A Source Reconstruction Technique Using Eigenmode Currents

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***Abstract*-Diagnosis of array antennas is one of the biggest challenging problems. Source reconstruction of array antennas is a promising technique for diagnosis of array antennas. However, it is well known that conventional source reconstruction techniques suffer from ill-conditioned nature of problems under study. In this paper, a novel source reconstruction technique based on eigenmode currents of the antenna under study (AUT) is applied to diagnosis of array antennas. It is clarified that the number of eigenmode currents for source reconstruction should be reduced to a moderate value in order to alleviate ill-conditioned nature of the problems under study.**

I. Introduction

Array antennas are widely used for various applications such as wireless communications, direction of arrival, and wireless power transfer [1]-[4]. Performance of these array antennas can be kept only when all of the array elements are working. Therefore, maintenance of array antennas is quite important and defective elements in array antennas must be found in advance of maintenance.

Source reconstruction is one of the promising techniques for finding defective elements. Source reconstruction is so-called inverse problem, i.e. unknown source distribution is estimated from known near-field distribution. It is well known that the inverse problem suffers from ill-conditioned nature of the problem under study because Maxwell's equations only describe relationship between known source distribution and unknown near-field distribution, not vice versa.

Various source reconstruction techniques have been proposed and diagnosis of antennas has been performed [5]-[9]. Recently, a novel source reconstruction technique using eigenmode currents has been proposed [10]. The proposed technique enables to alleviate ill-conditioned nature of the problem under study using limited number of eigenmode currents for source reconstruction while most of the conventional source reconstruction techniques resorts to mathematical approach to alleviate ill-conditioned nature [11]-[13].

In this paper, the source reconstruction technique based on eigenmode currents is applied to diagnosis of array antennas. Numerical simulation is performed and parameters for source reconstruction are optimized. This paper is enhancement of a journal paper [10].

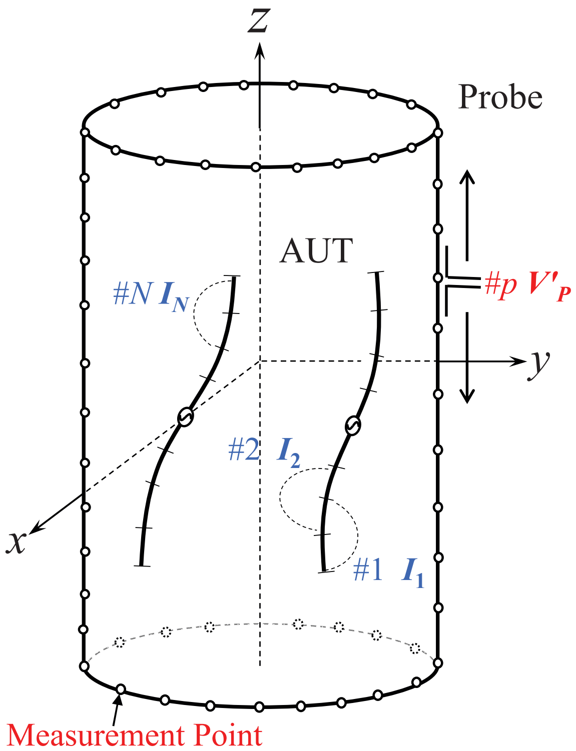

Figure 1. Antenna under test enclosed by a cylindrical scanning surface.

II. Source Reconstruction Based on Eigenmode Currents

A. Eigenmode Current Decomposition

Fig. 1 shows AUT enclosed by a cylindrical scanning surface. It is assumed that geometry and operating frequency of the AUT are known. Then, a $N \times N$ impedance matrix $\mathbf{Z}$ of the AUT is readily available using method of moments (MoM) where N is the number of unknown current segments [14], [15]. After that, eigenmode currents of the AUT can be obtained from $\mathbf{ZZ}^{\ddagger}$. Since $\mathbf{ZZ}^{\ddagger}$ is so-called Hermitian matrix, eigenmode currents obtained from $\mathbf{ZZ}^{\ddagger}$ are orthonormal each other [16]-[19]. Therefore, once eigenmode currents of the AUT are known, unknown current distribution of the AUT can be decomposed into summation of eigenmode currents multiplying by unknown coefficients as follows,

$$\mathbf{I} = \sum_{n=1}^{N} \alpha_n \mathbf{e}_n \tag{1}$$

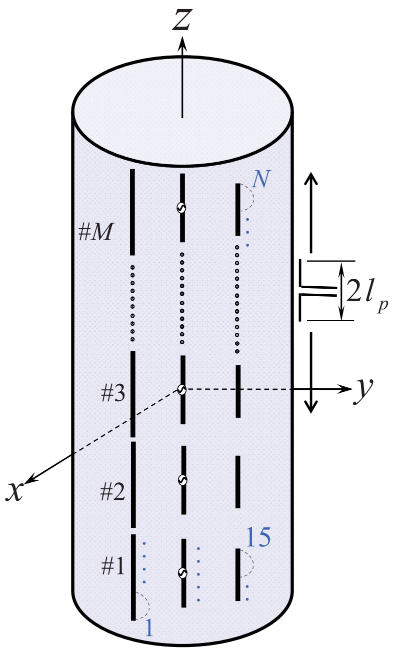

Figure 2. Linear Yagi-Uda array antenna.

