Array Antenna Design with WIPL-D

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Abstract: Array antenna design at Syracuse Research Corporation using WIPL-D is demonstrated by two examples: a switched beam conformal array and a phased array. The conformal array is a cylindrical array of vertical column subarrays. The phased array is planar array of microstripline integrated balun dipoles. In both cases, theory is compared with measurement.

Keywords: Method of Moments, WIPL-D, Conformal Array Antennas, Phased Array Antennas

1. Introduction

For over 40 years, Syracuse Research Corporation has been developing high performance radar systems, many of which include array antennas. Recently, several of these antennas have been designed with use of the Method of Moments EM Analysis code WIPL-D [1]. Some results pertaining to a conformal array and a planar phased array are discussed below. In both examples, theory is compared with measurement.

2. Conformal Array

Figure 1 shows a section of a cylindrical array of vertical dipoles. The full array has 24 columns, each having six printed dipoles. The cylinder is constructed of 24 flat conducting strips forming a 24-sided polygonal cylinder. The test article is a quarter of this array (six columns of elements in front of a quarter of the cylinder). Figure 2 shows measured and computed (using WIPL-D) realized element gain patterns for the test article. (The realized element gain pattern is obtained by exciting a near central element and terminating all others.) The WIPL-D model included the dipoles and the partial cylinder. It did not include dipole feedlines and dielectric supporting material. The broad beamwidth patterns correspond to the WIPL-D simulation of only one column of dipoles in front of the partial cylinder and the exact solution of a point dipole in front of a corresponding infinite circular cross section cylinder [2]. The narrow beamwidth patterns pertain to the measured data of the actual test article and to the WIPL-D simulations of the test article. The narrow beam, apparently due to mutual coupling, was unexpected. Corroboration between measurement and simulation was crucial to accepting this important result.

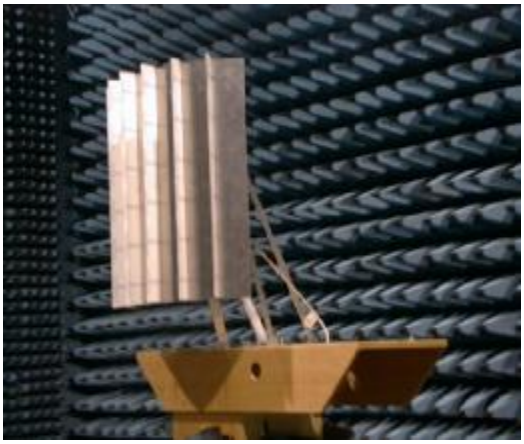

Figure 1. Conformal Array Test Article

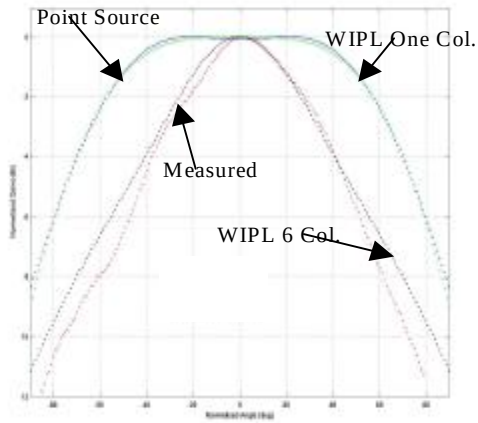

Figure 2. Element Gain Patterns

3. Planar Array

WIPL-D also was applied in the design of a large planar array of printed integrated balun dipoles of the type described in [3]. The WIPL-D model is shown in Figures 3 and 4. The dipole was printed on one side of a dielectric substrate (Figure 3). The ground for the microstrip feedline/balun was printed on this layer, as well. The feedline/balun was printed on the reverse side of the substrate (Figure 4). The narrowed conductor served as a quarter wave resistance transformation to yield nearly 50 Ohms at the feed port (beginning of the narrowed conductor). In practice, the element would be fed with a 50 Ohm microstrip transmission line extending from the array combiner to the feed port. In the WIPL-D model, however, a feed pin was inserted at the feed port. The feed pin and entire element model is shown in Figure 5, with the substrate thickness artificially enlarged many times for clarity.

