PLANAR ARRAY DIAGNOSTIC FROM CYLINDRICAL NEAR-FIELD MEASUREMENTS

J. Romeu*, S. Blanch, L. Jofre
E.T.S.I. Telecomunicación
Apdo. 30.002, 08080 Barcelona (Spain)

Introduction

Cylindrical near field measurements are often the only feasible alternative to measure the characteristics of large planar arrays. As the number of single elements that build the array increases, it is necessary to have means of diagnostic and adjustment. In this communication we present an inversion procedure to obtain the current distribution on a tilted planar array from a cylindrical near field measurement. Possible advantages of this method in front of planar scanning [1] are a reduction of the truncation errors due to a near field measurement on a more encircling surface.

Inversion Procedure

Let us consider a geometry, as shown in figure 1, where we assume an electrical current distribution placed on a primed coordinate system that is tilted an angle α respect to the z axis.

The use of the Planar Wave Spectrum (PWS) is particularly well suited to perform the current reconstruction on a planar surface. The PWS can be obtained in the following way:

If $V_h(z,\phi)$ and $V_v(z,\phi)$ are the voltages measured by a dual polarized probe scanning the field produced by the antenna under test on a cylinder of radius Ro enclosing the AUT. The far field produced by the AUT is found using the near to far field algorithms [2]. The far field is related to the PWS through the expression

$$\vec{E}(k_y, k_x) = j\frac{1}{2\pi}k_x\vec{A}_E(k_y, k_z) \tag{1}$$

$$k_x = k_0\sin(\theta)\cos(\phi)$$

$$k_y = k_0\sin(\theta)\sin(\phi)$$

$$k_z = k_0\cos(\theta)$$

For our reconstruction purposes we wish to have the PWS expressed in terms of the tilted coordinate system. A plane wave propagating in the k_x, k_y direction, propagates in the prime coordinate system in the direction

$$k_y' = k_y \tag{2}$$

$$k_z' = k_z\cos(\alpha) + \sqrt{(k_0^2 - k_y^2 - k_z^2)}\sin(\alpha)$$

90CH2776-3/0000-1318 $1.00 ©1990 IEEE

After an interpolation process the PWS in the prime coordinate system is obtained. The PWS is directly related to the current distribution in the y'z' plane. Assuming no magnetic currents the inversion procedure is :

$$\vec{J}(y',z') = \frac{1}{(2\pi)^2}\int\int_{-\infty}^{\infty}\frac{1}{\eta}\tilde{X}^{-1}\vec{A}_E(k_y',k_z')e^{-jk_z'z'}e^{-jk_y'y'}dk_y'dk_z' \tag{3}$$

where $\tilde{X}^{-1}$ is the tensor

$$\tilde{X}^{-1} = -2\frac{k_0}{k_x'}\begin{bmatrix} 1-\frac{k_z'^2}{k_0^2} & \frac{k_y'k_z'}{k_0^2} \\ \frac{k_y'k_z'}{k_0^2} & 1-\frac{k_y'^2}{k_0^2} \end{bmatrix} \tag{4}$$

The reconstruction process can be strongly simplified when the AUT is a planar array. Let us consider an array of NxM equal elements, in this case the radiated field is

$$\vec{E}(k_y',k_z') = \vec{T}(k_y',k_z')\sum_{m=0}^{M}\sum_{n=0}^{N}B(m,n)e^{-jk_y'\Delta y'm}e^{-jk_z'\Delta z'n} \tag{5}$$

where $\vec{T}(k_y',k_z')$ is the radiation pattern of a single element of the array and B(m,n) is the complex value of the excitation of the element (m,n), $\Delta y'$ and $\Delta z'$ are the spacing between elements. The far field in the ky'kz' space is obtained using transformation (2). By dividing the far field by the radiation pattern of the single element we have

$$\tilde{B}(k_y',k_z') = \sum^{M}\sum^{N}B(m,n)e^{-jk_y'\Delta y'm}e^{-jk_z'\Delta z'n} \tag{6}$$

That is, the discrete Fourier transform of the excitation function. This is a periodic function in the ky'kz' space with a period $2\pi/\Delta y'$ and $2\pi/\Delta z'$. On the other hand it is well known that propagation acts as a filter, so our knowledge of the function $\tilde{B}(k_y',k_z')$ will be limited to the dominion

$$k_y'^2 + k_z'^2 < k_0^2 \tag{7}$$

where Ko is the wave number.

These two last facts imply that for element spacing smaller than $\lambda/\sqrt{2}$ we won't be able to reconstruct a full period of $\tilde{B}(k_y',k_z')$, being our recontruction a low pass version of the actual one. When the spacing is greater than $\lambda/\sqrt{2}$ we have more than one period of the funcion, thus we have all the necessary information to perform the inversion of expression (6). The process can be efficiently implemented by the use of the FFT algorithm. As pointed out in [3] the implementation has to be made carefully, since the use of the FFT may force a periodicty different from the real one.

