Computational and Experimental Study on the Localization of Impulsive Noise Source

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ABSTRACT

In this paper, the localization of impulsive noise source or ultra-wideband source is discussed computationally and experimentally. First, the source of impulsive EM noise from electric power equipment is modeled with the use of the FDTD method. Then, the results using the FDTD method are directly used for the localization of source. The localization scheme used is the time delay of arrival. The validity of the computational results is compared with experimental results.

INTRODUCTION

Partial discharge (PD) activity is a symptom of an insulation breakdown or a warning for the insulation failure of electric power apparatus. It may emit impulsive EM noise that would interfere communication systems, such as wireless communication, television and radio broadcasting, and so forth. For realizing high reliability on power system and better EM environment, it is desirable to identify the location of PD source with high accuracy. Therefore, we proposed the broadband interferometer on the basis of the time difference of received pulses [1]. In addition, Peck and Moore [2] proposed to adopt HT algorithm for improving the accuracy of the direction-of-arrival (DOA) estimation. Most papers on the DOA estimation of the impulsive EM noise were mostly concentrated on measurement, together with simple theory. In theoretical models, generally, a plane wave is considered as the wave source, that is, EM field is implicitly assumed as the far field. However, typical distance between antennas and the PD source is the order of several ten meters. For the application to narrow-band EM wave source detection, novel DOA estimation methods in near field are proposed (e.g., [3]), instead of conventional far-field approximation. For further development of the ultra-broadband source detection system, it is fairly desirable to model the EM field around the PD source computationally, and then to develop and validate novel algorithm using the computational results.

The purpose of this paper is to model the propagation for impulsive EM noise from electric power apparatus with the use of the 2-D FDTD method. Then, the results obtained are directly used for estimating its location. In particular, the results obtained are compared with experimental ones.

NUMERICAL AND EXPERIMENTAL METHOD

In this paper, the FDTD method is used for computational modeling. For EM field from the PD source, the current source is used. A waveform from the PD source is determined parametrically using the results from experiment in open site. It should be noted that attention is paid to the frequency band between 25 and 150 MHz, where the majority of the signal generates. In this frequency range, the EM waves for FM radio broadcastings behave as undesirable far-field signals. The total-field/scatter-field formulation [4] is used for representing the broadcastings.

Only the outline of our measurement system is described, since it can be found in [1]. Four sets of VHF broadband plate antennas are used as the EM wave sensors. These antennas are located at the apices of the square with its side length of 3.0 m. The antennas are connected to a digital storage oscilloscope by coaxial cables.

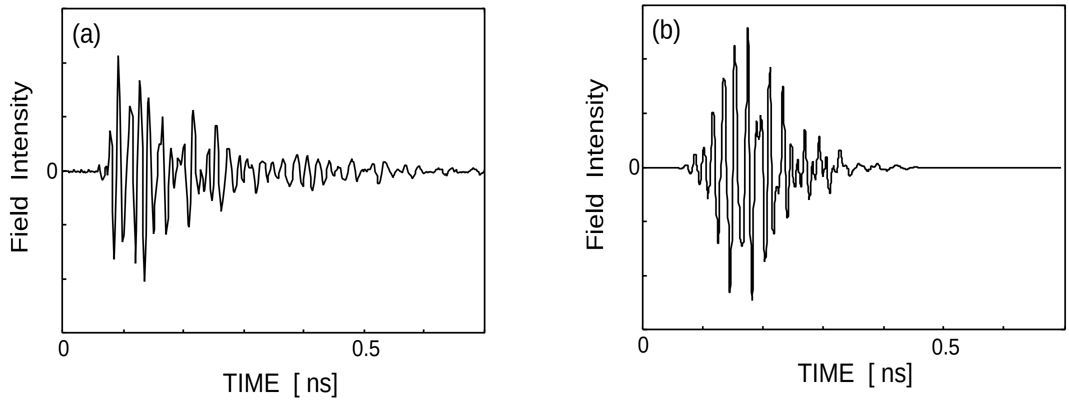

Figure 1: The FDTD modeling of EM pulse emitted from the partial discharge source with the background noise (the FM broadcastings).

Modeling of the impulsive noise source

The impulsive EM noise source is modeled using the current source. In particular, the hard source expressed by (1) is used [4].

$$E^n = \frac{\Delta t}{\varepsilon_0} \cdot \frac{I^n}{\Delta l} \tag{1}$$

First, a typical waveform recieved by one of the antennas is shown in Fig.1 (a). For incorporating with this waveform and realizing various waveforms in the FDTD method, we assume that the EM wave emitted from PD sources can be expressed parametrically by the following equation:

$$E = \sum_i A_i \exp\{-(t-\tau_i)^2/2\sigma_i^2\} \cdot \sin(2\pi f n \Delta t). \tag{2}$$

Figure 1(b) shows the waveform obtained by (2). Reasonable agreement between measurements and the modeling is obtained with i=4 in (2).

Algorithm for the Localization of Source

First, the siginal is denoised using the wavelet transform [5]. Next, the time delays of the arrival for EM signals at each antenna are estimated. It should be noted that three independent time difference is obtained. For this purpose, the time when the amplitude of recieved signal takes the maximum is sought. Since the time resolution of the digital storage oscilloscope is 2.0 ns, an interpolation is used for its proper estimation. Finally, the wideband source is localized by solving a couple of equations (Eq.(1) in [1]) by substituting the time differences into the Newton-Raphson method for th equations.

