GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 7/19/78

Project Title: Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements

Project No: E-21-629

Project Director: Dr. E. B. Joy

Sponsor: National Science Foundation

Agreement Period: From 7/1/78 Until 12/31/79 (Grant Period)

Type Agreement: Grant No. ENG 78-01587

Amount: $17,500 NSF
        4,115 GIT (E-21-325)
        $21,615

Reports Required: Annual Progress Report (if 2nd increment of funding is awarded); Final Technical Report; Summary of Completed Project

Sponsor Contact Person (s):

Technical Matters

Jay H. Harris
Program Officer
Devices and Waves Program
National Science Foundation
Washington, D. C. 20550
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(thru OCA)

Ms. Mary Frances O'Connell
Grants Manager
MPE/BBS/SE Branch
Division of Grants and Contracts
National Science Foundation
Washington, D. C. 20550
Phone: (202) 632-2858

Defense Priority Rating: N/A

Assigned to: Electrical Engineering

(School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)
Library, Technical Reports Section
EES Information Office
EES Reports & Procedures
Project File (OCA)
Project Code (GTRI)
Other
SPONSORED PROJECT TERMINATION SHEET

Date: 10/5/81

Project Title: Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements

Project No: E-21-629

Project Director: Dr. E. B. Joy

Sponsor: National Science Foundation

Effective Termination Date: 2/28/81

Clearance of Accounting Charges: 2/28/81

Grant/Contract Closeout Actions Remaining:

- [x] Final Fiscal Report
- [ ] Final Invoice and Closing Documents
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Assigned to: Electrical Engineering (School/Laboratory)

COPIES TO:

Administrative Coordinator
Research Property Management
Accounting
Procurement/EES Supply Services

Research Security Services
Legal Services (OCA)
Library

Computer Input
Project File
Other
Progress Report
National Science Foundation Grant No. ENG78-01587

ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS

Introduction

The research program has as its overall goal, the determination of the accuracy of calculating far field antenna patterns from measurements made in the near field of the antenna. Specifically the near field measurements are taken over a finite portion of a planar surface located near the antenna. Past research in the area of near field antenna measurements have demonstrated empirically that accuracies greater than or equal to the best far field range measurements can be achieved for high gain antennas if the near field measurement area is greater than two and one half times the antenna aperture and that the measurement area includes all near field values with amplitudes greater than 45 dB below the peak near field value. These criteria, however offer no guarantee of accuracy in all cases, and at best are only applicable to high gain antennas with single main beams such that the near field energy is concentrated in a single localized area on the planar measurement surface. The criteria are also very costly in measurement facilities and measurement time as the measurement facility and the number of measurements must in proportion to two and one half times the antenna aperture area, not the aperture area itself. Thus a rigorous, generally applicable, accuracy bound is needed to allow the use of smaller measurement areas with known far field pattern accuracy relationships. Thus for a given desired accuracy the near field measurement procedure could be specified.

Initial Investigation

The far field radiation pattern of an antenna is proportional to the two dimensional Fourier transform of the near field distribution of the antenna specified on a planar surface. Initial effort was devoted to the investigation of two general approaches for determining the Fourier transform of a finite set of sampled data. The first approach was expansion of the finite set of sampled data as a summation of prolate spheroidal wave functions and then extrapolation of this summation to the unsampled portion of the plane and subsequent computa-
tion of the Fourier transform of the extrapolated summation. The second approach was the windowing of the finite set of sampled data to smooth the discontinuity at the edge of the finite measurement window followed by computation of the Fourier transform of the windowed data. Such classic window functions as the Hanning, Hamming and the general class of Blackman windows were used. Although the window functions do greatly reduce the effects of data truncation at the edges of the measurement window, they have no extrapolative powers to "analytically continue" the measurements, resulting in large far field pattern error bounds. Thus it has been concluded that windowing the data is not helpful in determining the accuracy of calculated far field patterns from near field measurements.

**Prolate Spheroidal Expansion**

The prolate spheroidal expansion of the finite set of sampled near field measurement data was found to lead to an upper bound on the accuracy of far field radiation patterns determined from spatially limited near-field measurements.

