DOA Estimation for UWB EM Pulses with a Broadband Interferometry

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Introduction: Various techniques of direction-of-arrival (DOA) estimation for electromagnetic (EM) waves have been developed in accordance with the spread of wireless communications. Most of the DOA techniques are applicable only for static monochromatic waves. In other words, less attention is paid to the DOA estimation for ultra-wideband (UWB) EM waves. Lightning discharge and electric power equipments are typical sources of impulsive EM pulses, and their DOA estimations are important from the viewpoint of EM compatibility. The frequency spectrum of such EM waves is largely dependent on the kind of sources, temperature, humidity and so forth. Therefore, sufficient intensity of EM power could not be always obtained by using conventional monochromatic approaches. For a class of EM waves with a wideband spectrum, mutual coupling between antennas would not be negligible at the lower frequency band. In this paper, the concept of conventional interferometry for narrow band is extended for UWB signals on the basis of our previous paper (R. Mardiana and Z. Kawasaki, *IEEE Trans. Instrum. & Meas*., 2000). First, an interferometer under consideration is analyzed by using the FDTD method to calculate the interaction of antennas. Then, a novel signal processing scheme for wideband pulses is presented with the influence of mutual coupling of antennas taken into account.

Methods: We consider two circular plate antennas for DOA estimations (See Figure). We pay attention to the frequency band between 25 MHz and 250 MHz. Mutual impedances of the antenna array are calculated using the FDTD method as a pre-processing. For an injection of plane wave, we can calculate induced currents at the feeding point of antennas in the time domain. The induced currents are transformed into the frequency domain by FFT. Then, the induced voltages of the antennas for each Fourier component are calculated. Finally, we can obtain the phase differences between the antennas at each component.

Results: For the incidence of EM pulses modulated by sinusoidal waves, the errors between computational and theoretical values are 3.5 degrees at most, although they are dependent on the frequencies of the EM waves. Note that no noise exists except for computational errors. We observe that the errors are mainly caused by the mutual coupling of the antennas. From the results, we find two difficulties left to be overcome. One is the frequency-dependent error in the estimated values for the angles of incidence. The other difficulty is the determination of proper values from the angles of incidence. In order to overcome the former, we propose to use a database that includes the correlation between estimated and theoretical values for the angles of incidence at each frequency. We can handle the latter difficulty by using the weighting function determined on the basis of the intensity of Fourier spectrum. Furthermore, in order to evaluate the general effectiveness of this system, we investigate the behavior of this system for the EM pulse emitted from discharge of needle-plane electrode. Gauss noise is added so that the S/N ratio becomes 5 dB. From numerical investigation, the above-mentioned scheme is found to suppress the estimated angle.

Conclusion: In this paper, we have presented a broadband interferometery for the DOA of UWB EM waves. The interaction between the antennas was calculated using the FDTD method, and taken into account in the analysis. We proposed the signal processing scheme for wideband pulse, and confirmed the effectiveness.

Fig: circular plate antenna array