A CONCURRENT PERIODIC/NON-PERIODIC TECHNIQUE FOR LARGE PHASED ARRAYS

K. Y. Sze*, K. F. Sabet and D. Chun
EMAG Technologies, Inc., 1340 Eisenhower Place, Ann Arbor, MI 48108, USA
*Email: kinsze@emagtechnologies.com

1. INTRODUCTION

For large phased arrays, periodic simulators are often utilized, whereby the array is assumed to be of infinite extent. Such simulators cannot predict the array edge effect. Several approaches, mostly asymptotic-based techniques, are presently available in the literature for this [1]-[4], which account for the array edge effect in their analyses. Nevertheless, these techniques are generally very complex and are currently applicable only to simple geometries.

In this paper, a brief overview of a proposed simple concurrent periodic/non-periodic analysis scheme, the **Decompose-Solve-Recompose** **(**DSR**)** technique, is presented for the modeling of planar large phased array (LPA) systems. The resulting 2D spatial DSR technique, known as the Hybrid Edge-Periodic DSR technique, requires the decomposition of a large planar array into an outer edge "ring" array and a central periodic array block. Since computational cost is a very important criterion in the analysis and design of an LPA, a cost function analysis example is presented, as initially studied in [5]. These studies are part of an effort to understand the characteristics of the Hybrid Edge-Periodic DSR technique for analyzing more general uniform and non-uniform LPA systems.

2. HYBRID EDGE-PERIODIC DSR TECHNIQUE

A 2D spatial DSR analysis, using the Hybrid Edge-Periodic DSR technique, is employed for the modeling a planar array of dipoles depicted schematically in Fig. 1. This DSR technique is new, and involves the decomposition of an LPA into an outer edge "ring" array and a central periodic array block, as shown in the figure. Each of these decomposed arrays are solved independently using the full-wave Method of Moments (MoM), or any other full-wave analysis methods. Subsequently, these results are recomposed back as a solution to the original problem. Mathematically, this can be viewed as a type of matrix decomposition technique.

Additional improvements of the Hybrid Edge-Periodic DSR technique may be achieved through the use of region "overlapping" between the edge rings and the periodic array block, as similarly implemented in PNM algorithms of [6][7]. An optimal choice of edge element ring width can also yield improved accuracy. The mechanism of region "overlapping" requires that inner edge rings be discarded and outer rings retained during the recomposition of solution. Periodic elements are then substituted in their place so that the final solution will still represent the correct number of array elements and their spatial positions in Euclidean space, as illustrated in Fig. 1. That is,

$$\text{Total Rings} = \text{Rings Retained} + \text{Rings Discarded}. \qquad (1)$$

These discarded rings actually served as "pawns" for approximating the mutual coupling effects on the rings retained. Nevertheless, the discarding (or overlapping) of edge element rings is generally more computationally expensive since more rings are necessary (due to the use of full-wave numerical methods for the edge array computation).

