E013-009 Room: 201B Time: May 27 11:15-11:30

Attenuation rate of the zeroth-order transverse magnetic mode in the Earth-ionosphere waveguide

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We evaluate attenuation of the zeroth-order transverse magnetic mode in the earth-ionosphere waveguide, which enables the polar ionospheric electric field to propagate instantaneously to low latitudes (Kikuchi and Araki, 1979). Assuming the three-layered model composed of the conductor (ionosphere) bounded by the MHD medium (magnetosphere) and vacuum (neutral atmosphere), we calculate electromagnetic energies penetrated into the ionosphere from the waveguide. It is found that a fraction of the penetrated energy is dissipated in the ionosphere, while the rest is transmitted into the magnetosphere. The attenuation of the TM0 mode can be evaluated from the ratio of the energy penetrated into the ionosphere to the energy transmitted horizontally in the waveguide. Assuming the daytime ionosphere (height-integrated conductivity,S =10mho) and the typical Alfvén velocity in the magnetosphere (Va = 1000 km), most energy penetrated into the ionosphere is dissipated in the ionosphere. The attenuation rate of the electric field is 0.0105 dB/1000km. For the nighttime condition (S = 1 mho), on the other hand, more than half the penetrated energy is transmitted into the magnetosphere, resulting in the attenuation rate of 0.0576 dB/1000km. However, if we assume that the field lines are connected to the ionosphere in the opposite hemisphere, all energy transmitted to the magnetosphere would finally be dissipated in the ionosphere after a relaxation time determined by the magnetospheric and ionospheric parameters. The energy dissipation in the 3-layer model is then exactly the same as that in the parallel plane transmission line with finite conductivity, and the attenuation rate for the nighttime condition is 0.115 dB/1000km. The intensity of the electric field transmitted over 10000km under the nighttime ionosphere would be 0.876 of that of the source electric field. The attenuation of the electric field can be neglected when compared with the geometrical attenuation due to the finite size of the source electric field.