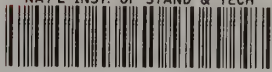


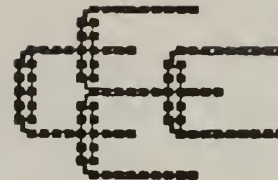
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**CENTER FOR ELECTRONICS AND
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TECHNICAL PROGRESS BULLETIN

U S DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Electronics and Electrical Engineering

COVERING SIGNALS AND SYSTEMS PROGRAM, APRIL - SEPTEMBER 1982

May 1983



U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary
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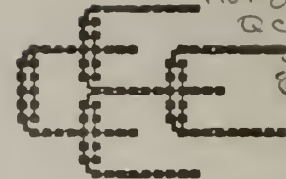
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SIGNALS AND SYSTEMS PROGRAM, ISSUE FOR APRIL 1982 - SEPTEMBER 1982

Introduction

This compilation of abstracts of papers approved for publication by the National Bureau of Standards covers the work of three technical divisions in the NBS Center for Electronics and Electrical Engineering for the second half of the Federal fiscal year, April 1982 through September 1982. These divisions are the Electrosystems Division at Gaithersburg, MD and the Electromagnetic Fields Division and Electromagnetic Technology Division in Boulder, CO. The work of these divisions collectively forms the Signals and Systems Metrology Program of the Center. A compilation of abstracts covering the work of the Signals and Systems Metrology Program for the first half of Federal fiscal year 1982 is available as NBSIR 83-2719-1.

The work of the remaining two divisions of the Center, the Semiconductor Materials and Processes Division and Semiconductor Devices and Circuits Division both at Gaithersburg, comprises the Semiconductor Technology Program. Abstracts covering this work for the entire Federal fiscal year 1982 (October 1981 through September 1982, fifty-third through fifty-seventh quarters of the Program) have been published in January 1983 as NBSIR 82-2636, Semiconductor Technology Program Progress Briefs [single copies available from the Center, see back page for address].

New Publication Covering Entire Center

Beginning with the first quarter of Federal fiscal year 1982 (October through December 1982), the Center is initiating publication of a single document to cover work in both the Semiconductor Technology Program and the Signals and Systems Metrology Program. The new publication will have the same name as the one you are now reading -- CEEE Technical Progress Bulletin -- and replace the STP Progress Briefs series. The primary purpose of the new Bulletin is to provide sponsors and other interested parties abstracts of documents approved for publication as soon as possible. Additional information will be provided on published papers; conference and workshop proceedings; special-format publications, such as magnetic data tapes and videotapes; new measurement services, including calibration services and standard reference materials; and a six-month calendar of Center events.

Publication Lists

Guides to earlier as well as recent work are the publications lists covering the work of each division. These are revised and reissued on an approximately annual basis and are available from the originating division [the publications from the Semiconductor Technology Program are covered in a single list, available from either division]. Readers are encouraged to contact any of the individuals listed on the back page for further information.

SIGNALS AND SYSTEMS METROLOGY PROGRAM, ISSUE FOR APRIL 1982 - SEPTEMBER 1982

Mission of Signals and Systems Program: The Signals and Systems Program of the Center for Electronics and Electrical Engineering provides national reference standards, measurement methods, supporting theory and data, and traceability to the national standards. The technical areas addressed in the Program are identified in the Table of Contents below.

The metrological products of the Program aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U. S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

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Note: Abstracts are presented alphabetically by first author within above areas.

Sponsors of Work Covered in this Publication: National Bureau of Standards; NBS Law Enforcement Standards Laboratory; Department of Defense: DoD Calibration Coordination Group, DoD Electromagnetic Compatibility Analysis Center, U.S. Air Force, USAF Newark Air Force Station, U.S. Army, U.S. Navy, USN Naval Systems Research and Development Command, USN Naval Weapons Station, USN Office of Naval Research; Department of Energy, DoE Bonneville Power Administration; Department of Health and Human Services, HHS National Center for Devices and Radiological Health (formerly Bureau of Radiological Health), HHS National Institute of Occupational Safety and Health; Department of Transportation, DOT National Highway Traffic Safety Administration; Electric Power Research Institute; and International Copper Research Association.

FAST SIGNAL ACQUISITION, PROCESSING, & TRANSMISSIONWaveform metrology

Andrews, J., Bell, B., Nahman, N. S., Baldwin, E. E.; **Reference Waveform Flat Pulse Generator**, Proceedings of Conference on Precision Electric Measurements, pp B10-12 (1982); also to be published in IEEE Trans. Instrumentation and Measurement [approved May 1982].

The NBS Reference Flat Pulse Generator is used to transfer dc voltage and resistance standards to the nanosecond domain. It provides a step amplitude of 1.000 V (open circuit) from a source impedance of 50.0 ohms. The transition duration is 600 ps and all perturbations are damped out to less than ± 10 mV within 5 ns. It can also be used as a time interval transfer standard.

Bell, B. A., Field, B. F., and Kibalo, T. H., **A Fast Response Low-Frequency Sampling Voltmeter**, NBS Tech. Note 1159 (August 1982).

A low-frequency voltmeter utilizing a sampling technique implemented with microprocessor-based electronics has been developed to perform as a true rms ac voltmeter and distortion analyzer. The instrument makes measurements accurate to ± 0.1 percent (of reading) of the fundamental frequency, total harmonic distortion, and true rms voltage of approximately sinusoidal inputs from 2 mV to 10 V and frequencies from 0.1 to 120 Hz. A major feature of this instrument is the special window crossing and error function algorithms which provide a software means for completing a measurement within two signal periods at frequencies below 10 Hz.

Gans, W. L., and Nahman, N. S., **Continuous and Discrete Fourier Transforms of Steplike Waveforms**, IEEE Trans. on Instrumentation and Measurement, IM-31 No. 2, p 97, June 1982.

A steplike waveform which has attained its final value is converted into a duration-limited one which preserves the spectrum of the original waveform and is suitable for discrete Fourier transform (DFT) computations. The method, which is based upon the response of a time-invariant linear system excited by a rectangular pulse of suitable duration, is first applied to continuous waveforms and then to discrete (sampled) waveforms. For completeness, the difference (error) between the spectra of a continuous waveform and a discrete representation of it are reviewed.

