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Endfire tapered slot antennas have demonstrated an unusual ability to perform well in wideband, wide-scan phased array antennas. Although these antennas have been in existence for 20 years and have been studied experimentally for most of that time, computational capabilities have only recently progressed to the point where numerical modeling of these antennas is feasible. This project was undertaken to investigate some of the fundamental parameters of tapered slot antenna arrays so that antenna designers and system planners can better understand how these antennas perform, what are their present limitations, and how can the best performance be obtained. Specifically, this project has: (1) Performed extensive parameter studies of single-polarized arrays, leading to a much better understanding of antenna design and performance, (2) Extended the analysis capability from single-polarized arrays to dual-polarized arrays, and (3) Conducted experimental studies to validate the computations and to discover new information. Many new results have been published in papers resulting from this project. Several scan blindnesses have been identified and one entire class of blindnesses has been characterized so

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that it can be easily predicted and corrective measured taken. An element resonance that can occur when separate substrates are used for each antenna in an array, as has been proposed by some designers for integrated phased arrays. This resonance is also understood and it can be avoided by altering the fabrication of the array. A new measurement technique that offers several advantages for measuring printed antenna arrays has been developed. Many key results from this project were summarized at a panel discussion co-organized by the Principal Investigator, at the 1995 IEEE International Antennas and Propagation Symposium.

CHARACTERIZATION OF TAPERED SLOT ARRAYS ON PROTRUDING SUBSTRATES

FINAL PROGRESS REPORT

DANIEL H. SCHAUBERT

1 MARCH 1996

U. S. ARMY RESEARCH OFFICE

CONTRACT DAAL03-92-G-0295

ELECTRICAL AND COMPUTER ENGINEERING
UNIVERSITY OF MASSACHUSETTS AT AMHERST

INTRODUCTION AND STATEMENT OF PROBLEM

Endfire tapered slot antennas have demonstrated an unusual ability to perform well in wideband, wide-scan phased array antennas. Although these antennas have been in existence for 20 years and have been studied experimentally for most of that time, computational capabilities have only recently progressed to the point where numerical modeling of these antennas is feasible. The Antenna Laboratory at the University of Massachusetts at Amherst is one of the few groups that has extensive experience with tapered slot antenna arrays based upon both experimental and numerical work. This project was undertaken to investigate some of the fundamental parameters of tapered slot antenna arrays so that antenna designers and system planners can better understand how these antennas perform, what are their present limitations, and how can the best performance be obtained. Specifically, this project has: (1) Performed extensive parameter studies of single-polarized arrays, leading to a much better understanding of antenna design and performance, (2) Extended the analysis capability from single-polarized arrays to dual-polarized arrays, and (3) Conducted experimental studies to validate the computations and to discover new information.

Several results obtained during this program are summarized in below. Further information can be obtained from the publications cited or by contacting the Principal Investigator, Daniel H. Schaubert, at 413-545-2530.

SUMMARY OF IMPORTANT RESULTS

Several interesting and important results have come from this project. Many results have been published in the papers and conference presentations cited below, while other discoveries are still being evaluated and/or prepared for publication. Two theses have been completed and a third is nearly complete. Five graduate students and one undergraduate student have received support from this contract and the associated AASERT program. The most important results are:

1. Arrays of wideband tapered slot antennas can operate with SWR < 2 over bandwidths of 5:1 while scanning +/- 45 degrees from broadside in any plane. (see publications 6 and 8)

2. Scan blindnesses can occur in these arrays and they often create the limitations on wideband performance. As the operating frequency increases, the angle at which an array is blind may move closer to or further from broadside, depending upon the particular mechanism that creates the blindness. (see publications 1, 2, 3, 6, 7, 8 and 11)

3. Some types of scan blindnesses can be controlled by redesign of the element or by altering the interelement spacing of the array. (see publications 2, 4, 6, 8, and 11)

4. One type of scan blindness that occurs in single-polarized arrays is associated with a guided wave on a corrugated surface that is derived from the array structure. This blindness can be predicted easily, and the array design can be altered to reduce or eliminate the adverse effects of this particular blindness. (see publications 2, 7 and 11)

5. There is an element resonance that can occur in antennas that are fabricated by using separate substrates for each element. This method of fabrication has been proposed by some designers and has been embraced by some designers of integrated phased arrays because of its modularity. Although procedures to reduce or eliminate the effects of this resonance have been identified, they impact the fabrication of the array and further study is needed to determine the best solution to this problem. (see publications 4 and 14)

6. A new measurement technique has been developed that permits the determination of the active input impedance of an element embedded in a scanning phased array. The technique can yield complex impedance or reflection coefficient at any frequency or scan angle and it does not require a corporate feed network, phase shifters, or connectors on the elements. (see publications 5 and 13)

7. The Principal Investigator was a co-organizer of a special panel discussion at the 1995 IEEE International Antennas and Propagation Symposium. The session, entitled "Wideband Vivaldi Notch Antennas and Arrays," was moderated by the Principal Investigator and included presentations and discussions with the audience by four industrial antenna designers with extensive experience in wideband array design: Shashi Sanzgiri, Texas Instruments (co-organizer), J. J. Lee, Hughes Aircraft Co., Jerome Pozgay, Raytheon Co., and Eric Lucas, Westinghouse. Interest in the subject was so great that the session had to be moved to a room nearly twice the size of the originally planned site, and attendance was capped at 75 to insure the session could accomplish its objectives.