The error in determining the far field radiation pattern from the prolate spheroidal expansion results from two sources. The first source is the spatial truncation of the near field measurement data to a finite portion of the plane. Results can be found in the literature which will lead to an error bound for the Fourier transform of such a spatially limited calculation if the function being transformed is also limited in the Fourier transform domain. Luckily electromagnetic near field distributions are bandlimited in the transform domain. The second source of error is the sampling of the near field distribution at sample spacings specified by the Nyquist criterion as applied to planar electromagnetic fields. The Nyquist criterion is only valid if the entire planar surface is sampled and does not apply if only a finite portion is sampled. Thus this research has been devoted to formulating the error due to sampling a finite portion of the planar surface and incorporating this formulation into the error bounds for determining the Fourier transform of a two dimensional, spatially limited planar distribution fitted with a two dimensional prolate spheroidal expansion. Such an upper bound has been found. The upper bound was found to be a function of the percentage of power measured in the finite region of the measurement plane compared to the amount of total power.
passing throughout the infinite near field measurement plane. No error is made in the computation of the far field radiation patterns for the case in which 100% of the power is measured and infinite error is made in the case of zero measured power. Although the theory and technique for the resulting upper bound of the error are general, the upper bound is dependant on the antenna pattern being measured and thus a specific percentage of power can not aprior be specified. For most cases however the percentage of power required for acceptable error appears to be in the range from 85 to 95% of the total power. An initial report of this work has been submitted for presentation at the National Radio Science Meeting, November 5-8, 1979 in Boulder, Colorado. Copies of the submitted abstract are attached.

Work Remaining

Work is now underway to determine the amount of power measured in the measurement window versus the total power crossing the measurement plane. For high gain, lossless antennas the total power is approximately equal to the power input to the antenna. A more general method of determining this power, however, is the computation of the power from the extrapolated prolate spheroidal expansion of the spatially limited measurement. In this case however there is an error in determining this power which is related to the error bound being sought. Although the error in determining the total power has only a second order effect on the error bound for the radiation pattern for most practical measurement situations, this error must be established.

The measurement portion of the research program in which near field distributions of varying spatial extent are measured, error bounds determined, far field patterns calculated and compared with the same patterns measured on a far field range has not begun. Also, only a small beginning has been made to publish this work in the open literature. These three remaining efforts are described in the accompanying proposal for continuation of this research.
The problem of determining the sampling window truncation error in calculating the far field radiation pattern of an antenna from near-field measurements made over a finite portion of a planar surface located near the antenna is discussed. The method of determining the error is not restricted to a specific type of antenna, but applies to a broad, general class of antennas.

Three things are known about the planar near field of an antenna which help in determining this error. First, the total power on the infinite near-field plane is finite. Secondly, the near-field plane is located a finite distance from the antenna so that the higher order evanescent modes have attenuated and the near field is approximately band-limited in the Transform domain. Third, the field attenuates as $1/r$ as $r$ approaches infinity. It is known that such a bandlimited finite power function can be reconstructed outside a finite window by expressing the function as a summation of prolate spheroidal wave functions fitted to the function within the window and that such a summation approaches $1/r$ as $r$ approaches infinity. By expressing the measured near field as such a summation, an expression is obtained for the error. An upper bound on this error is obtained as a function of the ratio of power measured to the total power by using the method of Lagrangian Multipliers. The total power passing through the infinite measurement plane is bounded by measuring the input power to the test antenna.

The method has been tested by measuring the near-field of an S-band antenna over a large near-field sampling window. The far-field was then calculated using the standard procedure. The near-field data was then truncated to two smaller window sizes and the far field calculated from the truncated data. The error bound was then calculated using the method described above. The actual error was determined by comparing the far field calculated from the truncated sampling windows with the far field calculated from the full size sampling window data. The far field of the antenna was also measured on a conventional far-field range and the calculated far field was compared to the measured far field. The results of these tests will be presented.

This material is based on work supported by the National Science Foundation under Grant No. ENG78-01587
ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS

INTRODUCTION

Near-field antenna measurements offer a practical example of a fundamental question in Fourier analysis: What is the error in determination of the Fourier transform of a bandlimited signal when only a sampled portion of the signal is known? Planar near-field antenna measurements are performed by sampling the electromagnetic field radiated by an antenna on a planar surface close to the antenna. Ideally, the entire surface should be sampled. No fundamental error in the computation of the Fourier transform would be made if the entire plane were sampled at the two-dimensional Nyquist rate. However, it is not possible to sample the entire plane and an error is made by the spatial truncation of the measurements. If the measurements were continuously made the resulting error in the calculated Fourier transform can be shown to be a convolution of the true Fourier transform with the Fourier transform of the rectangular window function. Recovery of the true Fourier transform might be possible using two-dimensional deconvolution techniques. The measurements are, however, not continuous, but are sampled at the Nyquist rate. The sampling complicates the analysis as the sampling functions assume knowledge of measurements outside the measurement window.
EARLY WORK

The first year effort was devoted to the search for alternate sampling functions, primarily the Prolate Spheroidal Expansion. Some progress was achieved as reported in the first progress report, and work is continuing.