Lentner, K.J., and Flach, D.R., **An Automatic System for AC/DC Calibration**, to be published in IEEE Trans. Instrumentation and Measurement.

An automatic ac/dc difference calibration system using direct measurement of thermocouple emfs is described. The system operates over a frequency range from 20 Hz to 100 kHz, covering the voltage range from 0.5 V to 1 kV. For all voltages the total uncertainty (including the uncertainty of the specific reference thermal converters used) is 50 ppm at frequencies from 20 Hz to 20 kHz, inclusive, and 100 ppm at higher frequencies up to 100 kHz. In addition to ac/dc difference testing, the system can be used to measure some important characteristics of thermoelements, as well as to calibrate ac voltage calibrators and precision voltmeters. Results of intercomparisons between the new system and the manual NBS calibration system, using single-range, coaxial-type, thermal voltage converters as transfer standards, are reported. The results indicate that the ac/dc differences measured are accurate to well within the combined total uncertainty limits of the two systems.

Waveform Metrology, cont'd.

Lentner, K.J., and Tremaine, S.G., **A Semiautomatic AC/DC Thermal Voltage Converter Calibration System**, NBSIR 82-2576 (September 1982).

A semiautomatic ac/dc difference calibration system is described. The system operates over a frequency range of 20 Hz to 100 kHz, covering the voltage range from 0.5 V to 1 kV. For all voltages at frequencies in the range from 20 Hz to 20 kHz, the total uncertainty is 50 parts per million (ppm), and 100 ppm for voltages at frequencies between 20 kHz and 100 kHz. In addition to ac/dc difference testing, the system can be readily adapted to calibrate precision ac digital voltmeters or ac calibrators. Results of extensive intercomparison testing of the new system against a manual test system are reported, using a multirange thermal transfer instrument as a transport standard. The results indicate that the ac/dc differences measured are well within the combined total uncertainty limits of the two systems.

Oldham, N.M., **A 50 PPM AC Reference Standard Which Spans 1 Hz to 50 kHz**, to be published in IEEE Trans. Instrumentation & Measurement.

A digital sinewave generator which spans 1 Hz to 50 kHz is described. The rms amplitude is characterized by an internal thermal converter and corrected by a microcomputer to an uncertainty of 50 ppm. Amplitude is programmable from 0 to 7.07 V rms.

Schoenwetter, H.K., **High Accuracy Settling Time Measurements**, to be published in IEEE Trans. Instrumentation & Measurement.

Methods are described for measuring the settling times and other dynamic characteristics of voltage and current output D/A converters (DACs), operational amplifiers, and precision

voltage step generators. Circuits are described for measuring voltage-output device settling times as short as 1 μ s to within a settling error of ± 2 ppm, and current-output device settling times as short as 40 ns to within a settling error of $\pm 0.012\%$.

Souders, T.M., Flach, D.R., and Wong, T.C., **An Automatic Test set for the Dynamic Characterization of A/D Converters**, to be published in IEEE Trans. Instrumentation & Measurement.

An automatic test set is described for measuring the dynamic characteristics of A/C converters having up to 16 bits of resolution. The test converter is exercised with stepped input changes typical of the conditions of actual use. All dynamic test parameters are under program control, making it possible to separate and measure dynamic errors of various sources. Typical test results are included.

Cryoelectronic Metrology

Brady, R.; **Correction to the Formula for the London Moment of a Rotation Superconductor**, to be published in Jnl. Low Temp. Physics [approved March 1982].

This paper gives full quantum-mechanical analysis of the magnetic field (first discussed by London) which appears spontaneously when a sample of superconductor is set into rotation. It shows that, for slow rotation velocities and using certain approximations, the field B threading a cavity within a superconductor which rotates at angular velocity ω , is given by

$$eB = 2(m_0 - W/c^2) \omega,$$

where $-e$ is the charge on the electron, m_0 is the free electron mass, W is the workfunction of the superconductor, and c is the velocity of light. In the calculation effects which are second-order in the rotation velocity have been ignored, and the result is only strictly valid at the zero of temperature.

Cryoelectronic Metrology, cont'd.

The application of this result to experiments using practical, non-ideal apparatus is then illustrated for a simple geometry.

Brady, R., Zimmerman, J. E., **Experiment on a Superconducting Gyroscope with No Moving Parts**, to be published in J. Low Temperature Physics [approved August 1982].

This paper describes an experimental investigation on a new type of superconducting gyroscope which has no moving parts. The theory of the effect by which the gyroscope works has been verified to an accuracy of 5%, and a rotation rate of 1 radian per second could be distinguished. Several unexpected sources of noise were encountered, and these are described along with suggestions for overcoming them. It appears to be feasible to make improvements in the sensitivity achieved in this experiment over four orders of magnitude.

Petersons, R. L., McDonald, D. G.; **Voltage and Current Expressions for a Two-Junction Superconducting Interferometer**, to be published in J. Applied Physics [approved July 1982].

The average voltage and circulating current of a superconducting interferometer containing two Josephson junctions are calculated analytically in various approximations, as functions of bias current and applied magnetic field or control current. The results are useful in calculations of the noise characteristics of a dc SQUID, as well as in other applications.

Antenna Metrology

Daywitt, W. C., **An Error Analysis for the Use of Lunar Radio Flux in Broadbeam Antenna-System Measurements**, to be published in IEEE Trans. Instrumentation and Measurement [approved June 1982].

Simple, precise expressions for lunar diameter, average brightness temperature, flux density, and shape factor are presented. An analysis of the relationship between these parameters and corresponding errors are included. For broadbeam antennas (half-power beamwidth $> 0.5^\circ$), results show that flux density and shape factor can be determined with errors less than 8% and 0.4% respectively at frequencies below 10 GHz. Extension of the analysis to higher frequencies is indicated.

Francis, M. H., and Yaghjian, A. D., **Computations of Antenna Side-Lobe Coupling in the Near Field Using Approximate Far-Field Data**, NBSIR 82-1674 (August 1982).