PUBLICATIONS RESULTING FROM THIS PROJECT

1. D. H. Schaubert, "Wide-bandwidth radiation from arrays of endfire tapered slot antennas," in *Ultra-Wideband, Short-Pulse Electromagnetics*, H. L. Bertoni, L. Carin and L. B. Felsen, ed., pp. 157-165, Plenum, New York, 1993.

2. D. H. Schaubert and J. A. Aas, "An explanation of some E-plane scan blindnesses in single-polarized tapered slot arrays," *1993 IEEE International Antennas and Propagation Symposium*, pp. 1612-1615, Ann Arbor, MI, 1993.

3. D. H. Schaubert, "Scanning characteristics of stripline-fed tapered slot antennas on dielectric substrates," *Proceedings of the 1993 Antenna Applications Symposium*, Robert Allerton Park, Monticello, IL, 1993.

4. D. H. Schaubert, "A gap-induced element resonance in single-polarized arrays of notch antennas," *1994 IEEE International Antennas and Propagation Symposium*, pp. 1264-1267, Seattle, WA, 1994.

5. D. H. Schaubert, W.-C. Chang and G. J. Wunsch, "Measurement of phased array performance at arbitrary scan angles," *Proceedings of the 1994 Antenna Applications Symposium*, Robert Allerton Park, Monticello, IL, 1994.

6. D. H. Schaubert and J. Shin, "Parameter study of tapered slot antenna arrays," *1995 IEEE International Antennas and Propagation Symposium*, pp. 1376-1379, Newport Beach, CA, 1995.

7. G. J. Wunsch and D. H. Schaubert, "Effects on scan blindness of full and partial crosswalls between notch antenna array unit cells," *1995 IEEE International Antennas and Propagation Symposium*, pp. 1818-1821, Newport Beach, CA, 1995.

8. J. Shin and D. H. Schaubert, "Toward a better understanding of wideband Vivaldi notch antenna arrays," *Proceedings of the 1995 Antenna Applications Symposium*, Robert Allerton Park, Monticello, IL, 1995

9. Y. Zilberberg, *Analysis of Single Polarized Stripline-Fed Slot Arrays with Metallic Walls*, MS Thesis, Electrical and Computer Engineering, University of Massachusetts at Amherst, February 1994.

10. J. Shin, *Improved Method of Moments Computations Applied to Tapered Slot Antenna Arrays*, MS Thesis, Electrical and Computer Engineering, University of Massachusetts at Amherst, September 1994.

11. D. H. Schaubert, "A class of E-plane scan blindnesses in single-polarized arrays of tapered slot antennas with a ground plane, to appear in *IEEE Transactions on Antennas and Propagation*, July 1996.

The following works are in progress and have been supported, in whole or in part, by this project.

12. G. J. Wunsch, *A Moment Method Analysis of Dual-Polarized Endfire Slotline Antenna Infinite Phased Arrays*, Ph.D. Thesis, Electrical and Computer Engineering, University of Massachusetts at Amherst, expected September 1996.

13. W.-C. Chang, *A New Measurement Technique for Phased Array Antennas*, MS Thesis, Electrical and Computer Engineering, University of Massachusetts at Amherst, expected September 1996.

14. D. H. Schaubert, "A gap-induced element resonance in arrays of notch antennas," to be submitted to *IEEE Transactions on Antennas and Propagation.*

15. J. Shin and D. H. Schaubert, "Design of tapered slot antenna arrays to improve wideband active impedance," to be submitted to *IEEE Transactions on Antennas and Propagation.*

16. G. J. Wunsch and D. H. Schaubert, "Some effects of crosswalls in single-polarized notch antenna arrays," to be submitted to *IEEE Transactions on Antennas and Propagation.*

LIST OF SCIENTIFIC PERSONNEL SUPPORTED ON THIS PROJECT

Weichun Chang (MS expected September 1996)
E. Gerecht (MS student)
J. Munro (AASERT, BSEE awarded May 1995, now in graduate school with NSF Fellowship and continuing work on tapered slot antenna arrays)
J. Shin (MS awarded September 1994 and continuing for Ph.D.)
G. Wunsch (AASERT, Ph.D. expected September 1996)
Y. Zilberberg (MS awarded February 1994)
D. H. Schaubert, Principal Investigator

REPORT OF INVENTIONS

No inventions resulted from this work.