LATEST WORK

The last year's effort has been directed toward development of a "iterative deconvolution" technique. This technique was originally suggested by Papoulis in his paper "A New Algorithm in Spectral Analysis and Band-Limited Extrapolation." Early investigation of the technique showed that it worked for strictly bandlimited, mathematical functions, but did not work for measured data. Effort is now concentrating on adding information contained in electromagnetic theory to the extrapolation processes.

The basic iterative technique as posed by Papoulis was to surround the spatially truncated data with zeros, perform a Discrete Fourier Transform (DFT), set DFT values whose transform coordinates were larger than the assumed band limit equal to zero, perform an inverse DFT, and reset values within the measured window to measured values. Repetition of this process, hopefully converged to an extrapolated version of the truncated data. The only additional information required was the two-dimensional bandlimits. This process is obviously not unique as many bandlimited finite data sets have identical center sequences. Error bounds on this technique must be infinite. However, experimentation with this technique on the two-dimensional sinc function and on the Blackman window functions showed that 90% of the energy in the functions could be predicted from 60% of the energy, a surprising result. Typically 5 to 10 iterations were sufficient for good results.
Application of this technique to measured data, generally was not successful. Even after 50 and 100 iterations, the technique was slowly converging on what appeared to be the wrong answer.

Work is now underway to add additional information regarding both the data and its Fourier transform. Typical types of information include:

1. Known finite total power contained in the extrapolated data.
2. Distance data behavior approaching the radiation condition: $1/r$.
3. Fourier transform exponential decay above the free space wavenumber.
4. Amplitude patterns of the Fourier transform.

WORK REMAINING

Addition of the above information types to enhance accuracy of the extrapolation technique.
PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address
Georgia Institute of Technology
Atlanta, GA 30332

2. NSF Program
Research Grant

3. NSF Award Number
ENG 78-01587

4. Award Period
From 7-1-78 To 2-28-81

5. Cumulative Award Amount
$40,099

6. Project Title
Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements

PART II—SUMMARY OF COMPLETED PROJECT (FOR PUBLIC USE)

This project examined the fundamental problem of estimating the Fourier transform of a two-dimensional process from a limited set of samples from this process. The process was known to be bandlimited in the Fourier transform sense and samples are taken at the Nyquist rate. This project showed that the Fourier transform of this process could not, in general, be accurately determined from this limited information. The Fourier transform of some strictly bandlimited functions could be accurately determined when as little as 60% of the energy content of the process was sampled. The Fourier transform of measured processes could not be accurately estimated, however, without the addition of some outside information.

A technique was developed for the accurate estimation of the Fourier transform from limited data when a basic model of the electromagnetic device or field was added to the computation. Neither the model or the computation process was in itself sufficient. Together, however, the Fourier transform could be accurately determined.

PART III—TECHNICAL INFORMATION (FOR PROGRAM MANAGEMENT USES)

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</table>

2. Principal Investigator/Project Director Name (Typed)
Edward B. Joy

3. Principal Investigator/Project Director Signature

4. Date
9-4-81

NSF Form 98A (5-78) Supersedes All Previous Editions
ACCURACY OF RADIATION PATTERNS DETERMINED
FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS

by

E. B. Joy

School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Final Technical Report
National Science Foundation Grant
ENG 78-01587