Computer programs, in particular CUPLNF and CUPLZ, are presently in existence to calculate the coupling loss between two antennas provided that the amplitude and phase of the far field are available. However, for many antennas the complex far field is not known accurately. In such cases it is nevertheless possible to specify approximate far fields from a knowledge of the side-lobe level of each antenna along the axis of separation, and the electrical size of each antenna. To determine the effectiveness of using approximate side-lobe level data instead of the detailed far fields we chose as our test antennas two hypothetical, linearly polarized, uniformly illuminated circular antennas for which the exact far fields are supplied to the program CUPLNF to compute the exact near-field coupling loss. Approximate fields are supplied to a new program ENVLP developed for the purpose of computing the approximate near-field coupling loss. The comparison of the results from ENVLP to those of CUPLNF indicates that the use of approximate far fields gives an estimate of the coupling loss which is good to about ± 5 dB. In addition, the plane-wave transmission formula for coupling between two antennas is used to estimate upper-bound values of coupling loss, comparing these upper bounds with the maximum coupling losses obtained

Antenna Metrology, cont'd.

from programs CUPLNF and ENVLP.

Kanda, M., **The Effects of Resistive Loading on TEM Horns**, IEEE Trans. Electromagnetic Compatibility, EMC-24, No. 2, pp. 245-255 (May 1982).

A short transverse electromagnetic (TEM) horn with continuously tapered resistive loading was developed for directional reception or transmission of picosecond pulses with minimal distortion. It was found to be broadband and nondispersive with a low VSWR. The receiving transient response of the resistively loaded "TEM" horn indicates that the waveform of a 70-ps impulse is well preserved. The theoretical analyses using the method of moments and the fast Fourier transform (FFT) technique were performed and agreed well with time-domain measurements.

Kanda, M., Chang, D. C., and Greenlee, D. H., **The Characteristics of Iris-fed Millimeter-Wave Rectangular Microstrip Patch Antennas**, Proc. 1982 IEEE Antennas and Propagation Symposium, University of Albuquerque, Albuquerque, New Mexico, May 24-28, 1982, pp. 292-295.

This paper describes the characteristics of iris-fed millimeter-wave rectangular microstrip patch antennas. A theoretical model is given to describe the iris-fed patch antenna based on aperture coupling to cavities. The impedance and antenna power patterns are given.

Kanda, M., and Ries, F. X., **Time Domain Sensors for Radiated Impulsive Measurements**, to be published in IEEE Trans. Antennas and Propagation [see also same title in Proc. IEEE Int. Symposium on Electromagnetic Compatibility, Santa Clara, California, September 8-10, 1982, pp. 296-301].

The purpose of this paper is to review various sensors and radiators commonly used for time domain antenna measure-

ments. The sensors and radiators discussed here are passive and analog devices which convert the electromagnetic quantity of interest to a voltage or current at their terminal ports. Moreover, they are primary standards in the sense that their transfer functions can be calculated from their geometries and are preferably flat (constant) across a wide frequency range. One of the major requirements for these sensors and radiators is that the electromagnetic far fields, transmitted or received, are replicas or high-fidelity derivatives of the original pulse. (Note that the transmitting transfer function of an antenna is the time derivative of the receiving transfer function of the same antenna which follows from the reciprocity theorem). For electric field strength measurements, linear antennas loaded nonuniformly and continuously with resistance, or both resistance and capacitance are discussed. Also a conical antenna and an asymptotic conical antenna are discussed from the standpoint of an improved figure of merit. For an improved directivity, various types of TEM horns are discussed, e.g., a conducting TEM horn, a CALSPAN antenna, and a resistively loaded TEM horn.

Ma, M. T., **Arrays of Discrete Elements**, Chapter 3 in book, *Antenna Engineering Handbook*, to be published in 1983.

Invited contribution for text to be published by McGraw-Hill Book Company.

Repjar, A. G., and Kremer, D. P., **Accurate Evaluation of a Millimeter Wave Compact Range Using Planar Near-field Scanning**, IEEE Trans. Antennas and Propagation AP-30, No. 3, pp. 419-425 (May 1982).

Significant progress in recent years has been made on planar near-field measurements for antenna calibrations. Such measurements are also useful in the alignment and evaluation of compact ranges because they provide more

Antenna Metrology, cont'd.

information than a limited number of analogue plots in one dimension. Contour plots of amplitude and phase data obtained from more complete 2-dimensional measurements precisely and accurately locate sources of problems in the range reflector, with phase contour plots being more useful as diagnostic tools.

Repjar, A. G., Newell, A. C., and Baird, R. C., **Antenna Gain Measurements by an Extended Version of the NBS Extrapolation Method**, Digest, 1982 Conf. on Precision Electromagnetic Measurements, Boulder, Colorado, June 28-July 1, 1982, pp. F7-F9.

A General Extrapolation Technique which eliminates the effects of ground reflections in absolute gain measurements is described. It utilizes the Extrapolation Method developed at NBS which, in its present form, utilizes only amplitude versus distance data. However, for broadbeam antennas such as those encountered below 1 GHz, ground reflections may produce unwanted oscillations in the amplitude versus distance data. Hence the data are not amenable to the curve fitting procedure of the Extrapolation Method. This problem can be overcome by including phase versus distance information to negate the effects of ground reflections.

Stubenrauch, C. F., Spiess, W., Galliano, P. G., and Babij, T., **International Intercomparison of Electric Field Strength at 100 MHz**, to be published in IEEE Trans. Instrumentation and Measurement [see also paper having same title in Digest, 1982 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 28-July 1, 1982, pp. P3-P4].

This paper discusses an international intercomparison of electric field strength at 100 MHz. Laboratories in

four countries participated in the intercomparison. Measurements from each of the laboratories fell within a range of +0.75 dB to -0.5 dB with respect to the overall average. The transfer standard used in the measurement is described and the details of the results are presented.

Wyss, J. C., Kanda, M., Melquist, D. G., and Ondrejka, A. R., **Optical Modulator and Link for Broadband Antennas**, Digest, 1982 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 28-July 1, 1982, pp. P16-P17.

To avoid pick-up and electromagnetic perturbation problems normally associated with the use of metallic cables between an antenna and receiver electronics, an optical modulator and optical link are used instead. Laser light (632.8 nm) is modulated at the antenna by an electro-optical, lithium tantalate crystal and is then transmitted optically to the receiver electronics where the laser light is detected using an avalanche phototransistor. The crystal is mounted directly on the antenna without amplifiers or other active components. In initial tests, a modulating voltage is applied directly to the antenna. The frequency response was tested to be flat (± 3 dB) from 10 MHz to at least 430 MHz. The output signal was linear from 0.01 - 10 V input with a signal to noise ratio of 2:1 at 10 mV input.

