A Source Reconstruction Technique for Planar Arrays of Wide Slots

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***Abstract*—A method to reconstruct the excitation coefficients of wide-slot arrays from near-field data is presented. The plane wave spectrum (PWS) is used for reconstruction, and the shape of the field distribution on a wide slot is considered in the calculation of the PWS. The proposed algorithm is validated through the reconstruction of the excitation coefficients of a wide-slot array with element failures from the simulated near-field data. The element failures are clearly located by the proposed algorithm.**

***Index Terms*—source reconstruction, near-field antenna measurement, plane wave spectrum, slot array antennas.**

I. Introduction

In the diagnostics of array antennas, the field distribution on the radiating elements or the excitation coefficients can be used to detect element failures and excitation anomalies. There are several methods to recover the field on elements from the measured near- or far-field data. The integral equation method [1] enables accurate reconstruction of the field on the elements, but heavy computation is required for electrically large antennas. The aperture field distribution can be obtained from measured near field on a scanning surface by back-propagation technique [2]. This method is computationally efficient because the FFT can be applied. However, the radiating elements have to be located on equally spaced FFT grids to obtain the excitation coefficients. The excitation coefficients can be calculated directly by applying the DFT to far-field pattern [3], however, the element pattern is not considered and the excitation coefficients cannot be reconstructed when the element spacing is less than half a wavelength. The excitation coefficients can also be calculated directly by the matrix method [4]. The element pattern is included in the matrix formulation.

We have proposed a source reconstruction technique for slot array antennas [5]. The spatial resolution of the reconstructed excitation coefficients is enhanced by applying the Gerchberg-Papoulis algorithm to the plane wave spectrum (PWS). In [5], the slots are considered as isotropic point sources. In this paper, the element pattern of a wide slot is incorporated by considering the shape of the field distribution on the slot in the calculation of the PWS. The proposed algorithm is validated through the source reconstruction of a wide-slot array with element failures.

II. Calculation of the Excitation Coefficients

The plane wave spectrum (PWS) is the Fourier transform of the electric field. In our previous work [5], slots are considered as isotropic point sources and the PWS is calculated directly from the excitation coefficients via the nonuniform DFT (NDFT). The x component of the PWS P_x is given by

$$P_x\left(k_{xm},k_{ym}\right)=\sum_{n=1}^{N}E_x\left(x_n,y_n\right)e^{-j\left(k_{xm}x_n+k_{ym}y_n\right)} \tag{1}$$

where $E_x(x_n,y_n)$ is the x component of the excitation coefficient of the n-th slot, and N is the number of the slots. The y component of the PWS is calculated in the same manner. The coordinates for the slots and the PWS are shown in Fig. 1.

When the slot width is large, the slots can be regarded as surface sources. The field on the wide slot varies in both the longitudinal and transverse directions [6]. By including the shape of the field distribution on the wide slots, the PWS can be rewritten as

$$\begin{aligned}&P_x\left(k_{xm},k_{ym}\right)\\&=\sum_{n=1}^{N}\int_{-l_n/2}^{l_n/2}\int_{-w_n/2}^{-w_n/2}E_x(x_n,y_n)\frac{\sin\left[\left(\zeta_n+l_n/2\right)\pi/l_n\right]}{\sqrt{1-\left(2\xi_n/w_n\right)^2}}e^{-j\left(k_{xm}x+k_{ym}y\right)}d\zeta_n d\xi_n\\&=\sum_{n=1}^{N}E_x(x_n,y_n)e^{-j\left(k_{xm}x_n+k_{ym}y_n\right)}\frac{2\pi l_n\cos\left[\left(k_{xm}\cos\varphi_n+k_{ym}\sin\varphi_n\right)l_n/2\right]}{\pi^2-l_n^2\left(k_{xm}\cos\varphi_n+k_{ym}\sin\varphi_n\right)^2}\\&\quad\cdot\frac{\pi w_n}{2}I_0\left(j\frac{w_n}{2}\left(k_{xm}\sin\varphi_n-k_{ym}\cos\varphi_n\right)\right)\end{aligned} \tag{2}$$

where I_0 is the modified Bessel function of the first kind.

