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Center for Electronics and Electrical Engineering

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INTRODUCTION TO THE CEEE TECHNICAL PUBLICATION ANNOUNCEMENTS

This is the eighth issue of a quarterly publication providing information on the technical work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Publication Announcements covers the first quarter of calendar year 1986.

Organization of Bulletin: This issue contains citations and abstracts for Center papers published in the quarter. Entries are arranged by technical topic as identified in the table of contents and alphabetically by first author within each topic. Following each abstract is the telephone number of the individual to contact for more information on the topic; unless otherwise noted, this person is the first author. This issue also includes an announcement of recently issued standard reference materials and a list of sponsors of the work.

Center for Electronics and Electrical Engineering: Center programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards.

The metrological products of these programs 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.

The work of the Center is divided into four major programs supporting semiconductor technology; fast signals acquisition, processing, and transmission; electrical systems; and the determination of electromagnetic interference. The Semiconductor Technology Program is the responsibility of the Semiconductor Electronics Division, and the Electromagnetic Interference Program is the responsibility of the Electromagnetic Fields Division. The Fast Signal Acquisition, Processing, and Transmission Program has components in three divisions (Electrosystems, Electromagnetic Fields, and Electromagnetic Technology), and the Electrical Systems Program has components in two (Electrosystems and Electromagnetic Technology). See the table of contents on the opposite page for identification of the topics covered by each program, as represented in this issue. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information.

Center sponsors: The Center Programs are sponsored by the National Bureau of Standards and a number of other organizations, in both the Federal and private sectors; these are identified on page 20.

Note on Publication Lists: Bibliographies covering both recent and earlier work are available from each division. The current issue of each is identified under the "Publications Lists" in the "Additional Information" section.

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SEMICONDUCTOR TECHNOLOGY

Silicon Materials

Baghdadi, A., **Measurement of the Oxygen and Carbon Content of Silicon Wafers by Fourier Transform Spectrophotometry,** Inorganic Materials Characterization, L.A. Casper, Ed., ACS Symposium Series 295, pp. 208-229 (American Chemical Society, 1986).

Fourier transform infrared (FT-IR) spectrophotometry is a rapid, nondestructive characterization technique which is being increasingly applied on a large scale to the routine measurement of the oxygen and carbon content of silicon wafers used for the fabrication of microelectronic devices. Control of the oxygen content is needed to achieve acceptable yields in modern device processing, particularly for those processes which utilize oxide precipitates to protect active regions of devices from contamination by metallic impurities during high-temperature processing. The interlaboratory reproducibility of the measurement is not adequate considering the degree of control of the oxygen that is required. This review focuses primarily on the measurement of oxygen and carbon in silicon and on methods for improving quantitative FT-IR absorption measurements on semiconductor wafers.
[Contact: (301) 921-3786]

Lowney, J.R., **Impurity Bands and Band Tailing in Moderately Doped Silicon,** J. Appl. Phys., Vol. 59, No. 6, pp. 2048-2053 (15 March 1986).

The density of states of the valence and conduction bands in silicon has been calculated at room temperature for dopant densities near the transition between the existence of a distinct impurity band and its coalescence with the continuum band to form a band tail. The dopant densities for the three cases considered are: 1) 1.5×10^{18} cm^{-3} acceptors; 2) 6.2×10^{18} cm^{-3} acceptors; and 3) 1.2×10^{19} cm^{-3} donors compensated by 6.2×10^{18} acceptors. The calculation is based on multiple-scattering theory with the self-energy calculated self-consistently to all orders of the interaction. The results show a small but significant amount of effective band-gap narrowing.
[Contact: (301) 921-3786]

Dimensional Metrology

Nyyssonen, D., **Procedure for Calibration of Ferrite Gaps in Magnetic Tape Heads Traceable to NBS AR-Chromium Optical Linewidth SRMs,** NBSIR 86-3306 (January 1986).

