AN ARRAY OF DIPOLES FOR PLANE WAVE SYNTHESIS

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Introduction

In electromagnetic susceptibility testing of electronic equipment and in antenna pattern measurements, the ideal incident field is a uniform plane wave. Far-field ranges are often unacceptable because they waste power outside the test zone and because the far-field distance is often very large. The compact range [1] uses a paraboloidal reflector to produce an approximately plane wave in the near field, but the compact range is most useful at frequencies above 1 GHz. For electromagnetic susceptibility testing at lower frequencies, phased arrays [2] have been considered for producing a plane wave in a near-field test volume. The purpose of this paper is to describe a small phased array that we have studied theoretically and experimentally.

Array Synthesis

The geometry of the seven-element, planar array is shown in figure 1. The equally spaced array elements are located at the vertices and at the center of a regular hexagon. This configuration can also be viewed as a triangular arrangement of the array elements; it is known to be very efficient in filling the planar array surface without producing grating lobes [3]. Each array element consists of a driven dipole and a passive reflector to reduce the radiation in the backward (negative y) direction.

The objective is to choose the element excitations to produce a high-quality plane wave throughout the rectangular test volume shown in figure 1. Here we consider only the broadside case so that the desired plane wave is z-polarized and propagates in the y direction. Because of the array symmetry, there are only three independent current excitations, (I_1, I_2, and I_3). The three base currents are optimized by a near-field array synthesis technique that utilizes a least-squares solution with a constraint on the source norm [2]. The source norm constraint is effective in reducing the field strength outside the test volume and has also been used to reduce reactive fields in far-field synthesis [4]. Mutual coupling between the array elements has also been included in the theory.

Results and Conclusions

We have obtained extensive theoretical and experimental results for a wide variety of array and test volume parameters [5]. Some typical theoretical results for the electric field strengths are shown in figure 2. The array parameters are: $s = \lambda$ (wavelength), driven dipole length = $\lambda/2$, reflector length = 0.26λ , and separation between the reflector and the driven element = $\lambda/4$. The test volume is centered at $y_0 = 2.75\lambda$ from the array, and the far-field distance is approximately 8λ. The ratio of the actual electric field E_z to the desired plane wave field E_0 is shown for a uniform array ($I_1 = I_2 = I_3$), a synthesized array, and a constrained synthesized array. The mean square error for the field averaged over the test volume is: 34.0% for the uniform array, 4.6% for the constrained synthesized array, and 2.0% for the synthesized array. The effect of the constraint is to reduce the field strength outside the test volume ($x > 0.75\lambda$), but to increase the field error inside the test volume. The uniform array results are generally poor unless the number of array elements is very large [2]. We show only the transverse (x) variation of the field through the center of the test volume ($y = y_0$) in figure 2, but the trends are similar throughout the rest of the test volume.

Experimental results were obtained with half-wave dipoles at a frequency of 500 MHz, and the agreement of the amplitude and phase of the electric field with the theoretical results was generally good. The details of the experiment and the calculations are given in [5].

We are continuing to work on near-field arrays. Important practical extensions include scanning the frequency and scanning the plane wave in angle of arrival. The frequency scan will require wide-band elements, and the angular scan will require a larger number of elements. The small narrow-band array studied here was intended primarily to demonstrate that the general principle is sound.