August 1981
INTRODUCTION

The research program had as its overall goal, the determination of the accuracy of calculating far-field antenna patterns from measurements made in the near-field of the antenna. Specifically the near-field measurements are taken over a finite portion of a planar surface located near the antenna. Past research in the area of near-field antenna measurements have demonstrated empirically that accuracies greater than or equal to the best far-field range measurements can be achieved for high gain antennas if the near-field measurement area is greater than two and one half times the antenna aperture and that the measurement area includes all near-field values with amplitudes greater than 45 dB below the peak near-field value. These criteria, however, offer no guarantee of accuracy in all cases, and at best are only applicable to high gain antennas with single main beams such that the near-field energy is concentrated in a single localized area on the planar measurement surface. The criteria are also very costly in measurement facilities and measurement time as the measurement facility and the number of measurements must in proportion to two and one half times the antenna aperture area, not the aperture area itself. Thus, a rigorous, generally applicable, accuracy bound is needed to allow the use of smaller measurement areas with known far-field pattern accuracy relationships. Thus, for a given desired accuracy the near-field measurement procedure could be specified.

FUNDAMENTAL QUESTION

The fundamental question, which spans many engineering disciplines, is: can the Fourier transform of a bandlimited continuous process of infinite extent be accurately determined from a finite set of samples of
this process, where the samples are taken at the Nyquist rate within the measurement "window."

PROLATE SPHEROIDAL WAVE FUNCTION APPROACH

The answer to the fundamental question posed above is: no. Either the measurement window must span the entire process or additional information must be used in the determination of the Fourier transform. The electromagnetics of this problem (other disciplines would need to use the basic equations which the field being measured must obey) show that electromagnetic fields must obey at least these three conditions:

1. The total energy in the field being measured is finite;
2. The field being measured is exponentially bandlimited; and
3. The fields being measured decrease as 1/r when the distance from the source r approaches infinity.

These three conditions suggested the use of prolate spheroidal wave functions as the sampling functions rather than the usual sinc functions. The attached abstract of our paper in the Proceedings of the National Radio Science Meeting, Boulder, Colorado, November 1979, details the results of this technique. In summary, when the percentage of the energy measured was known, an upperbound on the error in the calculated Discrete Fourier Transform (DFT) can be obtained. Typically, good error bounds required greater than 90% of the total energy be measured.

ITERATIVE EXTRAPOLATION

A technique originally described by A. Papoulis in, "A New Algorithm in Spectral Analysis and Band-Limited Extrapolation," IEEE Trans. on Circuits and Systems, Vol. CAS-22, No. 9, September 1975, has been implemented and modified. Papoulis's technique was shown to extrapolate spa-
tially limited data, but only for strictly bandlimited, mathematical func-
tions and was shown to produce unacceptable results on measured data. Additional information was found to be needed to yield accurate results.

The addition of the three conditions stated above, only marginally improved the basic extrapolation process. It did, however, confirm the accuracy bounds derived earlier with the Prolate Spherical Wave Functions. The attached abstract of our "Signal Processing in Electromagnetic Radiation Measurements," in the Proceedings of the IEEE International Circuits and Systems Symposium, Chicago, Illinois, April 27-29, 1981 presents some of the results of this research.

NEAR-FIELD, FAR-FIELD EXTRAPOLATION

An outgrowth of the above research on iterative extrapolation was the ability to extrapolate with high accuracy the near-field distribution of an antenna when a finite portion of the near-field distribution is known and the two principal plane amplitude cuts of the DFT are known. The modified extrapolation process not only extrapolates the near-field distribution in amplitude and phase but also accurately calculates the amplitude and phase of the DFT. A paper describing this technique is currently being prepared. An important application for this technique exists in antenna/ radome analysis where measured far-field amplitude only cuts are known (these are directly related to the DFT of the near-field distribution) and the field in the aperture of the antenna is known. The technique developed on this project then allows calculation of the rest of the planar surface fields and the DFT.
ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS:
T.S. Craven and E.B. Joy, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, GA 30332

The problem of determining the sampling window truncation error in calculating the far field radiation pattern of an antenna from near-field measurements made over a finite portion of a planar surface located near the antenna is discussed. The method of determining the error is not restricted to a specific type of antenna, but applies to a broad, general class of antennas.

Three things are known about the planar near field of an antenna which help in determining this error. First, the total power on the infinite near-field plane is finite. Secondly, the near-field plane is located a finite distance from the antenna so that the higher order evanescent modes have attenuated and the near field is approximately band-limited in the Transform domain. Third, the field attenuates as 1/r as r approaches infinity. It is known that such a bandlimited finite power function can be reconstructed outside a finite window by expressing the function as a summation of prolate spheroidal wave functions fitted to the function within the window and that such a summation approaches 1/r as r approaches infinity. By expressing the measured near field as such a summation, an expression is obtained for the error. An upper bound on this error is obtained as a function of the ratio of power measured to the total power by using the method of Lagrangian Multipliers. The total power passing through the infinite measurement plane is bounded by measuring the input power to the test antenna.