RESULTS

Figure 2 shows an example for the propagation of the EM wave emitted shown in Fig. 1(b) from the PD souce with the background noise. The frequencies of three plane wave are 80.2, 85.1, and 89.9 MHz, which are the FM radio broadcasting bands in the Kansai area of Japan. It should be noted that ratio of their amplitude is 4:6:3 with the angle of incidence of 65, 195, 310 degrees, respectively. As is evident from this figure, the radiation from the source is disturbed by the radio broadcasting. This effect might become significant in the presence of obstacles.

The following situation is considered for comparing the experimental and computational results. The impulsive source is assumed to locate at (x, y)=(6.9 m, 7.4 m) when the antenna 2 is at (x, y)=(0, 0) (See also Fig.4). Figure 3 shows the time delayes of arrivals for the total of 500 samples. In this figure, the horizontal lines in the figure are the ideal time difference. Note that subscripts i and j in t_{ij} means the time delay of arrival between the antennas i and j.

As seen from this figure, the errors caused by the measurements are small, but negligible for localization. Figure 4 shows the localization of the source. It should be noted that the Newton-Raphson method is not stable for some sets of time differences. The localization results which are stable for our algorithm are presented, that is, only 183 points are plotted among all sets of data. In this figure, the blue dot is the actual position of the PD source. The computational reslut is not shown, because it coincide with the theoretical position for the SNR = ∞.

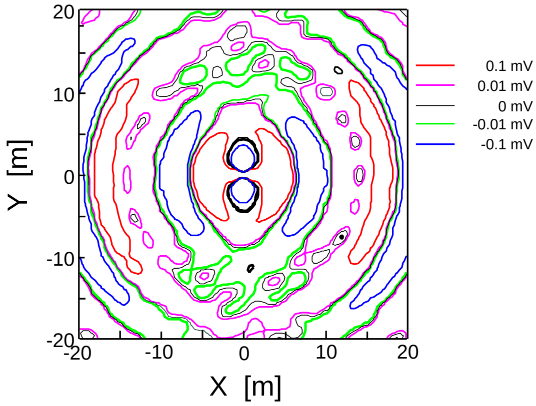

Figure 2: The FDTD modeling of EM pulse emitted from the partial discharge source with the background noise (the FM broadcastings).

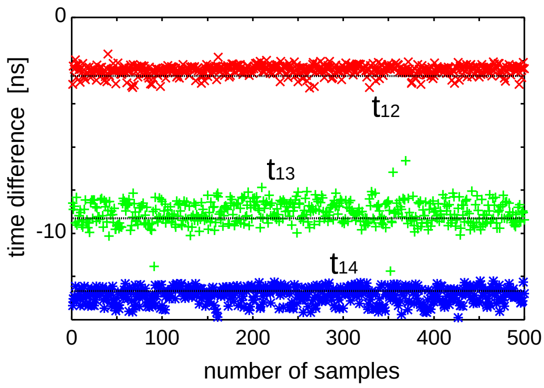

Figure 3: The time difference between the antenans.

SUMMARY

In this paper, propagations of impulsive EM noise and FM broadcastings were modeled using the FDTD method. Attention was paid to the comparison with computational and experimental results. Reasonable agreement was obtained between them. The detailed computational results will be presented at the conference. The FDTD code developed in this paper will be used for the development of DOA estimation algorithms in near field and in multi-path environments.

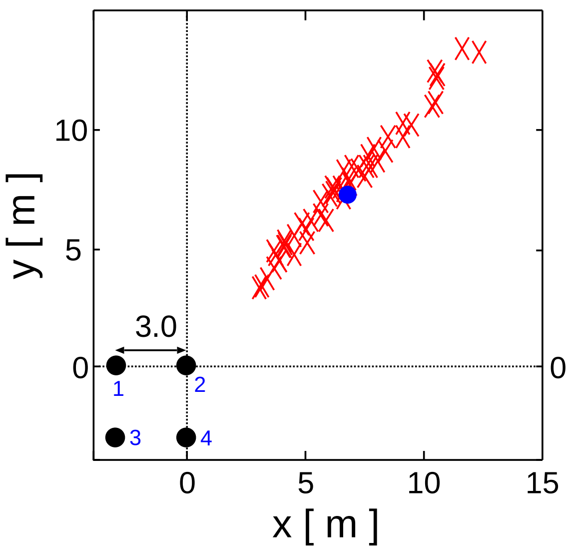

Figure 4: Experimetntal and computational results for the localization of the source.

References

[1] A. Tungkanawanich, Z. Kawasaki, and K. Matsuura, "Location of multiple PD sources on distribution lines by measuring emitted pulse-train electromagnetic waves," *Trans. IEE Japan*, vol.120-B, no.11, pp.1431-1436, 2000.

[2] C. H. Peck and P. J. Moore, "A direction-finding technique for wide-band impulsive noise source," *IEEE Trans. EMC*, vol.43, no.2, pp.149-154, 2001.

[3] R. N. Challa and S. Shamsunder, "Passive near-field localization of multiple non-Gaussian sources in 3-D using cumulants," *Signal Proc.*, vol.65, pp.39-53, 1998.

[4] A. Taflove and S. C. Hagness, COMPUTATIONAL ELECTRODYNAMICS: the finite-difference time-domain method, 2nd Ed., 1999.

[5] A. Tungkanawanich, Z. Kawasaki, J. Abe, and K. Matsuura, "Location of partial discharge source on distribution line by measuring emitted pulse-train electromagnetic wave," *IEEE Winter Meet.*, WM-329, 2000.