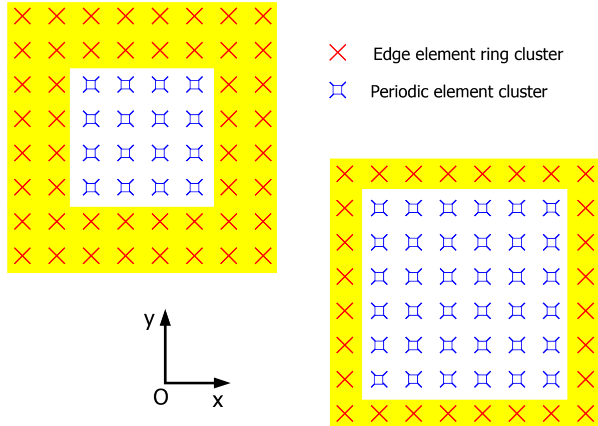
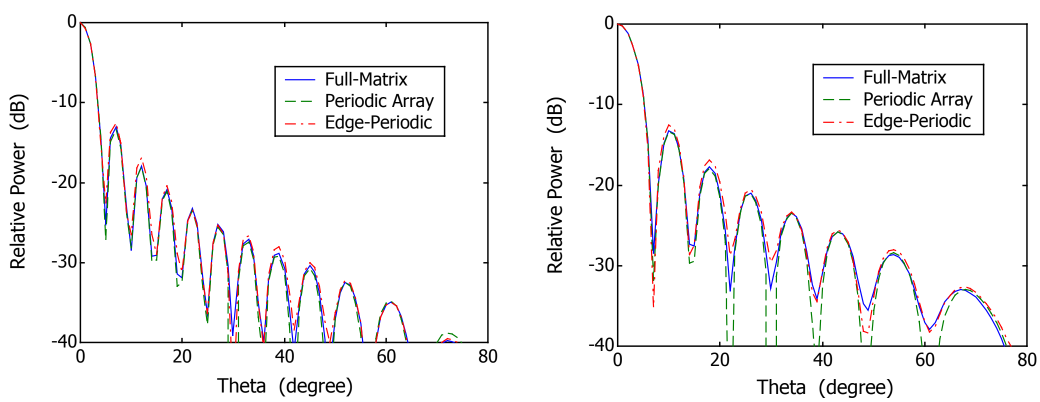


Fig. 1: Discarding an edge element ring for an 8x8 planar array using the Hybrid Edge-Periodic DSR technique. The original edge element ring cluster (top left) is 2 rings wide, and with the second ring in the cluster discarded (i.e. overlapped by the periodic element cluster), only the first ring is retained (bottom right).

The accuracy of this spatial DSR technique over the traditional periodic array windowing approach is investigated for a uniform 24x24-element array of microstrip dipoles etched on a ε_r=2.2 substrate of thickness 0.188λ_d, where $\lambda_d = \lambda_o/\sqrt{\varepsilon_r}$. The array dipoles are center-fed, each having a length and width of 0.578λ_d and 0.003λ_d, respectively, and their center-to-center element spacings in the x- and y- directions are 0.742λ_d and 0.494λ_d, respectively. These dipoles are arranged parallel to the x-axis, giving an E_x field polarization. For this LPA, the full-matrix solution, as computed using the full-wave MoM technique, is equivalent to the case having a total of 12 square rings with no rings discarded (i.e. with no periodic element utilized in the DSR modeling). On the other hand, the periodic array windowing solution is equivalent to that without any rings (i.e. with only periodic elements utilized in the DSR simulation). For example, a zero number of rings corresponds to a windowed periodic array solution. For a total number of rings between these two extremes, final solutions thus obtained are from combinations of solutions for both edge rings and inner periodic elements.



(a) (b)

Fig. 2: Far-field radiation patterns of a uniform 24x24-element array of microstrip dipoles etched on a ε_r=2.2 substrate of thickness 0.188λ_d (where $\lambda_d = \lambda_o/\sqrt{\varepsilon_r}$), obtained using different techniques: (a) E-plane, and (b) H-plane. Oriented parallel to the x-axis, the dipoles have lengths and widths 0.578λ_d and 0.003λ_d, respectively, and element spacings in the x- and y- directions are 0.742λ_d and 0.494λ_d, respectively. The Hybrid Edge-Periodic DSR results are computed using a total of 7 edge element rings with a 2-ring overlap.