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This material is based on work supported by the National Science Foundation under Grant No. ENG78-01587.
Applications of multidimensional digital signal processing techniques to electromagnetic radiation measurements and analysis are presented. Far field and near field radiation measurements and associated signal processing requirements are discussed. On-going signal processing efforts are mentioned.

Near Field Antenna Measurements

The distance from the antenna to the far field of an antenna required to perform direct far field radiation measurements becomes excessive as the size of the antenna increases and the wavelength decreases. Another approach for far field determination made practicable in part by computers and digital signal processing, is the measurement of near field radiation and the subsequent calculation of the far field. Several factors enter into the measurement and subsequent data processing of near field radiation. First, the probe antenna used to measure the near field radiation, distorts the near field being measured. The distortion effects have been rigorously analyzed and amount to a spatial convolution of the near field radiation being measured and the equivalent near field radiation distribution of the probe antenna. The signal processing effort is then to deconvolve these two two dimensional vector distributions. The vector deconvolution is easily performed in the wavenumber domain. Apriori knowledge or measurement of the far field radiation pattern of the probe antenna is required for the determination of the wavenumber spectrum of the probe. Figure 1 shows such a set of two dimensional far field antenna patterns of a small horn antenna. These graphs are plotted versus elevation and azimuth. The amplitude scale is in decibels from zero to -60 decibels. The phase scale covers a range of 360 degrees. Second, the near field must be sampled on a surface enclosing the test antenna. The surface is usually near the antenna to minimize the surface area and measurement data. It has been shown that the wavenumber spectrum, the two dimensional Fourier transform of a planar electromagnetic field distribution, is band-limited to a circular region. A square sampling lattice of spacing less than one half wavelength is required to prevent aliasing. Figure 2 shows two components of the electric field tangential to the measurement plane. The amplitude scales are in decibels from zero to -40 decibels. The phase measurement scale covers the full 360 degree range. Third, the measurement surface, in this case the planar surface, must be geometrically perfect to within approximately one two hundredth of a wavelength to yield accurate results. Deviations of nonideal surfaces must be measured and used in computation of the far field pattern. Figure 3 shows an actual measurement surface. Compensating for spatial and dimensional error distributions results in a major signal processing effort. The effort involves performing numerous two dimensional Fourier transforms of the electromagnetic fields and the surface and inverting a matrix of N^2 by N^2 elements where N is the total number of two dimensional near field measurements.

Figure 4 shows the amplitude of the far field elevation component of a 10 GHz off-set-feed parabolic dish antenna calculated from near field measurements. The accuracy to which the far field patterns of an antenna can be obtained using the near field measurement technique has been demonstrated to be equal to or superior to high quality far field measurements and is now being used for the acceptance testing of some large military radar system antennas.

On-going Signal Processing Efforts

Several multidimensional signal processing efforts are under way to enhance the near field measurement technique. These include: (1) hexagonal sampling of the planar near field radiation to save measurement and computation time, (2) near field measurement extrapolation to reduce the number and spatial extent of measurement, and (3) application of signal processing techniques to the cylindrical and spherical near field measurement surfaces.
Figure 1. Far Field Amplitude and Phase Patterns of Horn Antenna
Figure 2. Near Field Radiation Measurements
Figure 3. z—Position of Near Field Measurement Probe Within Planar Measurement Area

Figure 4. Amplitude of the Calculated Far Field Elevation Component
Mr. T. S. Craven's Ph.D. Dissertation research entitled:
"Accuracy of Radiation Patterns Determined from Spatially Limited
Near-Field Measurements," is currently in progress.

