Source Reconstruction Method Using Fourier Transform and Eigenmode Currents

Keisuke Konno[1]*, Kazuto Mochiki[1], and Qiang Chen[1]
[1] Department of Communications Engineering, Graduate School of Engineering,
Tohoku University, 6-6-05 Aramaki-Aza, Aoba-ku, Sendai-shi, Miyagi-ken, Japan
* Corresponding author, email: keisuke.konno.b5@tohoku.ac.jp

***Abstract*—This paper introduces a source reconstruction method using Fourier transform and eigenmode currents. Firstly, an equivalent current distribution over an estimation area is reconstructed via Fourier transform. The equivalent current distribution is expanded using the eigenmode currents of a small dipole array and a dipole element whose contribution to the equivalent current distribution is small is thinned. Finally, the equivalent current distribution is expanded using the eigenmode currents of the remaining dipole elements and is updated. Performance of the source reconstruction method is demonstrated via numerical simulation.**

***Keywords*—Fourier Transform, Eigenmode Current, Source Reconstruction**

I. INTRODUCTION

Source reconstruction methods are valuable tools for detecting unintended radiation sources or faulty antenna elements within electronic devices. One of the most difficult problems in using these methods is the problem of ill-posedness [1]. Various approaches such as linear algebraic approaches have been developed to overcome the problem of ill-posedness [2]- [4].

Recently, our group has demonstrated that eigenmode currents are useful for alleviating the ill-posedness and equivalent sources can be reconstructed successfully [5]- [7]. These eigenmode currents are computed from the impedance matrix of the real sources. Dominant eigenmode currents are only used to reconstruct the equivalent sources and remaining eigenmode currents with small effects on the equivalent sources are ignored in advance of the source reconstruction. As a result, the ill-posed original source reconstrucion problem becomes a well-posed problem because the number of eigenmode currents is reduced. One of the disadvantages of the source reconstruction methods using the eigenmode currents is that the geometry of the real sources must be known in advance of the source reconstruction. Therefore, it is difficult to apply the source reconstruction methods using the eigenmode currents to the source reconstruction of complex sources whose precise geometry is difficult to find.

This paper introduces a new two-step approach for source reconstruction that utilizes Fourier transform and eigenmode currents [8]. Firstly, an initial equivalent current over an estimated plane is reconstructed using Fourier transform. Then, the initial equivalent current distribution is updated using the eigenmode currents of equivalent sources. Unlike the other methods, the precise geometry of the real sources is unnecessary in this approach during the source reconstruction process.

II. SOURCE RECONSTRUCTION METHOD

Here, a source reconstruction method proposed in [8] is briefly reviewed. First, near-field distribution over an measurement surface is obtained and an initial equivalent current distribution over the estimation plane is obtained using following Fourier transform.

$$\boldsymbol{J}(\boldsymbol{r}') = \mathcal{F}^{-1}[\tilde{\overline{\boldsymbol{G}}}(\boldsymbol{k})^{-1} \cdot \tilde{\boldsymbol{E}}(\boldsymbol{k})]. \tag{1}$$

The current $\boldsymbol{J}(\boldsymbol{r}')$ obtained here is the initial equivalent current distribution on the estimation plane. $\boldsymbol{k}$ denotes the wavenumber vector in the spectral domain and ˜ indicates a physical quantity that is transformed from the spatial domain to the spectral domain using Fourier transform. $\tilde{\overline{\boldsymbol{G}}}(\boldsymbol{k})$ is Fourier transform of a dyadic Green's function in free space.

Once the initial equivalent current distribution is obtained, the equivalent current distribution is updated using the eigenmode currents of a small dipole array. The initial equivalent current distribution is decomposed using the eigenmode currents and a small dipole element whose contribution of the measured near-field distribution is large is only kept. Finally, eigenmode currents of the remaining small dipole elements are obtained and the updated equivalent current distribution is obtained as a superposition of the eigenmode currents.

III. NUMERICAL SIMULATION

A dipole array antenna shown in Fig. 1 is an antenna under test (AUT). Here, the number of dipole antennas is 3 and their length is $2l = 0.5\lambda$. Center position of the dipole antennas is $(x, y) = (-0.2\lambda, 0.5\lambda), (0.3\lambda, 0.1\lambda)$, and $(0.6\lambda, 0.05\lambda)$, respectively. All of the dipole antennas are excited uniformly. Near-field of the dipole array antenna is obtained using method of moments (MoM).

