NEAR-FIELD TO FAR-FIELD TRANSFORMATION OF BI-POLAR MEASUREMENTS BY EQUIVALENT MAGNETIC CURRENT APPROACH

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Introduction

An equivalent magnetic current (EMC) approach [1] has recently been proposed as an alternative method to the classical modal formulation for computing the far-field pattern of a radiating antenna from planar near-field measurements. The attractiveness of this EMC approach includes the possibility of producing the correct far-field pattern in *all* regions in front of a planar antenna under test (AUT), a drawback of the classical modal formulation due to its dependence on the Fourier transform and assumptions which must be made about the field outside of the measurement zone, and its adaptability to both irregularly sampled and non-canonical near-field measurement surfaces. A drawback of the EMC approach, however, is its significantly larger computational requirements.

In this paper, a comparison of the EMC and classical modal approaches for near-field to far-field transformation is examined in terms of the resultant far-field patterns. Measurement results for a waveguide-fed slot array using the UCLA bi-polar planar near-field measurement scanner [2] are presented. An implementation of the EMC approach for the bi-polar geometry is described and results obtained using different subsets of the measured bi-polar near-field data are presented and compared to that obtained using the classical modal approach. A comparison between these approaches in terms of the quality of the synthesized plane wave [3] has also recently been reported.

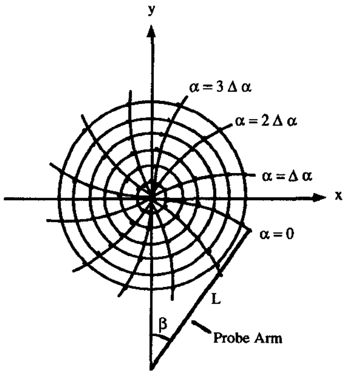

Figure 1. Bi-Polar Near-Field Sample Geometry

Equivalent Magnetic Current Approach for Bi-Polar Measurements

The bi-polar planar near-field antenna measurement technique is a highly accurate and cost-effective means for performing antenna measurements and diagnostics. The UCLA bi-polar planar near-field scanner consists of an antenna under test

(AUT) mounted to a rotary positioner which rotates about one axis and a probe antenna mounted to a probe arm which rotates about a second axis. The bi-polar technique results in near-field data collected on concentric rings with data samples located at the intersection with radial arcs (Figure 1). The classical modal approach for the near-field to far-field transform employs an optimal sampling interpolation (OSI) algorithm [4] so that an efficient fast Fourier transform (FFT) may be performed on the interpolated samples.

The equivalent magnetic current (EMC) approach is based on a model in which the AUT is represented by an array of equivalent magnetic dipoles. The excitation coefficients of the dipoles are chosen so that the equivalent array radiates a field that matches the measured near-field at some prescribed set of points. The far-field is trivially determined once the excitation coefficients for the dipoles are computed.

The excitation coefficients of the equivalent magnetic dipole array can be obtained by solving the linear system

$$\overline{\overline{C}}\,\overline{M}_{xy} = \overline{E}_{xy} \qquad (1)$$

where $\overline{M}_{xy}$ are the unknown coefficients, $\overline{E}_{xy}$ are the measured tangential components of the near-field on a plane a distance z_o in front of the AUT, and $\overline{\overline{C}}$ is the radiated field of each equivalent magnetic dipole given by

$$C_{mn} = \frac{e^{-jkR_{mn}} z_o}{4\pi R_{mn}^2}\left(jk + \frac{1}{R_{mn}} \right) \qquad (2)$$

R_{mn} is the distance from the n^th^ equivalent magnetic dipole to the m^th^ near-field sample. The computation of (2) can be simplified by conveniently defining the geometry of the equivalent array. In the case of the bi-polar measurements, the dipoles in the equivalent array are placed on a polar grid. The elements of matrix $\overline{\overline{C}}$ then only have to be computed for one radius of the array as the rest are obtained by rotation. The inversion of (1) is performed using the conjugate gradient (CG) - FFT algorithm.

Results

The algorithm for the equivalent magnetic current (EMC) approach described in the previous section has been applied to the bi-polar planar near-field measurement reported in [2] for the antenna of [2, Figure 5b]. The antenna under test (AUT) is an X-band (9.375 GHz) waveguide-fed planar slot array with a near-circular aperture measuring 23.0λ (H-plane) by 21.4λ (E-plane). The near-field scan plane had a radius of 23.65λ (55 rings, 165 samples per ring) located at a distance z_o=6.75λ yielding a valid angle, or the angle to which the far-field is expected to be accurate for the classical modal approach, of approximately 60 degrees (sin(θ)=0.87).

In order to apply the EMC approach, an equivalent array of magnetic dipoles arranged on a polar grid with 30 rings has been chosen. The radial spacing of the rings was 0.4λ with 165 dipole elements placed on each ring. The total number of equivalent magnetic dipoles is $30\times165+1=4951$.

Figure 2 shows a comparison of the EMC and classical modal processing results for the E-plane and H-plane far-field patterns of the AUT. In this case, the EMC approach utilized the entire bi-polar near-field dataset to determine the equivalent array excitation coefficients and required 150 iterations (at 2 minutes per iteration on a Pentium 100). The classical modal processing was performed using a 10×10 point OSI/FFT algorithm. The agreement between these techniques is excellent, particularly within the 60 degree valid angle.

