LINEAR ARRAY DIAGNOSTIC FROM NEAR-FIELD MEASUREMENTS

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Introduction

As the performances required to antennas increase, it is necessary to have means of evaluating the antenna characteristics besides the radiation pattern, providing in this way means of diagnostic and adjustment [1]. In this communication we present an inversion procedure to obtain the current distribution on a linear array from a near-field measurement. Since linear array may be building elements of larger planar arrays, this method allows to check and adjust the intermediate steps of large radiating systems.

Inversion Procedure

Let us consider a geometry as shown in figure 1, where we assume a current distribution directed towards the z direction as

$$\vec{J}(\vec{r}') = I(z')\delta(x')\delta(y')\hat{z} \quad (1)$$

The equation relating the current and the electric field is

$$\nabla^2 \vec{E} + k^2 \vec{E} = j\omega\mu\vec{J} + \frac{j}{\omega\epsilon}\nabla(\nabla \cdot \vec{J}) \quad (2)$$

For the z directed current, and the parallel field, the equation is

$$\nabla_t^2 E_z + \left(k^2 + \frac{\partial^2}{\partial z^2}\right)E_z = j\omega\mu J_z + \frac{j}{\omega\epsilon} \frac{\partial^2 J_z}{\partial z^2} \quad (3)$$

The Fourier transform of (3) is

$$\nabla_t^2 \tilde{E}_z + (k^2 - k_z^2)\tilde{E}_z = \frac{j}{\omega\epsilon}(k^2 - k_z^2)\tilde{J}_z \quad (4)$$

We defined the Fourier transforms of the currents and electric field as

$$\tilde{E}_z(k_z) = \frac{1}{2\pi} \int_{-\infty}^{\infty} E_z(z) e^{jk_z z} dz \quad (5)$$

$$\tilde{I}(k_z) = \frac{1}{2\pi} \int_{-\infty}^{\infty} I(z) e^{jk_z z} dz \quad (6)$$

The solution of the 2-D inhomogeneous wave equation (4) is

$$\tilde{E}(k_z) = -\frac{k^2 - k_z^2}{4\omega\epsilon} \tilde{I}(k_z) H_0^{(2)}((k^2 - k_z^2)\rho) \quad (7)$$

The inversion procedure from fields to currents is

$$\tilde{I}(k_z) = -\frac{k}{4\eta(k^2 - k_z^2)} \frac{1}{H_0^{(2)}((k^2 - k_z^2)\rho)} \tilde{E}(k_z) \quad (8)$$

From equation (6) $\tilde{I}(k_z)$ is the Fourier transform of the current distribution. If we have a current distribution, as the one produced by a linear array, it will be a periodic function with period $2\pi/d$ where d is the spacing between elements. On the other hand due to the filtering produced by propagation $\tilde{I}(k_z)$ evaluated from equation (8) will be limited to a domain $-k \leq k_z \leq k$ where k is the wave number. Then, if $d \leq \lambda/2$ we obtain a low-pass version of $\tilde{I}(k_z)$, otherwise if $d > \lambda/2$ only the information contained between $-\pi/d \leq k_z \leq \pi/d$ will be relevant.

The inversion procedure is based on Fourier Transforms, thus using FFT algorithms, the method can be efficiently implemented.

Results

Numerical simulations have been made considering a 50 element linear array. Single elements are half-wave length dipoles spaced 0.75λ . The measuring distance is 5λ and the frequency 10 GHz. The current distribution is a Taylor (one parameter) of 35 dB, with an gaussian distributed error of $\sigma = 1$ dB and an uniformly distributed error of ± 10 degrees in phase. Three cases have been considered: no-filtering of the spectrum, filtering with a Hamming window, and lowpass filtering with a cutoff frequency $k_z = \pi/d$.

In figure 2 the impulsional response for the three cases is shown. The best response is given by the Hamming window and the low-pass filter. In figures 3 and 4 the reconstructed module and phase for these two cases is compared with the current distribution. In table I, the rms error in the reconstruction is presented.

Conclusions

From a near-field measurement it is possible to reconstruct the current distribution of a linear array with an error smaller than 0.2 dB in amplitude and 2.5 degrees in phase when filtering is performed according to element spacing. Our future work will be concerned with current distribution of planar arrays from cylindrical near-field measurements.

References

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rms error	module (dB)	phase (deg)
Hamming window	0.49	2.89
Low-pass filtering	0.17	2.26

Table I, rms error in the reconstruction of the currents

Figure 1. Measurement geometry

Figure 2. Impulsional Response

Figure 3. Current Reconstruction (Module)

Figure 4. Current Reconstruction (Phase)