Yaghjian, A. D., **A Delta-Distribution Derivation of the Electric Field in the Source Region**, Journal of the Electromagnetic Society, 2, No. 2, pp. 161-167 (April/June 1982).

The sequential approach to distribution theory is used to rigorously derive the expression, which remains valid in the source region, for the electric field in terms of the electric dyadic Green's function. Sufficient conditions for the behavior of the current density that insure that the electric field obeys

Antenna Metrology, cont'd.

Maxwell's differential equations are determined explicitly.

Noise Metrology

Wait, D. F., **Precision Measurements of Antenna System Noise Using Radio Stars**, to be published in IEEE Trans. on Instrumentation and Measurement [see also paper having same title in Digest, 1982 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 28-July 1, 1982, p. F-17].

This paper reviews the National Bureau of Standards (NBS) precision noise measurements program for antenna systems which have been made using Cassiopeia A and the moon. The Earth Terminal Measurement System (ETMS) was developed by NBS to make measurements of figure of merit (G/T), and the noise equivalent flux (NEF). The accuracy of the noise measurements are typically between five and fifteen percent for systems with antenna gains between 51 and 65 dB and frequencies between 1 and 10 GHz.

Microwave and Millimeter-Wave Metrology

Hoer, C., **On Determining the Characteristic Impedance of a Coaxial Transmission Line**, to be published in IEEE Trans. Microwave Theory and Techniques [approved April 1982].

When a length of transmission line is used as the standard in calibrating a network analyzer, the loss and phase shift through the line are usually determined along with parameters describing the network analyzer. The characteristic impedance, Z_0 , of the line can be determined from this loss and phase shift and the capacitance of the line. The capacitance can be calculated from the line dimensions or measured at a low frequency such as 1 kHz. An example shows how the loss and phase shift, and hence Z_0 , of the line change with frequency.

Hoer, C., **Choosing Line Lengths for Calibrating Network Analyzers**, to be published (winter 1983-84) in IEEE Trans. Microwave Theory and Techniques, [approved April 1982].

Equations, examples, and a table are given to help choose the best length for a precision transmission line which is used in calibrating a network analyzer. One line will cover a frequency range of about 10:1. Two lines will cover a range of about 65:1.

Laser metrology

Case, W. E., **Documentation of the NBS C, K, and Q Laser Calibration Systems**, NBSIR 82-1676, (September 1982).

This report provides a complete guide for the documentation of the NBS laser power and energy calibration systems. The report also describes a detailed procedure for operating the three (C, K, and Q) calibration systems under computer control.

Optical Fiber Metrology

Danielson, B.L., Franzen, D.L., Gallawa, R.L., Kim, E.M., Young, M., **Characterization of a Concentric-Core Fiber**, NBSIR 82-1661 (April 1982).

Several optical properties of a concentric core fiber are examined. These include attenuation, radiation patterns, pulse broadening, index profile, backscatter signatures, signatures, and capture fraction experimental techniques are briefly described and the significance of the measured parameters is discussed.

Day, G. W., Danielson, B. L., Franzen, D. L., Kim, E., Young, M.; Editors, **Optical Fiber Characterization**, NBS SP- 637, Vol. 1, (July 1982).

Optical fiber waveguide measurements are described. Systems to determine the backscatter, bandwidth, and index profile covered in detail. Measurement

Optical Fiber Metrology, cont'd.

comparisons between laboratories are given for fiber attenuation, bandwidth, numerical aperture, and core diameter.

Gallawa, R. L., **On the Definition of Fiber Numerical Aperture**, Electro-optical Systems Design, p 47, April 1982.

This paper addresses the definition of the fundamental fiber optics term: fiber numerical aperture. The popular definition of the term is not adequate as a measure of light-gathering ability, because of leaky rays. Nevertheless, it is recommended that the term be accepted because of its utility for most fibers in use today.

Kim, E. M., Franzen, D. L., **Two-Dimensional Near-Field Contouring of Optical Fiber Cores**, to be published in Proc. of the Society of Photo-Optical Instrumentation Engineers [approved August 1982].

A microcomputer controlled system is described for measuring the two dimensional near-field radiation pattern from optical fibers. Because radiation measurements may be made in two dimensions, a novel method has been devised whereby a constant intensity contour of the core is mapped. A modified Left-Most-Looking (LML) digital image encoding algorithm is used to map the contour of the fiber core. The iso-intensity map provides information about the tolerance field, in which all of the measured iso-intensity points lie, and core noncircularity. Such information is useful in determining coupling efficiency at splices, connector joints, and terminal points. This paper will discuss the measurement apparatus, accuracy, precision, stability, and method of analysis of the NBS system. In addition, results will be presented on measurements of core diameters, the length dependence of such measurements, wavelength dependence of the radiation patterns, power law fits to the

patterns, calibration apparatus, and iso-intensity contours of telecommunications-grade fibers.

Other Fast Signal Topics

Gibson, K. A., and Miller, C. K. S., **Bibliography of the NBS Electromagnetic Fields Division Publications**, NBSIR 82-1673 (August 1982).

Covers period from January 1980 through December 1981.

Roe, K. C., and Wittmann, R. C., **Improved Coal Interface Detector**, NBSIR 82-1663 (May 1982).

This report describes the theory, design, construction and testing of an electromagnetic coal interface detector. The purpose of this type detector is measuring the thickness of roof coal left during underground mining operations. An above ground test facility constructed to evaluate the coal interface detector is also described.

Stoltenberg, R. E., and Wittmann, R. C., **Acoustical Interferometer Wader Final Report of Advanced Development Test and Evaluation**, NBSIR 82-1671 (June 1982).

This document reports and evaluates the results of the Advanced Development Test and Evaluation of the Advanced Development Model (ADM) of the Acoustic Interferometer Wader (AIW) detector. The Acoustic Interferometer is a security device designed to detect penetration of secure areas by human intruders traversing shallow water, primarily by wading. This report describes the conduct, analysis, conclusions, and recommendations of the final tests conducted by NBS to determine the performance of the ADM. The AIW detector is an active, low frequency, totally automatic system. It utilizes relatively low cost components and can be deployed and operated with minimal skills making it suitable for quick

Other Fast Signal, cont'd.

response situations. The Advanced Development, Test, and Evaluation activity examined the performance with respect to Probability and Detection, False Alarm Rate, and Nuisance Alarm Rate, for the following variables: environment; wader types, wader paths, wader attire, insonification, and time of day. The tests were conducted utilizing a computer-controlled sophisticated data acquisition and analysis system. This data acquisition system permitted a complete record of not only the system performance but the precise time record of logic events which allowed the investigation of an alternate family of performances based upon the same data base.

