Development of a system for estimating direction-of-arrival of electromagnetic interfering waves

Background

Pulsed electromagnetic interfering waves with wideband frequency characteristics may be emitted from power equipment owing to discharge phenomena, which may occur at faulty points, such as unintended narrow gaps between metal supports or deteriorated insulators. Therefore, it is necessary to localize the electromagnetic interference sources or estimate their direction-of-arrival (DOA) effectively to reduce maintenance and eliminate its effect on communication systems such as radio broadcasting, TV, and wireless LAN.

Objectives

The purpose of this study is to adopt an algorithm appropriate for the DOA estimation [*1] of pulsed electromagnetic interfering waves among conventional algorithms and develop a DOA estimation system with practical accuracy [*2].

Principal Results

1. Adoption of an algorithm appropriate for the DOA estimation

As shown in Table 1, several algorithms are used to estimate DOA of pulsed electromagnetic interfering waves or signals and localize their sources using an array antenna and so on. Among these algorithms, the beamformer method and the signal subspace method are considered to be effective for the DOA estimation of the pulsed electromagnetic interfering waves, since these two methods can take into account multiple and reflected waves. As a result of numerical simulations, we found the signal subspace method can attain higher estimation accuracy in the DOA estimation of the pulsed electromagnetic interfering waves.

2. Development of a DOA estimation system

We developed a DOA estimation system to receive pulsed electromagnetic interfering waves using an array antenna composed of four half-wave dipole antennas with a center frequency equal to 500 MHz [*3] and estimate DOA by the signal subspace method. The maximum number of the pulsed electromagnetic interfering waves which this system can deal with is three in principle since the number of the antennas in the array antennas is four. Note that more electromagnetic interfering waves can be handled using more antennas.

3. Relationship between DOA and estimation accuracy

As shown in Fig. 1, fixed and movable spherical gaps to simulate unintended gaps between metal supports are attached to a test transmission line whose height ranges from 12 to 14 m. The direction of the fixed gap is 0° and the direction of the movable gap ranges from 58.2° to 1.7°. With the application of a 97 kV voltage to the line, pulsed electromagnetic interfering waves are emitted by spark discharges occurring at the gaps. As shown in Fig. 2, using the developed system, the DOA of the pulsed electromagnetic interfering waves from the two gaps can be estimated within an error of 2° for each direction. Moreover, the fixed gap can be distinguished from the movable gap even when the direction between the two gaps is only 1.7°. As an example of the estimated results, Fig. 3 shows the estimated results for the DOA of the pulsed electromagnetic interfering waves when the direction of the movable gap is 58.2°.

Future Developments

Sensitivity characteristics of the system, a technique for estimating DOAs in elevation angle, and optimization of the array antenna will be analyzed.

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Reference

A. Tatematsu, et al., 2009, “A study on a source localization method for pulsed electromagnetic interference”, CRIEPI Report H08003 (in Japanese)

A. Tatematsu, et al., 2009, “Development of a system for estimating direction-of-arrival of pulsed electromagnetic interference”, CRIEPI Report H08019 (in Japanese)

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*1 : A source is localized by the intersection of DOAs estimated at several points in case of the DOA estimation.
*2 : In practical, it is required that the estimation error is within about 3° in case of a transimission line.
*3 : The center frequency is set to 500 MHz considering frequency characteristics of pulsed electromagnetic interfering waves, ease of a fabrication and portabitity of an array anntena.

