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The Far Field Transformation Using the Iterative SRM Based On the Phaseless Data

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Abstract— **Conventional equivalent source reconstruction methods (SRM) require both phase and amplitude information of the field data. However, there are situations where the phase information is not easy to obtain. Hence, developing novel SRM based on phaseless data is necessary. In this paper, a novel iterative SRM based on two sets of measured phaseless data is presented. It can reproduce the 3D radiation pattern with very good accuracy. Integral equation (IE) is employed to build reconstruct equivalent source. Combined field IE (CFIE) is also employed to obtain more physical current distribution.**

I.   INTRODUCTION

Source reconstruction method (SRM) is widely used as the near field measurement post processing technique to facilitate near-field far-flied (NF-FF) transformation, hot spot identification and so on. The traditional SRM requires both amplitude and phase information [1]. However, the phase information is not always available or impractical to obtain, especially at millimeter wave frequencies or above where phase measurement is highly sensitive to the environment and instruments. To overcome these deficiencies, SRMs employing phaseless data are developed by researchers to conduct the antenna diagnosis and NF-FF transformation [2-3]. However, the methods in [2-3] do not involve any communication between the two measurement surfaces. The equivalent source is obtained by direct optimization.

In this paper, an novel SRM based on the phaseless data is presented. The equivalent source is expanded using RWG basis functions and mapped to the surface of the radiator. The amplitude measurements can be conducted over two concentric spheres. For each source construction step, we only use the field amplitude over one sphere to build the equivalent source. Then the reconstructed equivalent source is utilized to calculate the phase and amplitude of the field over another measured sphere. Next the phase information is kept but the amplitude is replaced by the measured data. The resultant field data containing both phase and amplitude are utilized to correct the equivalent source again. We call this new source reconstruction process the "iterative SRM". Compared with the techniques in [2-3], the source update in our approach is facilitated by a forward and backward propagation over the two measurement spheres. The field data over only one sphere

is needed during each iteration step.

II.   PRINCIPLES OF SRM OVER ARBITRIARY SURFACE

A. SRM Using both Amplitude and Phase

Given a DUT or an AUT with arbitrary geometries, we assume that it is bounded by a surface S', and an equivalent current source distribution can be built over that surface. The equivalent source may be the electric current $\mathbf{J_s(r')}$ or magnetic current $\mathbf{M_s(r')}$ that reproduces the original radiation outside that surface. Referring to the inverse radiation procedure, the unknown source can be determined by the measured field data over an arbitrary domain, typically spherical surface or planar surface, etc.

The free space dyadic Green's function associates the equivalent current source with the measured field data. The measured electric field has contributions from both $\mathbf{J_s(r')}$ and $\mathbf{M_s(r')}$:

$$\bar{E}(\bar{r}_{Meas}) = \bar{E}_{Js'}(\bar{r}_{Meas}) + \bar{E}_{Ms'}(\bar{r}_{Meas}) \tag{1}$$

where $\bar{E}_{Js'}$ is the field radiated by the equivalent electric current, and $\bar{E}_{Ms'}$ corresponds to the field radiated by the magnetic current. They are formulated as

$$\bar{E}_{Js'}(\bar{r}_{Meas}) = -j\eta_0 k_0 \int_{s'} \left[\bar{J}_s(\bar{r}') + \frac{1}{k_0^2} \nabla \nabla_s' \cdot \bar{J}_{s'}(\bar{r}') \right] \frac{e^{-jkR}}{4\pi R} ds' \tag{2}$$

$$\bar{E}_{Ms'}(\bar{r}_{Meas}) = \int_{s'} \bar{M}_{s'}(\bar{r}') \times \nabla \frac{e^{-jkR}}{4\pi R} ds' \tag{3}$$

where k_0 is the free space wave number, η_0 is the free space intrinsic impedance, and R is the distance between the source point $\mathbf{r'}$ and observation $\mathbf{r}_{obs}$ or measurement position $\mathbf{r}_{Meas}$.

The surface of the DUT is discretized into triangles and the equivalent current $\mathbf{J_s(r')}$ and $\mathbf{M_s(r')}$ are further expanded by RWG basis [4]. Through the point matching, the Eqn. (1) will be discretized into a matrix system shown as below:

$$\begin{bmatrix} \bar{E}_{t1} \\ \bar{E}_{t2} \end{bmatrix} = \begin{bmatrix} \bar{\bar{Z}}(t_1, \bar{J}_{s'}) & \bar{\bar{Z}}(t_1, \bar{M}_{s'}) \\ \bar{\bar{Z}}(t_2, \bar{J}_{s'}) & \bar{\bar{Z}}(t_2, \bar{M}_{s'}) \end{bmatrix} \begin{bmatrix} \bar{P} \\ \bar{Q} \end{bmatrix} \tag{4}$$