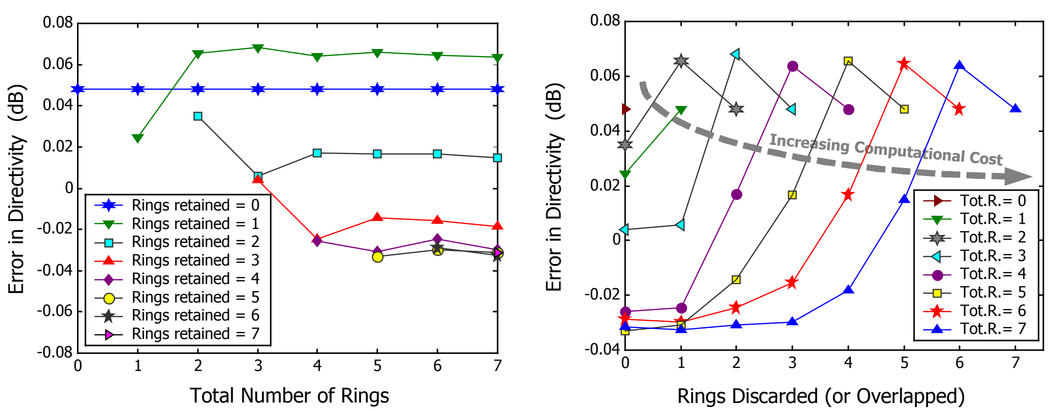
Fig. 2 shows its far-field radiation patterns, computed using the full-matrix (full-wave MoM solution), periodic array windowing and Hybrid Edge-Periodic DSR techniques. Their corresponding directivities are 30.89dBi, 30.94dBi and 30.86dBi, respectively. For the DSR modeling, radiation patterns are obtained using a total of 7 edge element rings with a 2-ring overlap. With realistic array edge effect incorporated into the analysis, this model predicts side-lobe patterns with good accuracy. More accurate side-lobe levels (SLL) may be obtained through the use of an optimal choice of the number of edge rings and overlapping. For the periodic array windowing approach, on the other hand, distinct nulls are predicted which are especially unrealistic in the H-plane.

A further investigation of a non-uniform variant of this 24x24-element LPA is presented in [8], and therefore, it will not be discussed here.

3. COST FUNCTION CHARACTERISTICS

A cost function analysis is performed for the uniform 24x24-element LPA described above, and its results are shown in Fig. 3. A full-matrix solution (full-wave MoM solution) is used as an exact solution for computing the error in directivity. Although the error in directivity is relatively small, errors in far-field radiation patterns can be significant. For the DSR case depicted in Fig. 2, the error in directivity is –0.031dB, which can be further improved if necessary.

The directivity sensitivity to total number of rings used, retained and discarded (overlapped) is also illustrated in Fig. 3. That is, the directivity becomes less sensitive as more rings are retained and the total number of rings utilized is increased. However, the computational cost is also increased. Thus, based on these observations, optimal DSR parameters for best accuracy at minimal cost can easily be obtained from data in the figure.



(a) (b)

Fig. 3: Hybrid Edge-Periodic cost function curves for a uniform 24x24-element array: (a) effect of increasing number of rings, and (b) effect of overlapping regions, represented as rings discarded (where Tot.R. ≡ Total Rings). All other array parameters are the same as in Fig. 2.

4. SUMMARY AND CONCLUSION

A simple concurrent periodic/non-periodic technique with a region overlap mechanism, similar to that utilized in PNM, is proposed for the analysis of planar LPA systems. This new method, known as the Hybrid Edge-Periodic technique, is a 2D spatial DSR technique that incorporates the array edge effect into its analysis. Simulations of a uniform 24x24-element LPA using this technique yield very good results. A cost function analysis can further provide optimal DSR parameters for LPA simulations at minimal cost.

While the periodic array windowing approach produces acceptable accuracy for a uniform LPA, this DSR technique will prove to be more superior for a large-scale non-uniform LPA. Also, for very complex LPA structures, this DSR technique may be implemented using a highly efficient full-wave solver, like the Finite Element – Boundary Integral (FE-BI) Method, instead of the MoM implementation utilized in this paper.

5. ACKNOWLEDGEMENTS

This research work was in part supported by the U.S. Navy SBIR Programs, contract numbers N00178-02-C-3001 and N68335-02-C-0437.

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