Table 1 Estimation methods of the DOA and the source position

Estimation method	Multiple waves	Reflected waves	Application to electromagnetic interfering waves	Outline and characteristics	Evaluation
Beamformer method	Yes	Yes	No	・Estimation of DOA by main beam ・low resolution	Excellent
Signal subspace method	Yes	Yes	No	・Estimation of DOA by vector space of received signals ・high resolution	Excellent
TDOA (Time difference of arrival) based method	Poor	Poor	Yes	・Estimation of source position (single source) and DOA (multiple sources) based on TDOA	Poor
ICA (Independent Component Analysis) based method	Yes	No	No	・Separation of multiple waves by ICA and DOA estimation	Poor

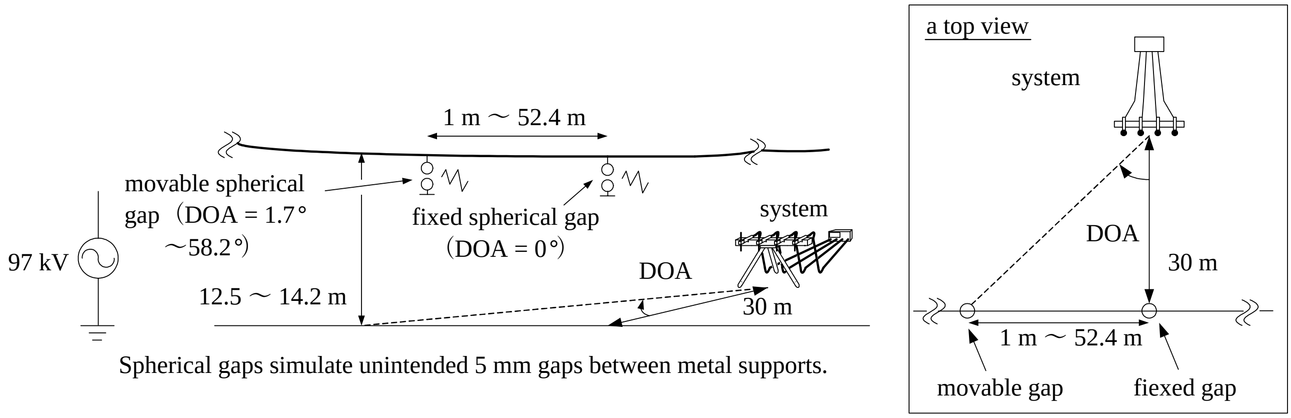

Fig.1 Experimental arrangement used for DOA estimation

The DOA of pulsed electromagnetic interfering waves emitted by the spark discharges occurring at the gaps are estimated using the developed system, when fixed and movable spherical gaps to simulate unintended gaps between metal supports are attached to a test transmission line with a high voltage.

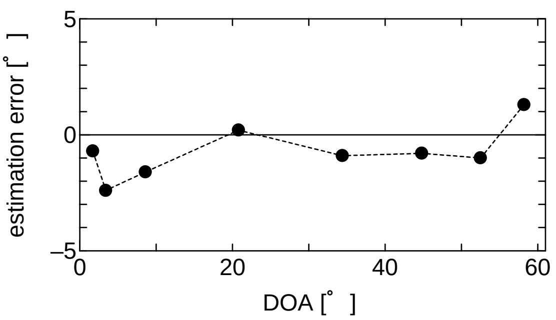

Fig.2 Relationship between DOAs and estimation errors

When the direction of the movable gap is changed from 1.7° to 58.2°, the DOA can be estimated within an error of 2° for each direction.

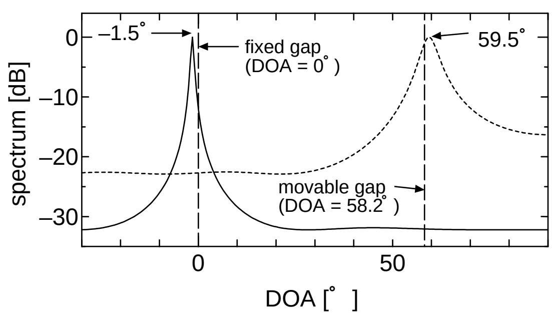

Fig.3 Example of the estimated results

This figure shows the estimated results when the direction of the movable gap is 58.2°. The peaks of the spectrum correspond to the estimated DOAs.