Mr. A. D. Dingsor's Master Degree Thesis entitled:
"Computer Simulation of Cylindrical Surface Near-Field Measurement
System Errors," was completed in August 1979.
SCIENTIFIC COLLABORATORS

Principal Investigator: Dr. Edward B. Joy (See attached Biographical Sketch)

Faculty Investigator: Dr. Gene K. Huddleston (See attached Biographical Sketch)

Graduate Research Assistants:

Mr. Tyson S. Craven
Mr. Andrew D. Dingsor
Mr. Bruce Eisenman
BILOGRAPHICAL SKETCH

JOY, EDWARD B. - Professor of Electrical Engineering
Georgia Institute of Technology

EDUCATION

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EMPLOYMENT HISTORY

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<td>Electronic Design Engineer</td>
<td>Summer 1963</td>
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<td>U. S. Navy</td>
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<tr>
<td>Jacksonville Shipyards</td>
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<td>Advanced Research, Inc.</td>
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CURRENT FIELDS OF INTEREST

Electromagnetic field analysis and measurement; radome analysis and design; underground power distribution and grounding systems; lightning measurement and protection.

THESIS AND DISSERTATION


PUBLICATIONS


MISCELLANEOUS ARTICLES


CONFERENCE PROCEEDINGS


Edward B. Joy - Biographical Sketch


MAJOR RESEARCH REPORTS


Edward B. Joy - Biographical Sketch


INVITED SEMINARS


Edward B. Joy - Biographical Sketch


SHORT COURSE LECTURES


Edward B. Joy – Biographical Sketch


CONSULTING ACTIVITIES

Martin Marietta Aerospace, Orlando, Florida
Radome Design and Analysis

Brooks Air Force Base, San Antonio, Texas
Digitally Controlled Electro-Mechanical Positioner System Design

Southeastern Center for Electrical Engineering Education, Auburn, Alabama
Effects of Lightning on Composite Material Aircraft

Simmons Industries, Atlanta, Georgia
Microwave Heating of Chickens

Scientific Atlanta, Atlanta, Georgia
1. Far Field Pattern Calculation from Near Field Measurement
2. Computer Graphics
3. Electromagnetic Interference
Edward B. Joy – Biographical Sketch

Vertex Systems, Inc., Tucker, Georgia
Lightning Protection of Digital Systems

Dow Badische Company, Williamsburg, Virginia
Electrostatic Shielding of Conductive Clothing

Technology Service Corporation, Silver Spring, Maryland
Lecturer on Antenna Theory, Design and Measurement
Near Field Antenna Measurement Systems

London, Yancey, Clark & Allen, Birmingham, Alabama
Safety of Electrical Equipment

Transit Products Company, Hapeville, Georgia
High Voltage Sparking

Beneke Corporation, Columbus, Mississippi
Microwave and Dielectric Heating of Wood

British Aerospace, LTD., Herts, England
Near Field Antenna Measurements

Lumpkin, Holland, Ray & Upchurch, Tupelo, Mississippi
Safety of Electrical Equipment

Amateur Radio Relay League, Newington, Connecticut
Near-Field and Far-Field Antenna Radiation Versus Antenna Tower Height

Ford Aerospace, Newport Beach, California
Radome Design and Analysis

Mullis, Reynolds, Marshall and Horne, Macon, Georgia
National Electrical Safety Code

Southwire, Carrollton, Georgia
Power Cable Corona Testing Apparatus Design

Dayton-Granger Aviation, Inc., Fort Lauderdale, Florida
Matching Aircraft Antennas

Marconi Space and Defense Systems, Stanmore, England
Radome Analysis Techniques

Naval Coastal Systems Center, Panama City, Florida
Sea Water Electrode Systems

Sanders Associates, Nashua, New Hampshire
Near Field Coupling of Antennas

New Mexico Engineering Research Institute, Albuquerque, New Mexico
Design of Blast Hardened Radome
Edward B. Joy - Biographical Sketch

Northrop Aircraft, Hawthorne, California
Radome Analysis

Harris Corporation, Broadcast Products Division, Quincy, Illinois
Near-Field Antenna Measurement Feasibility

Freeman and hawkins, Atlanta, Georgia
Transformer Protection

RESEARCH CONTRACTS/GRANTS -- PRINCIPAL/CO-PRINCIPAL INVESTIGATOR

   U. S. Army Missile Command, Huntsville, Alabama  
   E. B. Joy and G. K. Huddleston  
   $34,000  
   Duration: 1 year  
   March 7, 1972 - March 6, 1973

2. Extension of: "Radome Effects on the Performance of Ground Mapping Radar"  
   U. S. Army Missile Command, Huntsville, Alabama  
   E. B. Joy and G. K. Huddleston  
   $5,000  
   Duration: 5 months  
   March 7, 1973 - August 6, 1973