The PWS calculation can be expressed in a matrix form as $\vec{p}_x=W\vec{e}_x$, where

$$\vec{p}_x=\left[P_x\left(k_{x1},k_{y1}\right),\ \ldots,P_x\left(k_{xM},k_{yM}\right)\right]^T \tag{3}$$

$$\vec{e}_x=\left[E_x\left(x_1,y_1\right),\ \ldots,E_x\left(x_N,y_N\right)\right]^T \tag{4}$$

The M is the number of the PWSs. An element W_{mn} of the matrix W is given by

$$W_{mn}=\begin{cases}e^{-j\left(k_{xm}x_n+k_{ym}y_n\right)} & (5)\\ e^{-j\left(k_{xm}x_n+k_{ym}y_n\right)}\dfrac{2\pi l_n\cos\left[\left(k_{xm}\cos\varphi_n+k_{ym}\sin\varphi_n\right)l_n/2\right]}{\pi^2-l_n^2\left(k_{xm}\cos\varphi_n+k_{ym}\sin\varphi_n\right)^2}\cdot\dfrac{\pi w_n}{2}I_0\left(j\dfrac{w_n}{2}\left(k_{xm}\sin\varphi_n-k_{ym}\cos\varphi_n\right)\right) & (6)\end{cases}$$

Equations (5) and (6) are for point and surface sources, respectively. The excitation coefficients are given by $\vec{e}_x = W^{\dagger}\vec{p}_x$, where $W^{\dagger}$ is the pseudoinverse matrix of W.

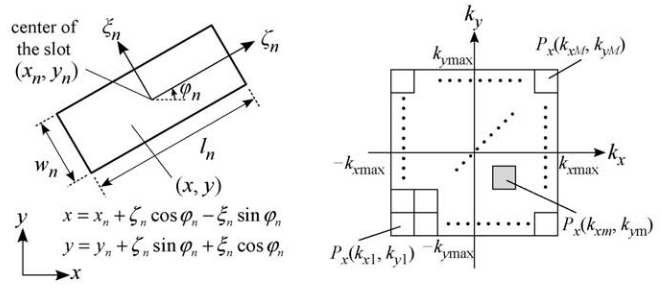
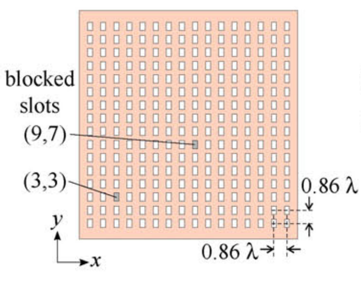


Fig. 1. Coordinates for a wide slot and PWS

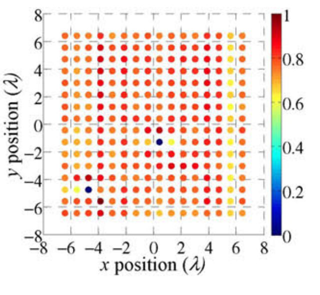
III. Source Reconstructin of Wide-Slot Array with Element Failures

A 16×16-element slot array [7] shown in Fig. 2(a) was simulated in Ansys HFSS. The ratio of the slot width to the length is 0.53, and the spacing of the slots is 0.86 λ in both x and y directions. The slots indexed as (3,3) and (9,7) are blocked with PEC as element failures, and the near field on a scanning plane was calculated. The setup of the scanning plane is listed in Table I. The scanning area was chosen to cover most of the radiated fields from the AUT. Figure 2(b) shows the relative amplitude of the simulated electric field at the center positions of the slots, which will be used as the reference excitation coefficients.

The proposed algorithm was applied to the simulated near-field data on the scanning plane. Calculations of the excitation coefficients using (5) and (6) (point and surface sources) are compared. The amplitudes of the reconstructed excitation coefficients on (3,3) and (9,7) slots are shown in Table II. The element failures are clearly identified in both cases. The errors of the reconstructed excitation coefficients for (5) and (6) compared to the reference coefficients in Fig. 2(b) are −30.1 dB and −39.2 dB, respectively. The excitation coefficients are recovered more accurately when the slots are considered as surface sources.



(a) Array configuration.



(b) Relative amplitude of the field at the center of the slots (HFSS).

Fig. 2. A 16×16-element array of wide slots with element failures.

TABLE I. Setup of the Scanning Plane

Scanning area	194 λ × 194 λ
Sampling interval	0.45 λ
Distance from the AUT	6.3 λ

TABLE II. Relative Amplitude of the Excitation Coefficients of the Blocked Slots

Blocked slot	Reconstructed (point source)	Reconstructed (surface source)	Reference (HFSS)
(3, 3)	0.108	0.0209	0
(9, 7)	0.0993	0.0193	0

IV. Conclusion

In this paper, the authors extended the source reconstruction technique [5] for wide-slot arrays. The element pattern of a wide slot is incorporated in the calculation of the PWS by considering the shape of the field distribution on the slot. The proposed algorithm was applied to the simulated near-field data of the wide-slot array with element failures. The excitation coefficients are reconstructed more accurately when the shape of the field distribution on the wide slots is considered. The proposed algorithm will be applied to the measured near-field data.

Acknowledgements

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