zenith angle of the sun.

In this work, we apply LWPC to the extremely low frequency (ELF : 0- 3kHz) band and focus on the group velocity of electromagnetic impulses generated by lightning discharges, known as "sferics". The group velocity shows variation as a function of the electron density profile of the lowest region of the ionosphere known as the D-region. The D-region's electron density profile can generally be fitted as an exponential function quantified by two key parameters, 1) the scaling factor for the reflection height of the Earth-ionosphere waveguide 2) the sharpness of the exponential profile. We analyze the change of the group velocity for profiles with reflection heights ranging from 70-90 km as well as sharpness magnitudes ranging from .4-6 km^{-1}. These parameters correspond to day and night conditions. The variation of the propagation velocity in an Earth-ionosphere waveguide containing a non-exponential electron density profile is also analyzed.

Other factors that are analyzed in this work are the path lengths of the propagation, the conductivities of the ground, different directions of propagation, geographic locations of the transmitter and receiver, propagation across the day-night terminator, as well as the trend of propagation velocity change under the event of a sudden ionospheric disturbance (SID). A SID occurs when the sun emits a short wavelength X-ray carrying a high-level of energy towards the Earth. These X-rays carry enough energy to penetrate into the D-region and induce photo-ionization. This photo-ionization process lowers the reflection height and increases the sharpness of the profile. Two models for predicting the change of the electron density profile under a SID event have been developed. The first developed model simply changes linearly with the logarithm of the strength of the X-ray flux. This model is relatively accurate in predicting the change of the amplitude and phase, but does not capture the relaxation of the ionosphere after the SID event took place. The relaxation time depends on the number of electrons that were freed during the event and the duration of time needed for these electrons to reattach to the ions in the D-region. The second model captures the relaxation of the ionospheric profile after the event. The results show that ELF propagation velocity increases during a SID event.