Propagation characteristics of wideband electromagnetic wave in the ionosphere

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This paper analyzes propagation of wideband electromagnetic (EM) wave in the ionosphere. The influence of total electron contents (TEC) of the ionosphere on the propagation of EM wave is investigated numerically. Our attention is paid to VHF band, which is dominant frequency band of EM waves emitted from lightning discharge. It is reasonable to use these waves because of frequent occurrence in nature, and thus these EM waves experience significant dispersion as compared with microwaves during the propagation in the ionosphere.

The refractive index of the propagation in the ionosphere is derived by using the equation of Appleton-Hartree. The ionosphere is divided into slabs with the thickness of 1 km, in which the parameters of ionosphere are assumed as constant. Particularly, the altitude distribution of electron density is taken into consideration. From a wave equation, the propagation constant of a plane wave can be obtained, and transfer function in each layer can be derived. The transfer function from the lower boundary of the ionosphere to an arbitrary altitude can be obtained by multiplying them. From this transfer function and a known incident EM wave, an electric field of the EM wave at arbitrary altitude can be obtained by the inverse fourier transform.

Variations of pulse width and difference in the arrival time between each frequency component due to the dispersion in the ionosphere were revealed. It was found that the difference in the arrival time between the frequency components of 26 and 48 [MHz] is about 30 microseconds in daytime. This result was in good agreement with the data obtained from the FORTE satellite. Additionally, the mode splitting at the low frequency was confirmed. The point to be stressed is that group delay of the EM wave was dependent on the altitude distribution of electron density, especially when the peak electron density was the order of 10^12[m^-3] or more.