Young, M., **Objective Measurement and Characterization of Scratch Standards**, to be published in Proc. Society of Photo-Optical Instrumentation Engineers [approved July 1982].

The manufacture of scratch standards for use with MIL-O-13830A has been hampered by the lack of an objective measurement technique. The U.S. National Bureau of Standards has therefore undertaken a comprehensive program to provide quantitative measurements of the light scattered by the scratches and to correlate them with assessments made by trained observers. In this paper, I apply scalar diffraction theory to developing design criteria for a polar scanning apparatus, describe the apparatus, and show scans from one full set of secondary standards. Comparing these scans with the visual assessments is not straightforward.

ELECTRICAL SYSTEMSPower Systems Metrology

Hebner, R.E., **Development of Power System Measurements -- Quarterly Report January 1, 1982 to March 31, 1982**, NBSIR 82-8528 (June 1982).

This report documents the progress on four technical investigations sponsored by the Department of Energy and performed by the Electrosystems Division, the National Bureau of Standards. The work described covers the period from January 1, 1982 to March 31, 1982. The report emphasizes the calibration of instruments designed to measure the 60-Hz electric field in biological exposure facilities, selected errors inherent in the use of time-domain reflectometry to determine the rf characteristics of power cables, the measurement of the rate of decomposition of SF₆ in positive dc-corona discharges, and in the measurement of space charge in transformer oil between 100°C and 150°C.

Hebner, R.E., **Developments of Power System Measurements -- Quarterly Report October 1, 1981 to December 31, 1981**, NBSIR 82-2501 (May 1982).

This report documents the progress on four technical investigations sponsored by the Department of Energy and performed by the Electrosystems Division, the National Bureau of Standards. The work described covers the period from October 1, 1981 to December 31, 1981. The report emphasizes measurements of ion density in air, the use of signals above 1 GHz to detect incipient faults in cables, the measurement of by-products which develop during partial discharge activity in SF₆, and the determination of the breakdown behavior of an oil-paper interface.

Hillhouse, D. L., Petersons, O., and Sze, W. C., **A Simplified System for Calibration of CCVTs in the Substation**, NBS Tech. Note 1155 (May 1982).

Coupling capacitor voltage transformers (CCVTs) are widely used for the revenue metering of energy exchanged between utilities at EHV (345-500 kV) interties. These devices are installed permanently in substations, and must be calibrated there. Allowable error is

Power Systems Metrology, cont'd.

$\pm 0.3\%$ and ± 4.6 mrad (milliradians). NBS developed, and has had in operation for several years, a prototype system for field calibration of these CCVTs. This prototype system is more accurate, more complicated, more bulky, and more costly than is essential for this application. This report describes a simplified, lighter, and less costly CCVT calibration system, newly developed and field tested by NBS. The principal elements of this system are a portable reference standard transformer and moderate voltage power supply (14.4 kV), a modular capacitive transfer standard divider, and a voltage comparator. Results obtained with this system agree with the prototype to within $\pm 0.03\%$ and ± 0.1 mrad. The prototype system is installed permanently in a dedicated calibration truck. The new system could operate with a non-dedicated truck to transport the disassembled modular divider, and a van to transport the rest of the components and to serve as a field laboratory.

Kelley, E. F., Hebner, R. E., Forster, E. O., and FitzPatrick, G. J., **Observations of Pre- and Post-Breakdown Events in Polydimethylsiloxanes**, Proc. 1982 IEEE Int. Symposium on Electrical Insulation, Philadelphia, PA, June 7-9, 1982, pp. 255-258.

The effect of viscosity and rate of voltage application on the electrical breakdown process in four polydimethylsiloxane fluids has been investigated under nonuniform field conditions using a highspeed image converter camera. The viscosity of these fluids ranged from 10 to 10,000 cSt, and the rate of rise of the approximately trapezoidal voltage pulse varied from 10 to 42 kV/ μ s. It was noted that, within experimental error, viscosity had no effect on the breakdown process. When the cathode was a point, pre-breakdown streamer propagation was shown to be related to the rate of rise of the applied voltage, and the breakdown

voltage was highest for the highest rate. When the anode was a point, the streamer propagation was approximately independent of applied voltage. The time to cross the gap of 3mm was determined to 0.6 ± 0.1 μ s independent of the fluid's viscosity. The implications of those findings are discussed in the light of existing theories.

McKnight, R. H., **The Measurement of Net Space Charge Density Using Air Filtration Methods**, NBSIR 82-2486 (April 1982).

The efficiency of a high efficiency particulate air (HEPA) of absolute filter for removing charge from an air stream has been measured for a variety of space charge and air flow conditions. Ion densities ranged from 10^5 to $10^6/\text{cm}^3$ and were for positive and negative space charge as well as mixtures. For all conditions studied, the transmission of the filter was less than 0.1%. For space charge consisting predominantly of ions of one polarity, space charge density measurements made using HEPA filters and ion counters may be compared directly. The filter is well suited for all accurate measurements of net space charge density. Three other types of fibrous filters also have been studied.

McKnight, R.H., and Kotter, F.R., **A Facility to Produce Uniform Space Charge for Evaluating Ion Measuring Instruments**, to be published in IEEE Trans. Power Apparatus & Systems [also available as NBSIR 82-2517 (June 1982)].

A low-speed wind tunnel containing space charge has been constructed and evaluated. The facility is used for testing the performance of ion counters and net space charge measuring devices. Depending on location within the system, space charge densities range from 2.5 to 5.7×10^{-8} C/m³. The space charge density is spatially uniform within $\pm 5\%$ over more than 90% of the cross-sectional area of the test volume, but

Power Systems Metrology, cont'd.

decreases by approximately 20% between two positions separated by 1 m. Ion densities achieved in this system are comparable to those found near high-voltage dc transmission lines but are free from the accompanying large electric fields.