3. "An Investigation of the Accuracy of Far-Field Radiation Patterns Determined from Near-Field Measurements"  
   U. S. Army Missile Command, Huntsville, Alabama  
   E. B. Joy and G. P. Rodrigue  
   $58,000  
   Duration: 14 months  
   June 1, 1972 - August 1, 1973

4. "Analysis and Evaluation of Radome Materials and Configurations for Advanced RF Seekers"  
   U. S. Army Missile Command, Huntsville, Alabama  
   G. K. Huddleston, E. B. Joy and H. L. Bassett  
   $30,000  
   Duration: 8 months  
   April 27, 1973 - December 31, 1973

5. "Measurement and Analysis of the Electromagnetic Coupling to Under-ground Structures"  
   USAF Aerospace Defense Command, Colorado Springs, Colorado  
   E. B. Joy  
   $303,280  
   Duration: 51 years  
   July 1, 1972 - December 31, 1977
6. "A Study of Phased Array Antenna Patterns Determined by Measurements on a Near-Field Range"
   U. S. Army Missile Command, Huntsville, Alabama
   E. B. Joy and G. P. Rodrigue
   $100,000
   Duration: 14 months
   December 11, 1973 - February 11, 1975

7. "Multi-Purpose Missile (MPM) High Performance Trade-Off Development"
   Martin Marietta Aerospace Company, Orlando, Florida
   E. B. Joy and G. K. Huddleston
   $100,000
   Duration: 14 months
   December 11, 1973 - February 11, 1975

8. "Near-Field Data Handling Techniques and Probe Design Considerations"
   U. S. Army Missile Command, Huntsville, Alabama
   $21,000
   Duration: 5 months
   July 1, 1974 - December 1, 1974

9. "A High Current Minesweeping Electrode Investigation"
   U. S. Naval Coastal Systems Laboratory, Panama City, Florida
   E. B. Joy and R. F. Hochman
   $30,000
   Duration: 7 months
   March 1, 1976 - September 30, 1976

10. "Develop a Computer Program to Calculate Earth Potentials Due to Faults on URD Cable or Loss of Concentric Neutral"
    Electric Power Research Institute, Palo Alto, California
    $70,751
    Duration: 14 months
    March 1, 1976 - April 30, 1977

    U. S. Naval Coastal System Laboratory, Panama City, Florida
    R. F. Hochman and E. B. Joy
    $44,982
    Duration: 6 months
    July 24, 1976 - January 31, 1977

12. "Development of Fabrication and Processing Techniques for Laser Hardened Missile Radomes"
    Martin Marietta Aerospace Company, Orlando, Florida
    G. K. Huddleston and E. B. Joy
    $17,242
    Duration: 13 months
    August 13, 1976 - September 13, 1977
13. "Final Design and Analysis of High Current Minesweeping Electrodes"
   U. S. Naval Coastal Systems Laboratory, Panama City, Florida
   E. B. Joy and R. F. Hochman
   $53,895
   Duration: 1 year

14. "A Feasibility Study of Nobel Metal Coated Graphite - Conductive
    Polymer Materials for Minesweeping Electrodes"
    U. S. Naval Coastal Systems Center, Panama City, Florida
    R. F. Hochman and E. B. Joy
    $34,914
    Duration: 12 months
    August 15, 1977 - August 31, 1978

15. "LMS Electrode Feasibility Study"
    U. S. Naval Coastal Systems Center, Panama City, Florida
    R. H. Hochman and E. B. Joy
    $42,132
    Duration: 4 months

16. "Accuracy of Radiation Patterns Determined from Spatially Limited
    Near-Field Measurements"
    National Science Foundation, Washington, D. C.
    E. B. Joy
    $49,415
    Duration: 2 years
    July 1, 1978 - February 28, 1981

17. Analytical Compensation for Near-Field Probe Positioning Errors in
    Calculated Far-Field Antenna Patterns"
    U. S. Army Research Office, Durham, North Carolina
    E. B. Joy
    $82,475.80
    Duration: 2 years
    July 1, 1978 - June 30, 1980

18. "Graphical and Tabular Results of Computer Simulation of Faulted URD
    Cables"
    Electric Power Research Institute, Palo Alto, California
    A. P. Meliopoulos, E. B. Joy and R. P. Webb
    $69,000
    Duration: 1 year
    July 15, 1978 - July 14, 1979