$$\bar{P} = [P_1, P_2 \dots, P_N]', \quad \bar{Q} = [Q_1, Q_2 \dots, Q_Q]'$$
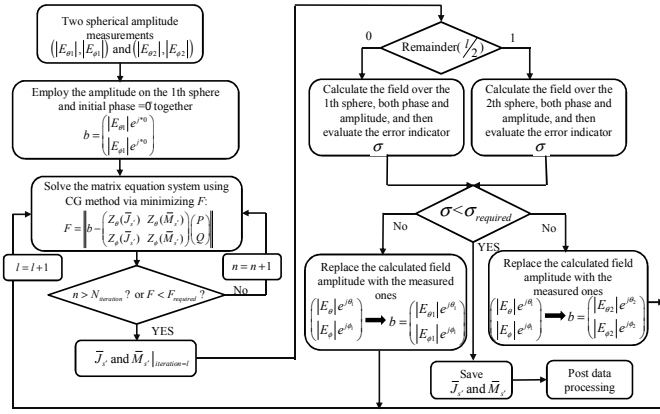
Fig. 1. Flow chart of the iterative SRM using the amplitude-only data

where vectors $\bar{P}$ and $\bar{Q}$ are coefficients of equivalent currents.

Then, the equivalent source can be obtained by solving this matrix system.

B. Iterative SRM Using Phaseless Field Data

The basic principle described above will not work for SRM using the phaseless data. Hence, the following phaseless method developed from the traditional SRM is investigated as below:

The iterative SRM only needs the field amplitude over two well separated domains surrounding the DUT/AUT to be measured. In our method, spherical surface is adopted as the measurement domain. At the first iteration, only the field amplitude over one sphere with an initial phase is employed to facilitate the source reconstruction. Then, the reconstructed source is applied to calculate the field over another sphere. The amplitude of the calculated field will be replaced by the measured one while the phase information is kept. Then the next iteration begins. The iteration will keep going until the stop criteria is achieved. The detailed iteration scheme is presented in Fig.1.

III. NUMERICAL RESULTS.

To verify the accuracy and validity of the proposed iterative SRM, a horn antenna [5] operating at 1.645 GHz is numerically investigated. The amplitudes of the field data are obtained over two concentric spheres with radii equal to 2m and 3m, respectively. In our measurement setup, the separation distance d≈5λ is picked up to guarantee the phase change.

The equivalent current surface is chosen to fit the physical surface of the horn antenna. The reconstructed current is shown in Fig.2 (a). The far field pattern is shown in Fig. 3, where very good agreement is achieved.

The reconstructed equivalent current is quite different from the physical current distribution since it is polluted by the null space of EFIE operator. An effective method to remove this null space is to employ both EFIE and MFIE. Hence, the iterative SRM algorithm is formulated using CFIE. The reconstructed current employing CFIE is shown in Fig. 2(b). A
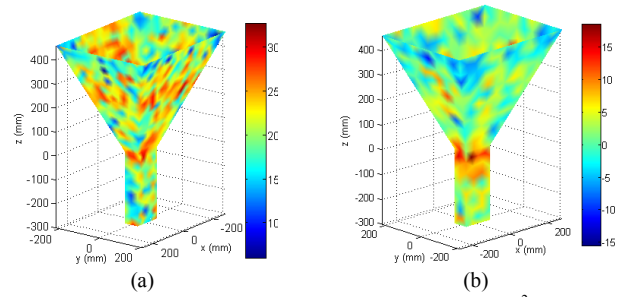

Fig. 2. Reconstructed electric current density (dB A/m^2) distribution. (a) Iterative SRM using EFIE. (b) Iterative SRM using CFIE.
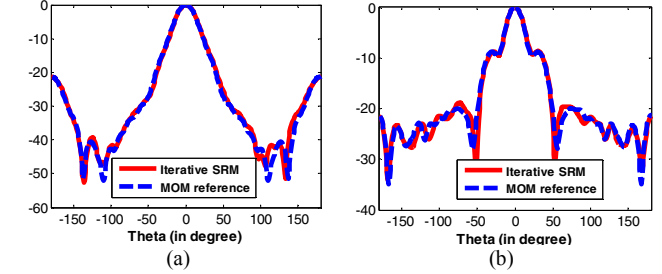

Fig. 3. Reconstructed far field pattern using field data with amplitude-only information. (a) E-pattern in XOZ plane. (b) H-pattern in XOZ plane.

significant improvement of the current distribution illustrates the effectiveness of the method. More results will be presented during the conference.

III. CONCLUSION

A novel iteration SRM in a forward-backward fashion based on phaseless measurements is presented. The equivalent sources that can fit arbitrary surfaces are reconstructed using the amplitude-only information of the field. Numerical study shows the accuracy and effectiveness of our method.

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