McKnight, R.H., Kotter, F.R., Mikasian, M., and Hagler, J.N., **1981 Annual Report -- Electrical and Magnetic Field Measurements**, NBSIR 82-2527 (July 1982).

The NBS program is concerned with developing methods for evaluating and calibrating instrumentation for use in measuring the electric field and various ion-related electrical quantities in the vicinity of high-voltage direct-current (HVDC) transmission lines and in apparatus designed to simulate the transmission line environment.

The laboratory investigation of errors associated with above-ground operation of sensors for measuring vertical current density has been completed. Significant errors were observed for both unguarded and guarded sensors, ranging from 4 to 25% for the guarded plates and 10 to 35% for the unguarded plates for a wide range of geometrical parameters. Preliminary results from a field day held in October 1981 are in agreement with the laboratory results.

A new low-speed air-flow facility has been constructed. Using multiwire planar corona discharge ion sources, ion densities from $1.6 \times 10^5/\text{cm}^3$ to $1.4 \times 10^6/\text{cm}^3$ have been measured using an absolute filter technique.

Losses at the inlet of a parallel plate ion counter due to fringing fields have been determined using an ion counter with variable geometry. Calculations based on a two-dimensional finite element code predict a greater loss than actually observed, but are in

qualitative agreement with experimental results.

The above-ground operation of a parallel plate has been investigated using a monopolar line. The initial results obtained show that the ion densities measured using the counter are strongly dependent on ion counter potential. These results represent only a limited set of measurements, but indicate problems associated with above-ground measurements of ion density.

The transmission of charge in an air stream through a high-efficiency particulate air (HEPA) filter has been determined to be less than 0.1% for a wide range of flow and ion density conditions. The result indicates that a HEPA filter may be useful in calibrating ion counters when the net space charge density and ion density are equivalent.

A retarding field scheme has been considered for use in measuring the mobility spectrum of the ions in the low-speed air flow facility. The results of a limited number of measurements show that the method may be a useful one for this application but that a number of problems need further investigation, including the effects of space charge.

Ramboz, J. D., Ondrejka, A. R., and Anderson, W. E., **Sampling-Rate Drift Problems in Transfer Function Analysis of Electrical Power Cables**, Proc. Waveform Recorder Seminar, Boulder, Colorado, October 1981, NBS Spec. Pub. 634, pp. 47-53 (June 1982).

An examination of measurement problems caused by sampling-rate drift has been initiated at the National Bureau of Standards. This work arose from the study of degradation in underground power distribution and transmission cables, where precise measurements of radio-frequency dispersion characteristics (i.e., attenuation and phase delay as a function of frequency) are necessary. Cable dispersion results are

Power Systems Metrology, cont'd.

obtained using time-domain-reflectometry and fast Fourier transform methods and spectra obtained from different data sets are compared. But because the data are necessarily taken at different times, drifts in sampling rate can occur and cause erroneous results in the frequency domain. Measurement methods for the detection of sampling rate drifts and computation methods for correcting the data are discussed and illustrated.

Van Brunt, R. J., **Effects of H₂O on the Behavior of SF₆ Corona**, Proc. Seventh Int. Conference on Gas Discharges and Their Applications, London, England, August 31-September 3, 1982, pp. 255-258.

The effects of trace amounts of H₂O vapor (<300 ppm) on point-to-plane dc-corona inception and corona pulse characteristics in SF₆ were investigated. Corona discharges were generated in short gaps, 1.0 to 3.0 cm, for sharp point electrodes of diameter ~0.1 mm, and for gas pressures in the range of 100 to 400 kPa. Trace levels of H₂O were introduced by electrical heating of a wire in the gas, and its concentration was monitored with a gas chromatograph-mass spectrometer. Water vapor was found to significantly enhance the intensity of corona at a given voltage, as indicated by an order of magnitude or more increase in average discharge current and corona pulse rate. The presence of small quantities of H₂O greatly inhibits formation of positive streamer burst pulses and significantly modifies the shape of the corona pulse height distribution. On the other hand, introduction of H₂O results in only a slight reduction in the overall dielectric strength of SF₆.

Pulse Power Metrology

Kotter, F.R., and Smith, A.N., **A Study of Air-Gap Breakdown at 28.5**

kilohertz, to be published in IEEE Trans. Power Apparatus and Systems.

Measurements of the electrical breakdown of both quasi-uniform- and highly non-uniform-field air gaps at a frequency of 28.5 kHz are reported. Gap lengths between a variety of electrode geometries ranged from a few centimeters to over 2 m. Breakdown voltages significantly below the corresponding 60-Hz values were observed with electrodes for which appreciable pre-breakdown discharges occurred. A pattern of "anomalous" flashovers at considerably lower than the normal breakdown voltages was noted with quasi-uniform field gaps. The results appear to correlate well with the data found in the literature for higher frequencies but lower voltages.

McKnight, R.H., and Hebner, R.E., Editors, **Measurement of Electrical Quantities in Pulse Power Systems**, Proc. Workshop on Measurement of Electrical Quantities in Pulse Power Systems, NBS Special Pub. 628 (June 1982).

The Workshop on Measurement of Electrical Quantities in Pulse Power Systems addressed measurements in pulse systems having the characteristics of pulse duration less than a millisecond, system voltages greater than 10 kilovolts, and system currents greater than 10 kiloamperes. The presented papers were divided into four categories: voltage measurements, current measurements, power and energy measurements, and data acquisition. Included are discussions of applications of conventional measurement techniques and state-of-the-art systems.

Magnetic Materials and Measurements

Fickett, F. R., **Low Temperature Material Perspective**, Advances in Cryogenic Engineering, 28, pp. 1-16, July 1982.

The evolution of materials research at cryogenic temperatures is traced from its earliest beginnings to the present

Magnetic Materials & Meas., cont'd.

day. The emphasis is on developments in the United States. Nonsuperconducting components of cryogenic systems are the main topic, but practical superconductors are not neglected. An assessment of the data base as it now exists is presented as well as some projections for the future. A few mild-mannered comments are made regarding the modern tendency to first build large devices and then do the materials research.

Zimmerman, J. E., **Biomagnetism: an Interdisciplinary Approach - Chapter 2; Magnetic Quantities, Units, Materials, and Measurements - Chapter 3** of book, *Cryogenics*, to be published as NATO Advanced Study Institute Publication [approved September 1982].