Equivalent current distribution of the dipole array antenna is estimated using the source reconstruction method using Fourier transform and the eigenmode currents. The estimated equivalent current distribution is shown in Fig. 2. As shown in Fig. 2, it is found that the equivalent current distribution

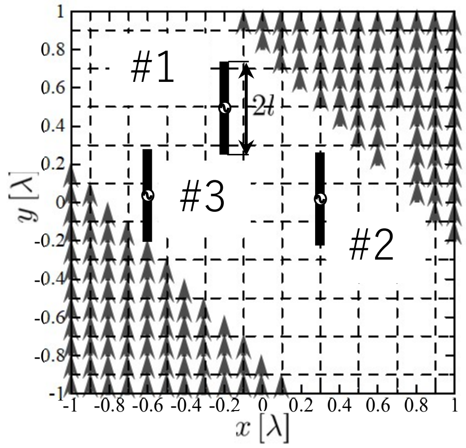

Fig. 1. Dipole array antenna.

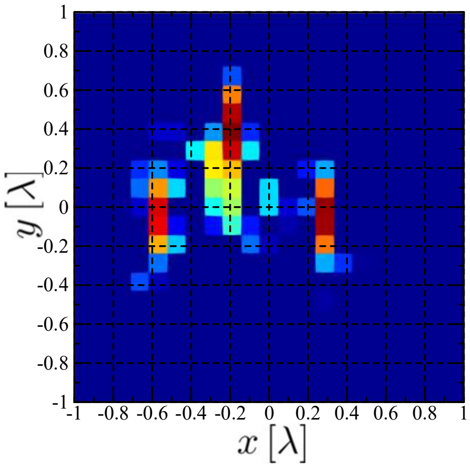

Fig. 2. Equivalent current distribution of the dipole array antenna.

is found around the position where the real dipole sources are. Although the position of the real dipole sources is unknown during the source reconstruction, it is found that the source reconstruction method works and the equivalent current distribution corresponding to the real sources is available.

IV. CONCLUSIONS

In this paper, a source reconstruction method using Fourier transform and eigenmode currents was introduced. Performance of the source reconstruction method has been demonstrated based on numerical simulation.

ACKNOWLEDGMENT

This work was financially supported by JSPS KAKENHI Grant Number 22K04061. Discussions with the members of the Cooperative Research Project Program of the Research Institute of Electrical Communication, Tohoku University, were helpful for this work.

REFERENCES

[1] T. K. Sakar, D. D. Weiner, and V.K. Jain, “Some Mathematical Considerations in Dealing with The Inverse Problem,” IEEE Trans. Antennas Propag., vol. AP-29, no. 2, pp. 373-379, March 1981.

[2] T. Brown, I. Jeffrey, and P. Mojabi, “Multiplicatively Regularized Source Reconstruction Method for Phaseless Planar Near-Field Antenna Measurements,” IEEE Trans. Antennas Propag., vol. 65, no. 4, pp.2020–2031, April 2017.

[3] P. A. Barriere, J.-J. Laurin, and Y. Goussard, “Mapping of Equivalent Currents on High-Speed Digital Printed Circuit Boards Based on Nearfield Measurements,” IEEE Trans. Electromagn. Compat., vol. 51, no. 3, pp. 649–658, Aug. 2009.

[4] J. Colinas, Y. Goussard, and J. J. Laurin, “Application of the Tikhonov Regularization Technique to the Equivalent Magnetic Currents Nearfield Technique,” IEEE Trans. Antennas Propag., vol. 52, no. 11, pp. 3122–3132, Nov. 2004.

[5] K. Konno, S. Asano, T. Umenai, and Q. Chen, “Diagnosis of Array Antennas Using Eigenmode Currents and Near-Field Data,” IEEE Trans. Antennas Propag., vol. 66, no. 11, pp. 5982-5989, Nov. 2018.

[6] K. Konno and Q. Chen, “A Source Reconstruction Technique Using Eigenmode Currents,” Proc. ISAP2019, Oct. 2019.

[7] X. Wang, K. Konno, and Q. Chen, “Diagnosis of Array Antennas Based on Phaseless Near-Field Data Using Artificial Neural Network,” IEEE Trans. Antennas Propag., vol. 69, no. 7, pp. 3840-3848, July 2021.

[8] K. Mochiki, K. Konno, and Q. Chen, “Estimation of Equivalent Current Distribution Using Fourier Transform and Eigenmode Currents,” IEEE Trans. Electromagn. Compat., vol. 64, no. 5, pp. 1380-1390, Oct. 2022.