Spatio-temporal development of ionospheric current system and its relation to atmospheric waveguide modes

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Since electric conductivities witin the atmosphere are much weaker than conductivities in the ionosphere and the Earth's interior, it can be a good approximation to regard the Earth as a perfect conductor. In such situation, electromagnetic disturbances can be efficiently trapped in the atmospheric region (Kikuchi and Araki, 1979). As in a similar way of usual waveguide system, all of the electromagnetic field disturbances propagating in the IAE waveguide system can be described by superposition of Transverse Magnetic (TM) mode, Transverse Electric (TE) mode, and Transverse Electro-Magnetic (TEM) modes.

To realize the TEM mode, surface current on the Earth need to be induced as translational symmetric current (TSC) of the longitudinal part of ionospheric current, and displacement current between ionosphere and atmosphere need to be generated. The magnetic field perturbations produced by this TSC are canceled out above the ionosphere and below the Earth's surface: in contrast in the atmospheric region, the amplitude of magnetic fields are enhanced as a result of superposition. By taking into account the inductive electric fields produced by the TSC to the magnetosphere-ionosphere coupling process, we formulate governing equations for ionospheric current spatio-tempral development. In this system, TE mode is generated by the transverse part of ionospheric current and the TEM mode is generated by the longitudinal part of the ionospheric current, and these currents are coupled through the multi-step Hall effect (Yoshikawa and Itonaga, 2000).

The inductive time scale of the system is enhanced by the factor of square of the ratio of Hall to Pedersen conductivities and natural frequency of the system. The exsitence of the natural frequency reflects the energy exchange between transverse and longitudinal current system by the inductive Hall effect. This natural frequency causes resonant coupling between field-aligned current and ionospheric current system. We found that when the ionospheric conductivity conditions are in the aurora particle precipitation regions, the resonant frequency becomes around the Pi2 frequency range and Q factor of the system became around 4 or more. This result may strongly relate to the Pi2 generation mechanism when the aurora substorm is triggered. We will demonstrate the ionospheric current developments whose nature is something like an aurora formations.