The intent of the overall work is that it be intelligible to both physical and medical scientists. Chapter 2 covers the terminology of magnetism, simple theory of magnetostatics, Ohm's Law, electric and magnetic SI units, magnetic materials, magnetic sensors, and magnetic measurements. Chapter 3 covers Nyquist noise and construction of dewars and refrigerators for SQUID magnetometers.

Superconductors

Clark, A. F., **Development of Standards for Superconductors**, NBSIR 82-1678 (July 1982).

A cooperative program with the Department of Energy, the National Bureau of Standards, and private industry is in progress to develop standard measurement practices for use in large scale applications of superconductivity. The goal is the adoption of voluntary standards for the critical parameters and other characterizations of practical superconductors. Progress for the period October 1980 through January 1982 is reported. The major effort was the development of a standard test method

for critical current, the necessary back-up research, and the coordination of the adoption of the test method and a standard terminology through the subcommittee level in ASTM.

Ekin, J. W., **Effect of Strain on the Critical Parameters of V₂ (Hf,Zr) Laves Phase Composite Superconductors**; *Appl. Phys. Ltrs.*, 40(9), pp. 844-846, May 1982.

Strain effects on the critical parameters of composite-processed V₂ (Hf,Zr) Laves phase superconductors have been examined. The critical temperature is found to be insensitive to the strain induced by the thermal differential contraction between the composite components. Critical current versus uniaxial strain curves obtained are completely flat at magnetic fields up to 19T. It also turns out that the bulk upper critical field shows essentially no sensitivity to uniaxial strain. These results, which are quite different from those reported for Al₅ compound superconductors, are discussed in terms of the structural insensitivity of the Laves phase superconductors. Fractography suggests that the mechanical properties of V₂ (Hf,Zr) composite conductors may be improved by the grain refinement of component alloys.

Ekin, J. W., **Superconductors**, to be published as Chapter 13 in book, *Materials at Low Temperatures* [approved May 1982].

An introduction to practical superconductors is presented. Topics covered are critical temperature, critical magnetic field, critical current, conductor fabrication, stability, ac losses, and mechanical properties. An introduction to each property is presented along with typical data on practical materials and a brief treatment of the experimental methods used to measure the property. For quick reference, the chapter contains an overall summary and reference guide to the principal parameters affecting superconductor material

Superconductors, cont'd.

selection and multifilamentary composite design.

Ekin, J.W., Flukiger, R., Specking, W., **Effect of Stainless Steel Reinforcement on the Critical-Current versus strain Characteristic of Multi-filamentary Nb₃Sn Superconductors**, to be published in Applied Physics Letters [approved August 1982].

A series of multifilamentary Nb₃Sn superconductors were fabricated containing from 0% to 52 vol.% stainless steel reinforcement strands as an integral part of the conductor. Critical-current versus strain measurements are reported which show that the stainless steel introduces a relatively large compressive prestrain $\epsilon_m = 0.84\%$ for 52 vol.% stainless steel. Accompanying this high compressive prestrain in the reinforced conductors is a large degradation of the conductor's critical current, I_c . The I_c degradation relative to the strain-free value has been measured, for example, to be more than 50% at 13 T for $\epsilon_m = 0.64\%$. Several methods are discussed for reducing the large I_c degradation in A15 superconductors containing integral reinforcement.

Ekin, J. W., Pittman, E. S., Supercynski, M. J., and Waltman, D. J., **Training Studies of Epoxy-impregnated Superconductor Windings**, Advances in Cryogenic Engineering, 28, pp. 719-728, (Plenum Press, NY), July 1982.

A systematic study of training is being carried out in epoxy-impregnated NbTi superconductor windings. The effects of the following factors on training are reported. 1) coating the superconductor with an epoxy release agent, 2) adding a milled fiberglass filler to the epoxy impregnant, 3) prestressing the superconductor prior to winding, 4) room temperature cycling of a trained winding, and 5) vacuum impregnating superconductor windings with wax instead of epoxy. The results indicate that a

major source of training in epoxy impregnated magnets is microfracture of the epoxy resin.

Goodrich, L. F., Fickett, F. F., **Critical Current Measurement: A Compendium of Experimental Effects**; Cryogenics, pp. 225-242, May 1982.

The results of a program to evaluate the measurement of the critical current of relatively small (<600A) practical superconductors are presented. Experimental data showing the effect of various parameters on the measurement are given. Specific areas covered are: experimental design and sample mounting; electric field and resistivity criteria; field and current; and temperature and strain effects. The goal of the presentation is to describe the critical current measurement process and its pitfalls in sufficient detail to serve as a guide for those relatively new to the field of practical superconductors.

Goodrich, L. F., Ekin, J. W., and Fickett, F. R., **Effect of Twist Pitch on Short-Sample V-I Characteristics of Multifilamentary Superconductors**, Advances in Cryogenic Engineering, 28, pp. 571-58, (Plenum Press, NY) July 1982.

The voltage tap location on short samples of twisted multifilamentary superconductors can result in anomalous V-I characteristics and significantly affect the determination of critical current. A phenomenological model of the effect has been developed based on the twist pitch of the wire and current-transfer theory. Extensive experimental data has ruled out other potential explanations for the observed behavior.

ELECTROMAGNETIC INTERFERENCE

Adams, J. W., **Measurement of Electromagnetic Radiation from Electric Rail Cars**, NBSIR 82-1669 (August 1982).

Existing Electromagnetic Compatibility (EMC) standards are not directly

ELECTROMAGNETIC INTERFERENCE, cont'd.

applicable for measuring Electromagnetic Interference (EMI) from an electric-rail vehicle. This report describes a measurement system and procedure that has potential for making the needed measurements. This system and procedure need further evaluation, use, and improvement before they could be considered for general use. The problems that were considered are discussed, and those that need additional work are given. Sample measured data from a MARTA rail car is given. The measurements were performed at the Department of Transportation Test Center near Pueblo, Colorado.

Crawford, M. L., **Evaluation of Shielded Enclosure for TEMPEST Measurements Without and With RF Anechoic Material**, Record, Tri-Service TEMPEST Symposium, Lawrence Livermore Labs., Livermore, CA, November 16-18, 1982 [approved September 1982].