The EMC approach, as mentioned earlier, has as a major drawback in the larger computation time required to perform the near-field to far-field transformation. Nevertheless, there do exist circumstances where the classical algorithm cannot be easily applied. Figure 3 illustrates the EMC results obtained by utilizing a decimated subset of the original bi-polar measurement. In this case, 20 *outer* rings, specifically rings 16, 18, 20,...52, 54, have been eliminated for the EMC processing. This reduction in the near-field data could be associated with a reduction in the required measurement time. The results for the E-plane and H-plane far-field patterns are compared to the same OSI/FFT results of Figure 2. The results are in good agreement with that obtained when the entire bi-polar measurement is retained.

Figure 4 shows the EMC results obtained from another decimated subset of the original bi-polar measurement. In this case, 20 *inner* rings, specifically rings 1, 3, 5,...37, 39, have been eliminated prior to the EMC processing. The outer (lower) sidelobes in the H-plane have been affected in this case while the E-plane results remain, for the most part, unchanged.

Conclusions

This paper has examined the application of the equivalent magnetic current (EMC) approach for performing near-field to far-field transformation in the bi-polar planar near-field modality. Results were, in general, found to be comparable with those obtained from the classical modal approach when the same near-field data was used. It has been determined that the spatial distribution of the retained near-field samples is an important factor affecting the accuracy of the resultant far-field patterns.

While the EMC approach has a major drawback in the larger required processing time compared to the classical modal approach, the possibility of a "less-severe" valid angle limitation and its greater potential for irregular measurement surfaces is promising. Continuing research is focused on examining the requirements for the number of equivalent magnetic dipoles, their spatial distribution, and the effect of the measuring probe. In addition, similar requirements for the near-field samples are also being investigated.

References

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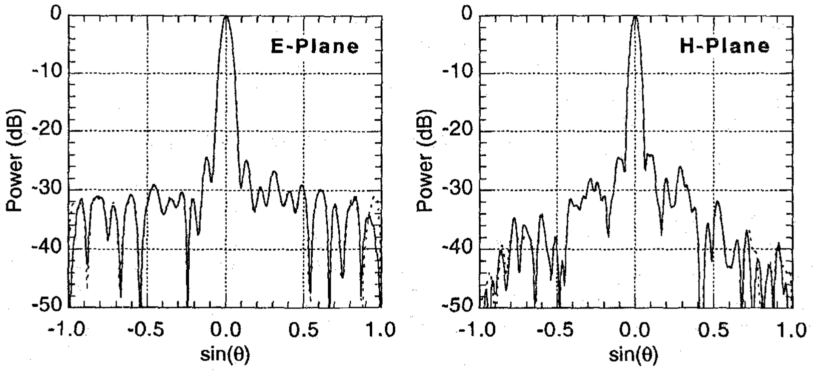

Figure 2. E- and H- plane patterns for EMC (dotted line) and classical processing (solid line). Entire bi-polar dataset is retained in the EMC processing.

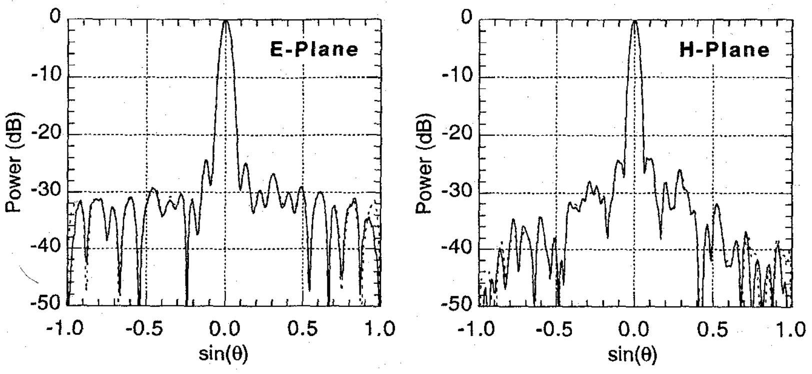

Figure 3. E- and H- plane patterns for EMC (dotted line) and classical processing (solid line). Outer rings of bi-polar dataset are decimated in the EMC processing.

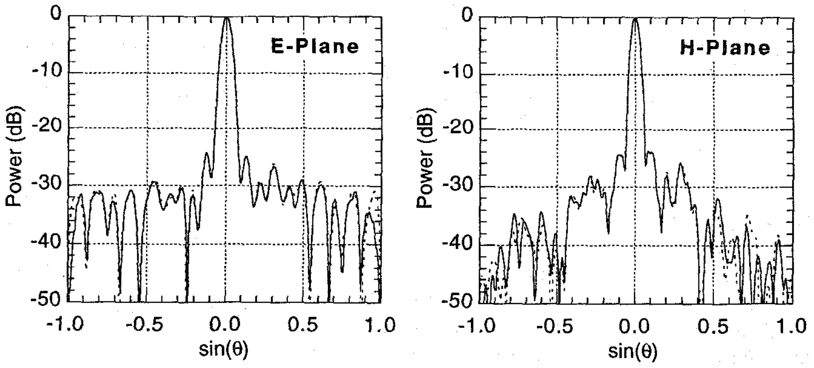

Figure 4. E- and H- plane patterns for EMC (dotted line) and classical processing (solid line). Inner rings of bi-polar dataset are decimated in the EMC processing.