References

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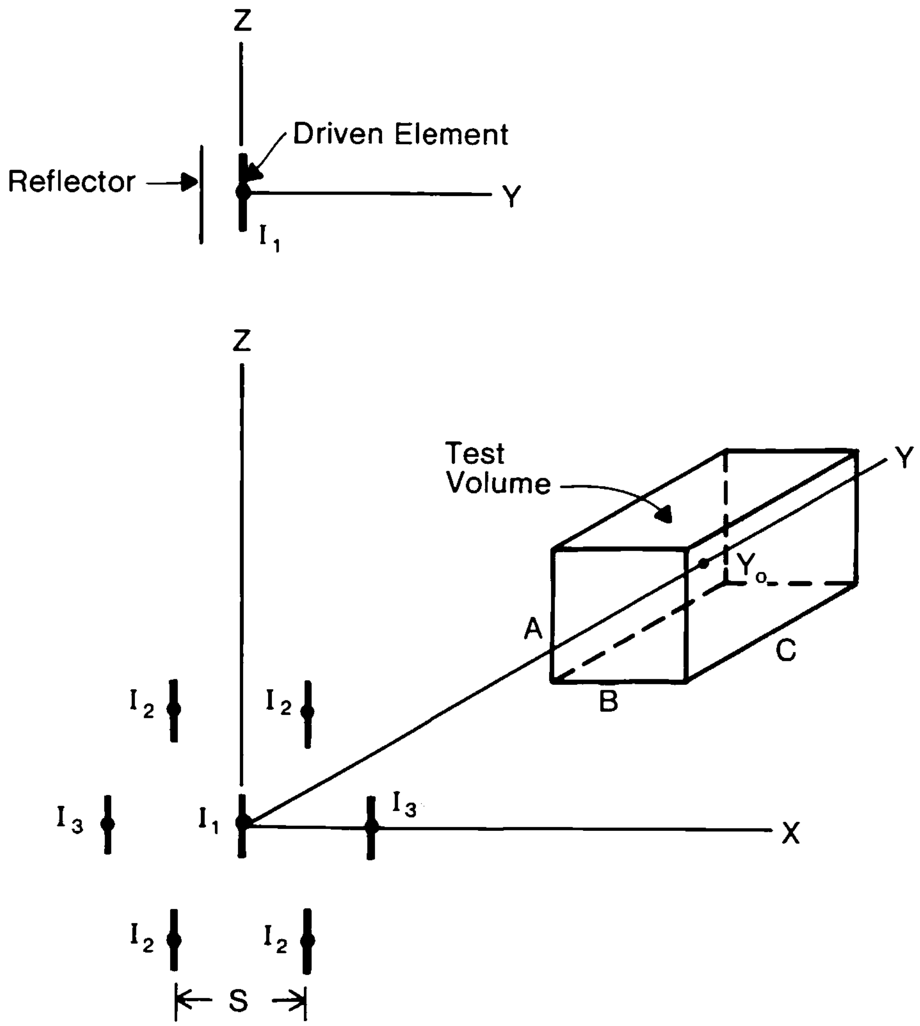

Figure 1. A seven-element, hexagonal array. Each element consists of a driven dipole and a passive reflector. The rectangular test volume (A x B x C) is centered on the y axis at $y = y_0$.

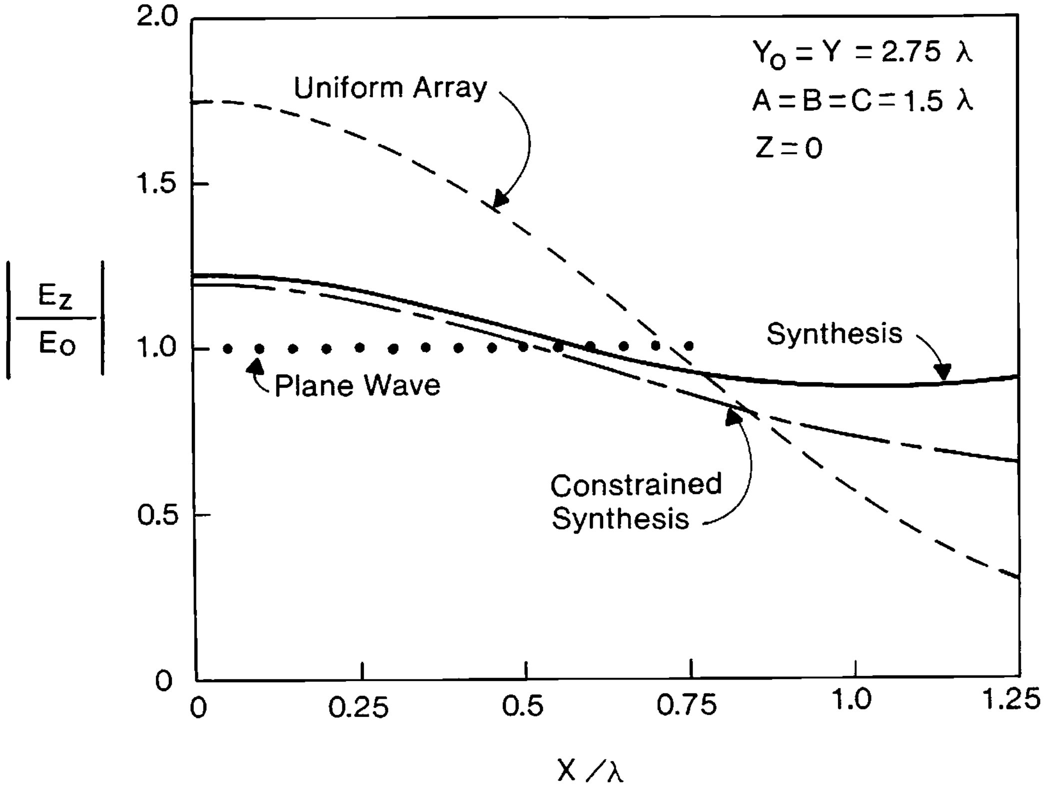

Figure 2. Normalized magnitude of the electric field for a synthesized array, a constrained synthesized array, and a uniform array. The perfect plane wave is shown for comparison.