where α_n is unknown coefficient for nth eigenmode current to be obtained and $\mathbf{e}_n$ is the nth eigenmode current.

Here, it is known that contribution of eigenmode currents to real currents is inversely proportional to its corresponding eigenvalue. This means that contribution of eigenmode currents corresponding to large eigenvalue on real currents is quite small. Therefore, ill-conditioned nature of source reconstruction can be alleviated without losing accuracy when the number of eigenmode currents for source reconstruction is reduced from N to L.

B. Source Reconstruction

Source reconstruction of the AUT using eigenmode currents is as follows.

1. Eigenmode currents of the AUT obtained numerically using MoM.
2. For Eq. (1), the number of eigenmode currents for source reconstruction is reduced from N to L.
3. A probe is scanned on a cylindrical surface and receiving voltage is measured at P sampling points.
4. Mutual impedance matrix between the AUT and the probe is obtained.
5. Under the assumption that eigenmode currents are source of receiving voltage of the probe, a matrix equation for unknown coefficients α_n is obtained and solved using a singular value decomposition (SVD).
6. By substituting α_n into Eq. (1), source reconstruction is performed and the AUT is diagnosed.

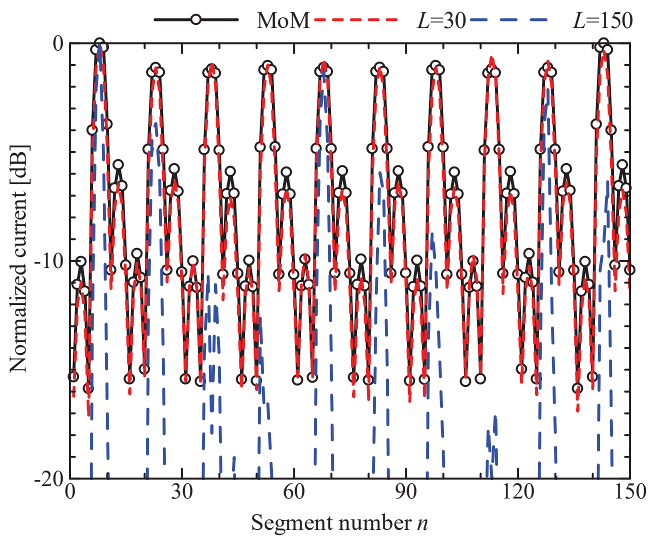

Figure 3. Reconstructed current distribution of Yagi-Uda array antenna.

Interested readers can refer [10] for details.

III. Numerical Results

Performance of source reconstruction technique is demonstrated numerically. Fig. 2 shows a linear Yagi-Uda array antenna. Length of a reflector, radiator, and director is 0.6λ, 0.5λ, and 0.4λ, respectively. Spacing among reflector, radiator, and director is 0.25λ. Number of array elements is 10 and array spacing is 0.65λ. Radius and height of cylindrical scanning surface are 0.3λ and 6.6λ, respectively. Near-field distribution on the cylindrical surface is measured at P=1340 sampling points using a small dipole and its length is 0.1λ.

Fig. 3 shows reconstructed current distribution. It is found that reconstructed current using all eigenmode currents (L=150) suffers from ill-conditioned nature and shows large error. On the other hand, reconstructed current using part of eigenmode currents (L=30) is in good agreement with that of MoM. It can be concluded that the number of eigenmode current should be reduced to moderate number in order to alleviate ill-conditioned nature.

IV. Conclusions

In this paper, performance of a novel source reconstruction technique has been demonstrated numerically. Source reconstruction of Yagi-Uda array antennas has been performed. Reconstructed current is in good agreement with that of MoM only when moderate number of eigenmode currents is used for source reconstruction.

Acknowledgment

We would like to thank staffs in Cyberscience Center, Tohoku University for their helpful advices. This work was financially supported by JSPS KAKENHI Grant Number 18K13736 and 18K04116. I deeply appreciate Mr. Shohei Asano because of his great help on this research.

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