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The problem addressed in this research is the derivation and development of an analytic technique for compensation of probe positioning errors in the calculation of far-field antenna patterns made from near-field measurements.

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ANALYTICAL COMPENSATION FOR NEAR-FIELD PROBE POSITIONING ERRORS IN CALCULATED FAR-FIELD ANTENNA PATTERNS

Final Technical Report

by

Edward B. Joy
School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

For

U.S. Army Research Office
Electronics Division
P. O. Box 12211
Research Triangle Park, NC 27709

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INTRODUCTION

Near-field antenna measurements offer several advantages over far-field techniques. Studies at Georgia Tech and NBS have shown that the accuracy of planar near-field techniques to be at least as good as far-field techniques.

In the calculations of the far-field pattern of an antenna from sampled near-field distributions, it is assumed that the distribution is measured on an exact geometric surface such as a plane near the test antenna and that the data is sampled at precise locations on the specified surface. Both of these assumptions are false if errors are made in positioning the test probe in the near-field of the antenna.

The Georgia Tech planar near-field range probe positioning system, as an example, is accurate to within 0.040 inches in the planar or (z) error and .010 inches in (x,y) position. This accuracy has been shown to be acceptable at frequencies of 12 GHz or less.

Yaghjian of NBS derived a bound for probe positioning errors for high accuracy antenna pattern measurements. This bound requires position accuracy of $.004\lambda$ in (x,y, and z) for main beam gain accuracy of .01 dB.

Probe positioners with tolerances on the order of the Georgia Tech system are commercially available, at high cost, for use in a laboratory environment. If near-field techniques are to be used for field measurements or a low cost positioning system is to be used, the tolerances on the probe positioning system must be relaxed. A less accurate positioning system could be used if it were possible to determine positioning errors (i.e., the (x,y,z) positioning error for each measurement) and to mathematically correct for them.

A method now employed at NBS, Boulder, Colorado, for the determination of the exact sample location uses a commercially available laser interferometer. Other less precise methods are also possible.

PROBLEM STATEMENT

The problem addressed in this research is the derivation and development of an analytic technique for compensation of probe positioning errors in the calculation of far-field antenna patterns made from near-field measurements.

IMPORTANT RESULTS

An analytical technique has been developed for calculating far-field antenna patterns from measured near-field data that includes compensation for the effects of near-field probe positioning errors. The effect of several different types of probe positioning errors with magnitudes up to one wavelength have been computer simulated. The compensation technique has been used to correct for the effects of the error on both theoretical and measured near-field data. Complete correction of all points in the far-field pattern (for values as low as 40 dB down from the main beam peak) has been achieved for all cases studied.

Several approximate techniques for analytic compensation of probe position errors in planar surface near-field measurements have been investigated. The basic process is the determination of fields on a planar surface from fields on a nearby curved surface.

A "k-correction" technique was developed for probe position error compensation for high gain antennas. The aperture field is assumed to be a single plane wave propagating in the direction k, of the main beam maximum. Probe position errors for such a near field distribution made on this basis result in phase only corrections. This technique has been shown to be effective for probe position errors up to one tenth wavelength.

The development of this technique means that the accuracy of the near-field antenna measurement technique is no longer limited by the accuracy of the mechanical probe positioning system. The following benefits are gained from this research.

1. Antenna patterns can be calculated on existing near-field ranges with increased accuracy using the compensation technique
2. New near-field ranges can be build for lower cost since the tolerances on probe positioning systems can be relaxed.
3. The near-field technique can be used to field test antennas in their operating environment rather than under laboratory conditions.
4. The near-field technique can be used to determine far-field patterns for smaller wavelength antennas where a given mechanical error is a greater function of a wavelength.

The results of this research have been transferred to and implemented at RCA, Moorestown, NJ in connection with the U.S. Navy Aegis Radar program. Probe position compensation is necessary to provide the required accuracy of phase shifter alignment of the array. (See attached Technology Transfer Statement.)

PUBLICATIONS RESULTING FROM THIS RESEARCH

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PARTICIPATING SCIENTIFIC PERSONNEL

Name	Position	Advanced Degrees Awarded
Edward B. Joy	Professor, Principal Investigator	
Larry E. Corey	Graduate Research Assistant	Ph.D. in Electrical Engineering
Andrew D. Dingsor	Graduate Research Assistant	M.S. in Electrical Engineering
Richard E. Wilson	Graduate Research Assistant	(In Progress on Ph.D.)

TECHNOLOGY TRANSFER REPORT

by

Dr. Edward B. Joy
School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

The basic research conducted under ARO Project P-15646-EL entitled "Analytical Compensation for Near-Field Probe Positioning Errors in Calculated Far-Field Antenna Patterns" has resulted in some immediately applicable findings. The technology generated in this research has been transferred to the U.S. Navy Aegis Program at RCA, Moorestown, NJ, to solve a problem which was identified as a key technological risk in the development of a new generation, low sidelobe level, phased array for the Aegis System.

Low sidelobe level phased array antennas are only possible if the phase setting of each element can be accurately set to a predetermined value. The initial phase alignment of the antenna must be accomplished during production of the antenna. The initial phase alignment cannot be computed to the required accuracy based on the propagation path through the feed network from the sources to the elements due to the many unknowns and parameter variations in the feed system components and connections. The initial phase alignment must be accomplished using near field measurements. The measurements are made on a planar surface parallel to the face of the array, separated from the array by two to five wavelengths. The phase of each element is then calculated via a "backward transform" from the near field measurements. The accuracy of this phase computation is heavily dependent on the accuracy of the near field measurements.

The largest contributor to the error in near field measurements for most near field measurement systems is the error in positioning the near field probe antenna to the prescribed data taking locations on the planar measurement surface. Compensations for such probe positioning errors in near field measurements is the technology which was recently transferred to the U.S. Navy Aegis Program. Without this technology the phase alignment accuracies required could not have been achieved and a projected 88 billion dollar Navy program been in risk. (Many ships are contemplated as platforms for the Aegis System.) The Assistant Secretary of the Navy was made aware of this risk to the Aegis System and also made aware of this new technology which has "substantially eliminated" the risk.