This paper gives the results of measurements performed by the National Bureau of Standards to evaluate the potential influence of rf absorbing material installed inside a shielded enclosure on the accuracy of TEMPEST measurements made using the shielded enclosure. The facility evaluated was a 3.76-m wide by 6.2-m long by 2.44-m high shielded enclosure located at Hanscom Air Force Base, Massachusetts. The paper briefly discusses the measurement technique used, describes the test facility and test configurations, and the spherical dipole radiators used for generating the reference standard fields. Tests were performed to evaluate the influence of (1) placement location of both the source and receiving antenna inside the enclosure, (2) separation distance between source and receiving antenna, and (3) height of source above the floor of the enclosure on the measurement results. Measurements made before and after installation of the rf absorbing material indicated a significant improvement in accuracy (error typically

less than ± 10 dB as compared to > 30 dB) at frequencies above 30 MHz where the absorber is effective.

Driver, L. D., and Cruz, J. E., **Development of the NBS Isotropic Magnetic-Field Meter (MFM-10)**, 300 kHz to 100 MHz, Proc. IEEE Int. Symp. on EMC, Santa Clara, California, September 8-10, 1982, pp. 460-467.

An isotropic magnetic-field meter is described which provides accurate near-zone measurements of H-fields over the range of 0.01 A/m to 250 A/m from 300 kHz to 100 MHz. This instrument's many advanced features include (1) wide frequency coverage, (2) large dynamic range, (3) flat frequency response, (4) high overload capacity, and (5) the capability of measuring each of the three orthogonal H-vectors, as well as their Hermitian magnitude.

FitzGerrell, R. G., **Free-Space Transmission Loss for Anechoic Chamber Performance Evaluation**, IEEE Trans. Electromagnetic Compatibility EMC-24, No. 3, 356-358 (August 1982).

Performance of a rectangular, RF, anechoic chamber is evaluated by measuring the relative insertion loss versus separation distance between sources of chamber illumination and small dipole or open waveguide antennas on a particular measurement axis. Measuring data are compared to free-space transmission loss calculated using finite-range source antenna gains. A lack of fit between measured insertion loss and calculated transmission loss is a measure of reflections from chamber surfaces assuming the finite-range gain calculations are exact for the separation distances considered. This assumption is made as a result of excellent agreement between a smooth curve fit to the measured data and the calculated free-space data.

Kanda, M., Ries, F. X., Driver, L. D., and Orr, R. D., **Design Considerations for Broadband Magnetic-Field Sensors**,

ELECTROMAGNETIC INTERFERENCE, cont'd.

Digest, 1982 Conference on Precision Electromagnetic Measurements, Boulder, Colorado, June 28-July 1, 1982, pp. P11-P13.

Basic design considerations required to produce broadband magnetic-field sensors are discussed. Three different configurations are discussed. The advantages and disadvantages of each configuration are presented in terms of its sensitivity and bandwidth. A physical discussion is given for the operation of a shielded loop.

Koepke, G. H., and Ma., M. T., **A New Method for Determining the Emission Characteristics of an Unknown Interference Source**, Proc. IEEE 1982 Int. Symposium on Electromagnetic Compatibility, Santa Clara, California, September 8-10, 1982, pp. 151-156.

A method for determining radiation characteristics of leakage from electronic equipment for interference studies is being developed. The system uses a transverse electromagnetic cell to isolate the equipment under test from the environment and to provide the coupling mechanism for power and phase measurements. This method will completely determine the far-field radiation power pattern and the total power radiated based upon an equivalent electric and magnetic dipole source model.

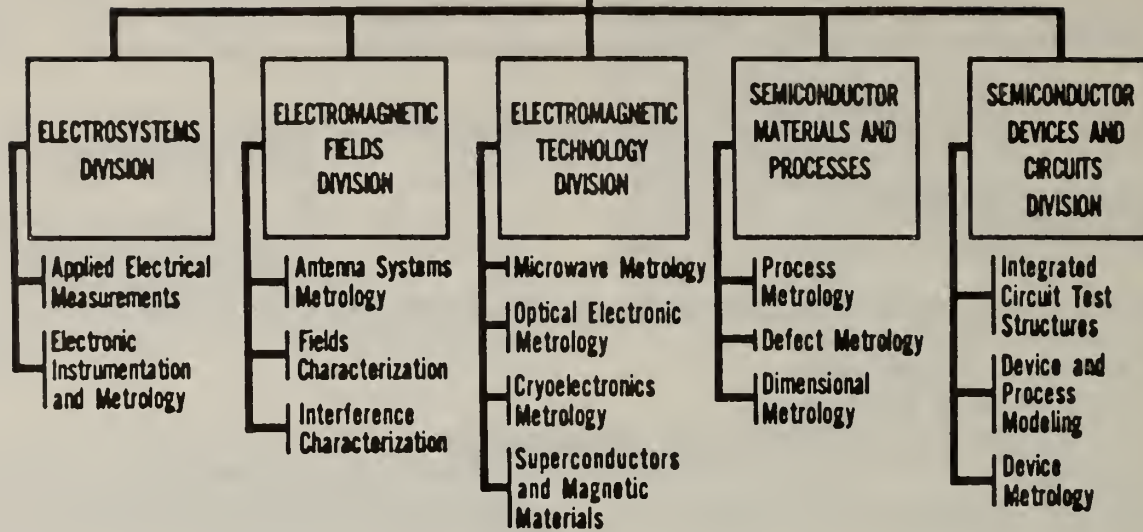
Wilson, P. E., Chang, D. C., and Ma, M. T., **Input Impedance of a Probe Antenna Exciting a TEM Cell**, NBS Tech. Note 1054 (April 1982).

The input impedance of a probe antenna exciting a transverse electromagnetic (TEM) transmission line cell is formulated by a variational approach. The formulation also utilizes the results from a previous work on the field distribution inside a TEM cell excited by a vertical electrical Hertzian dipole. The final result of impedance is shown to consist of two distinct

terms, which are respectively contributed by the ordinary rectangular waveguide and the gap perturbation. Numerical results for both the real and imaginary parts of the impedance are given. The resistive part is found to be proportional to the square of the probe length, and the reactive part largely capacitive. The analysis presented herein may be used to study the effect of cables associated with equipment to be tested inside a TEM cell.

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