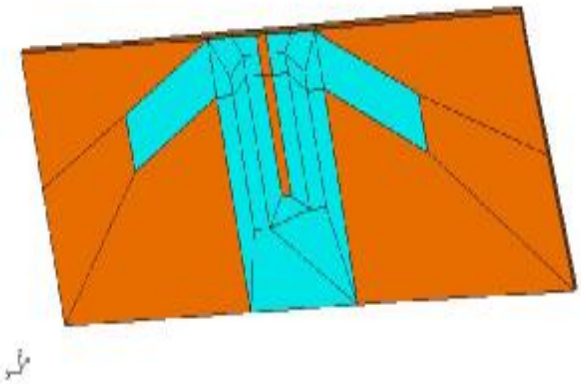

Figure 3. Printed Dipole Model

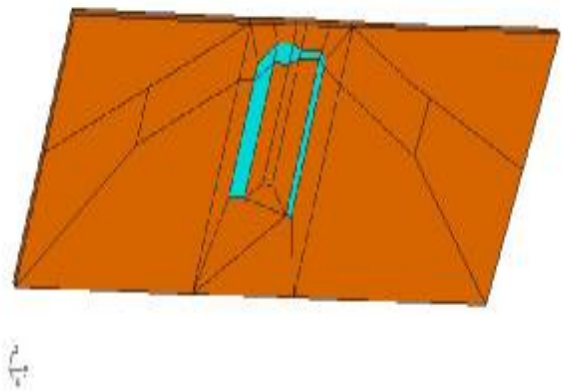

Figure 4. Printed Feedline/Balun Model

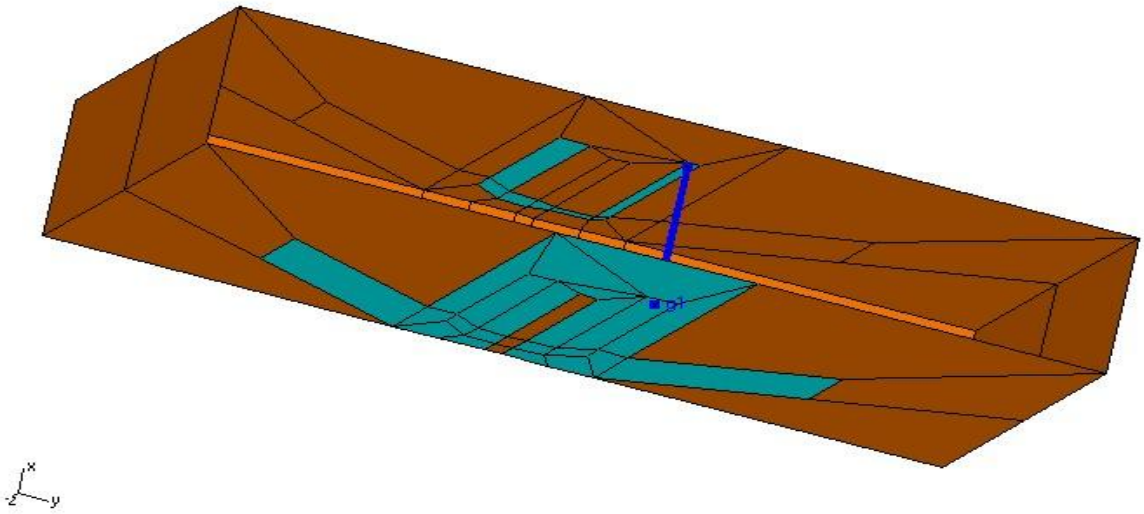

Figure 5. Integrated Balun Dipole Model with Substrate Artificially Enlarged for Clarity

Figure 6 shows a 19-element triangular lattice array of such elements. The WIPL-D model contained almost 10,000 Moment Method unknowns. Figure 7 shows a related test article. (The element lattice is rectangular in this test article, but the one used for comparison with the WIPL-D model was triangular.) The realized element gain was computed and measured with respect to the center element of the array. Figure 8 shows the resulting patterns and the good agreement between theory and measurement. Mutual coupling was measured and computed, as well. Figure 9 shows the good agreement between theory and measurement for mutual coupling. Each line corresponds to two-port mutual scattering parameter measurements between the center element and another element. Corresponding to each line are three WIPL-D computed values (low, central, and high band values). Lines labeled 34 and 43 refer to first ring coupling: 34 for E-Plane, 43 for diagonal plane. Other lines refer to second ring coupling in various planes, in particular, 42 for H-Plane and 24 for E-Plane. This agreement validated the use of WIPL-D for determining active impedance.