19. "Design Study for High Current Magnetic Minesweeping "S" Cable"
    Naval Coastal System Center, Panama City, Florida
    E. B. Joy and R. F. Hochman
    $59,994
    Duration: 8 months
    August 9, 1978 - April 20, 1979
20. "Underground Cable Test Simulation and Analysis"
   Florida Power and Light Company, Miami, Florida
   $24,927
   Duration: 16 months
   January 1, 1979 - April 30, 1980

    Scientific Atlanta, Inc., Atlanta, Georgia
    E. B. Joy
    $5,000 (Fellowship for Graduate Student)
    Duration: 1 year
    October 1, 1978 - September 30, 1979

22. "Development of High Current Conductive Polymer Minesweeping Electrodes"
    Naval Coastal Systems Center, Panama City, Florida
    R. F. Hochman and E. B. Joy
    $63,258
    Duration: 11 months
    January 25, 1979 - December 21, 1979

23. "Modified S-3 Nobel Metal Feasibility Anode Study"
    Naval Coastal Systems Center, Panama City, Florida
    E. B. Joy and R. F. Hochman
    $37,975
    Duration: 8 months
    July 23, 1979 - May 1, 1980

    E. B. Joy
    $5,000 (Fellowship for Graduate Student)
    Duration: 1 year
    January 1, 1980 - December 31, 1980

    E. B. Joy
    $44,000
    Duration: 11 months

26. "Special Research Equipment: Automated Radiation Laboratory"
    National Science Foundation
    G. K. Huddleston, E. B. Joy, W. M. Leach
    $116,403
    Duration: 17 1/2 months
27. "Transmission Grounding"
   Electric Power Research Institute, Palo Alto, California
   $165,413
   Duration: 1 year 8 months
   October, 1980 - July 1, 1982

28. "Conductive Polymer Development for Minesweeping Electrode Jackets"
   Naval Coastal Systems Center, Panama City, Florida
   E. B. Joy and R. F. Hochman
   $119,856
   Duration: 14 months
   September 9, 1980 - October 30, 1981
HUDDLESTON, GENE K. -- Associate Professor
School of Electrical Engineering
Georgia Institute of Technology

EDUCATION

BEE, Georgia Institute of Technology
MSEE, Georgia Institute of Technology
Ph.D. in EE, Georgia Institute of Technology

EMPLOYMENT HISTORY

Georgia Power Company, Atlanta, Georgia
Co-op Student 1960-1963

U.S. Marine Corps
Reconnaissance Officer and Technical Writer 1964-1968

Georgia Institute of Technology
Graduate Research Assistant 1968-1970
Research Engineer 1970-1972
Instructor, Electrical Engineering 1972-1977
Lecturer, Electrical Engineering 1977-1978
Assistant Professor, Electrical Engineering 1978-1981
Associate Professor, Electrical Engineering 1981-Present

EXPERIENCE SUMMARY

As co-op student with Georgia Power Company, worked in steam-electric generating plant in instrumentation section and later as draftsman in transmission substation's section of electrical engineering department. As Marine officer, served as reconnaissance officer and troop leader and afterwards as correspondence course writer, supervisor of other course writers, and as ceremonial platoon leader. As graduate research assistant at Georgia Tech, worked on radome design techniques at millimeter wavelengths utilizing dielectric lenses and leaky wave antennas in radiant configurations. As research engineer, worked on determining high temperature dielectric properties of radome materials at X- and K-band frequencies and the instrumentation and computer programming required in this work; worked on radome sidelobe reduction techniques at X-band frequencies using anisotropic structures; worked on pyroelectric probe for microwave dosimetry applications; studied effects of microwave radiation on enzymes; worked on development of broadband electromagnetic window structure; worked on remote data acquisition system for pollution sensors; served as project director. As faculty member in the School of Electrical Engineering worked on radome analysis and design, lightning protection for solid state circuits, near-field antenna measurements, served as research project director; taught courses in digital system design and interfacing small computers, and advanced electromagnetic theory; served as chairman
Gene K. Huddleston - Biographical Sketch

of faculty committees; established automated radiation laboratory for electromagnetics research.

CURRENT FIELDS OF INTEREST

Antennas, radomes, lightning protection for solid state circuits, near-field/far-field transformations.

MAJOR REPORTS AND PUBLICATIONS


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