Results

Numerical simulations have been made considering an array of 40 by 40 small horizontal dipoles. Spacing between elements is $\Delta y' = 0.778\,\lambda$ and $\Delta z' = 0.875\,\lambda$. Tilt angle is 10 degrees. The radius of the measurement cylinder is 45 λ and its length is 70 λ. Current distributions are Taylor (one parameter) of -25 dB in y' and -40 dB in z'.

In figures 2 and 3 we show the difference between the theoretical current distribution and the reconstructed one in module and phase, for the central row and column. The error is below 0.5 dB and 2.5 degrees.The error is greater in the column due to the finite length of the measurement cylinder. The error is almost neglectable in the rows.

Conclusions

From a cylindrical near-field measurement it is possible to reconstruct the excitation of the elements of a tilted array. The process is based on the obtaintion of the PWS on a tilted coordinate system from the cylindrical near-field measurement.

The inversion procedure can be simplified in the case of planar arrays, providing that spacing between elements and radiation pattern of a single element is known.

Future work will be directed toward the experimental verification of the reconstruction and the consideration of the effects of measurement errors.

References

[1] J.J.Lee et alt., "Near-Field Probe Used as a Diagnostic Tool to Locate Defective Elements in an Array Antenna," IEEE Trans. Antennas Propagat., vol-36, June 1988.

[2] G.V. Borgiotti, "Integral Equation Formulation for Probe Corrected Far-Field Reconstruction from Measurements on a Cylinder," IEEE Trans. Antennas Propagat., vol-26, July 1978.

[3] J. Romeu, L. Jofre, M. Ferrando, M. Baquero, J. Clavera, "Linear Array Diagnostic from Near-Field Measurements," IEEE AP's International Symposium, San Jose , Cal., June 1989.

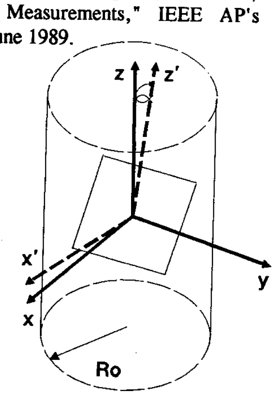

Figure 1. Measurement Geometry.

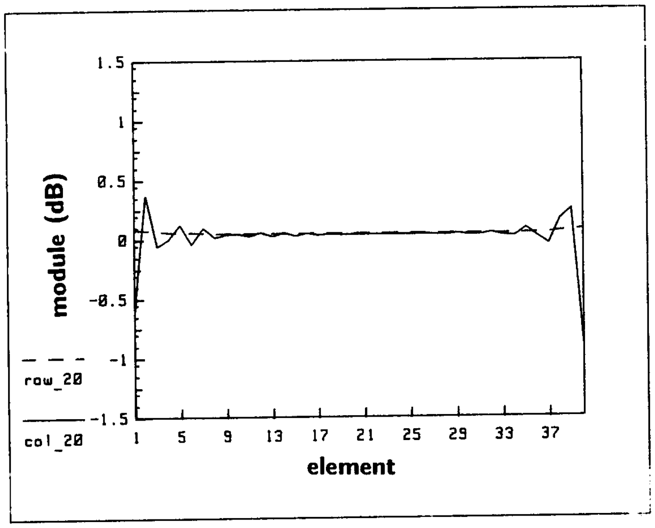

Figure 2. Difference between theoretical and reconstructed module.

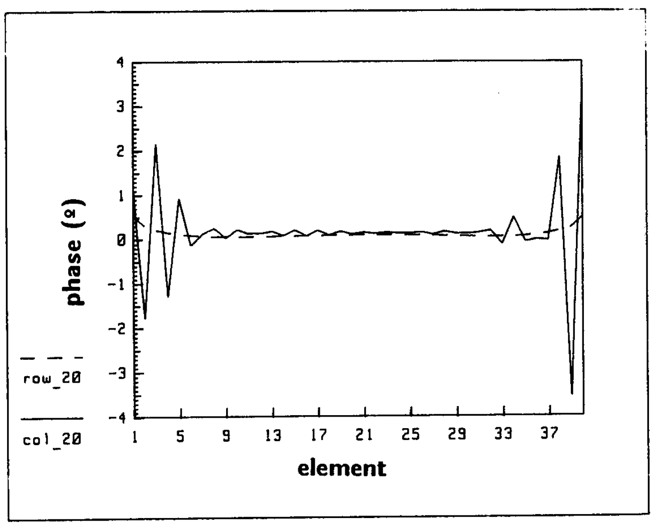

Figure 3. Difference between theoretical and reconstructed phase.