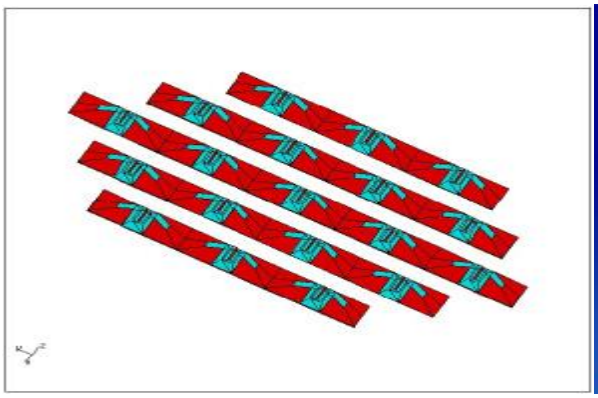

Figure 6. Planar Array Model

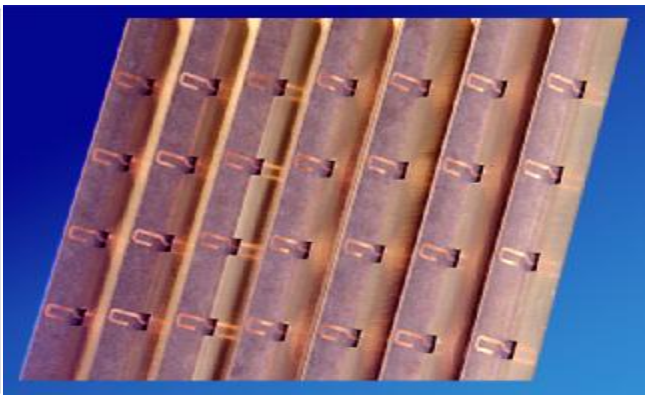

Figure 7. Planar Array Test Article

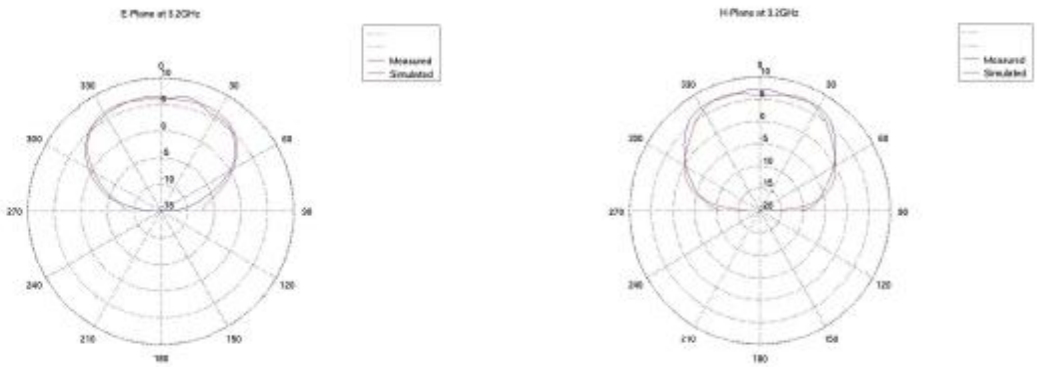

Figure 8. Measured and Computed Realized Element Gain Patterns

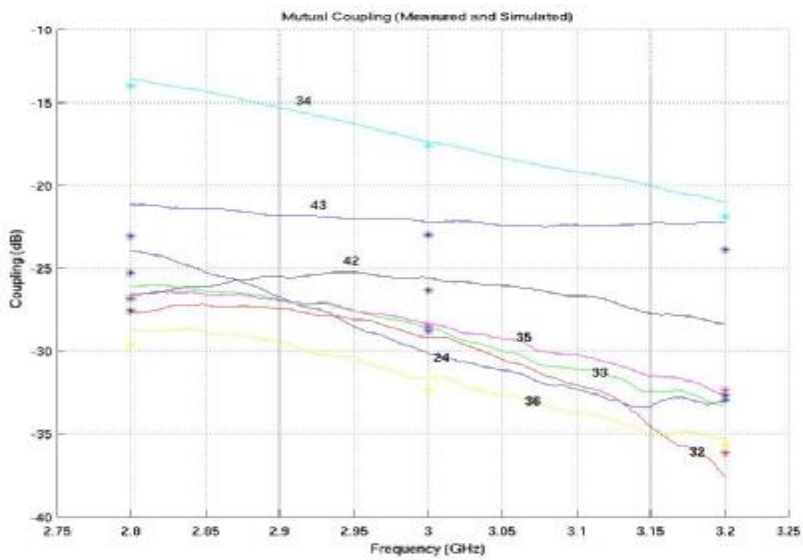

Figure 9. Measured and Computed Mutual Coupling

4. Conclusions

WIPL-D has been useful in designing array antennas at Syracuse Research Corporation. Two examples have been presented: a conformal array and a planar phased array. Good agreement between theory and measurement are shown.

References

[1] B. M. Kolundzija, et al., WIPL-D Electromagnetic Modeling of Composite Metallic and Dielectric Structures, Artech House, Inc., Norwood, MA, 2000.

[2] R. F. Harrington, Time-Harmonic Electromagnetic Fields, McGraw-Hill, New York, Problem 5-40, Page 262, 1961.

[3] B. Edwards and D. Rees, "A Broadband Printed Dipole with Integrated Balun," Microwave Journal, Bol. 30, pp. 339-344, May 1987.