Accurate calibration of micrometer and submicrometer optical linewidth measuring systems requires that the calibration standard match the properties of the line to be measured. The NBS photomask linewidth standards have been designed for use by the integrated circuit community and are not directly suitable for use in other applications. A method of calibrating systems for measuring the width of ferrite gaps in magnetic calibrating systems for measuring the width of ferrite gaps in magnetic tape heads has been developed that involves a two-step calibration using the NBS anti-reflecting-chromium photomask as the primary reference standard. This primary standard is used in transmitted green light to calibrate the linewidths on a secondary black-chromium photomask. This is a valid procedure because these lines are patterned in black-chromium layers that are thin compared to the wavelength of the green light and have negligible transmission. Since this secondary black-chromium photomask has similar optical properties to ferrite gaps when viewed in reflected green light, it can then be used to calibrate the linewidth measuring system to be used for ferrite gaps. The results of a preliminary study of this method shows that the errors associated with this two-step process are below 0.1 µm. The study also indicated that without this two-step process, the errors could be 0.3 µm or more.

Dimensional Metrology, cont'd.

[Contact: Robert D. Larrabee (301) 921-3625]

Integrated Circuit Test Structures

Ellenwood, C.H., and Mattis, R.L., **Release Notes for STAT2 Version 2.00A: An Addendum to NBS Special Publication 400-75,** NBSIR 85-3292 (January 1986).

STAT2 is a FORTRAN program which is used to analyze and display data from microelectronic test structures fabricated on semiconductor wafers. The program reads data as a two-dimensional array, extracts sample statistical values, identifies outliers, calculates replacement values for outliers, and makes histograms and circular gray-tone data maps. Version 2.00A is an adaptation of STAT2 to run under Version 3.2 of the RSX-11M operating system. This operating system is used on the automatic tester which acquires the test structure data. Data can therefore be taken and analyzed on the same system.
[Contact: (301) 921-3801]

Mattis, R.L., **Release Notes for STAT2 Version 1.7: An Addendum to NBS Special Publication 400-75,** NBSIR 86-3333 (March 1986).

This document describes the changes which have been made in the STAT2 computer program since its documentation in NBS Special Publication 400-75, Semiconductor Measurement Technology: A FORTRAN Program for Analysis of Data from Microelectronic Test Structures, and NBS Internal Report 83-2779, Release Notes for STAT2 Version 1.31. It is assumed that the reader has these documents, and no attempt is made to review STAT2 features or operation. The changes extend the functionality and versatility of the program. More specifically, the new features added in version 1.7 include data base extension, an input data format suitable for test sites not in a periodic array, an outlier exclusion algorithm suitable for small numbers of sites, common site exclusions for related data sets, a vector map, a scatter plot, a trend chart, extended macro command file capability, and other changes. Following the description of the changes is an annotated listing of new error messages. This document and the two previous publications cited constitute the documentation of version 1.7 of STAT2.
[Contact: (301) 921-3801]

O'Keeffe, T.W., Cresswell, M.W., Linholm, L.W., and Radack, D.J., **Evaluation and Improvement of E-Beam Exposure Routines by Use of Microelectronic Test Structures,** Extended Abstract Digest of the IEEE VLSI Workshop on Test Structures, Long Beach, California, February 17-18, 1986, pp. 182-194.

This paper describes the use of the cross-bridge test structure in conjunction with a series of interconnect test structures to assess and improve the exposure routines and procedures in the replication of submicron features. The interconnect test structures used in this experiment are resistors which include both serpentine and comb-like interconnect patterns and can be used to assess line continuity and line-to-line isolation. Results obtained during the evaluation of line continuity, resolution, linewidth, and proximity exposure effects are presented.
[Contact: Loren W. Linholm (301) 921-3801]

Radack, D.J., and Linholm, L.W., **The Application of Microelectronic Test Structures for Propagation Delay,** Extended Abstract Digest of the IEEE VLSI Workshop on Test Structures, Long Beach, California, February 17-18, 1986, pp. 191-207.

This paper presents a comparison of the ring oscillator, the inverter chain, and the delayed Johnson counter for measurement of the propagation delay of an inverter. It describes design considerations that will improve the precision and accuracy of the measurement. Modi-

IC Test Structures, cont'd.

fications to the delayed Johnson counter which allow timing comparisons to be performed on-chip are also described.
[Contact: (301) 921-3801]

Roitman, P., Suehle, J.S., Russell, T.J., and Gaitan, M., **On the Measurement of Capacitance on Wafers**, Extended Abstract Digest of the IEEE VLSI Workshop on Test Structures, Long Beach, California, February 17-18, 1986, pp. 96-104.

Capacitance measurements of both capacitor and transistor structures can provide critical parameters for process monitoring, process modeling, device modeling, and circuit modeling. However, accurate measurements of capacitance on small devices located on large silicon wafers are very difficult. The problem is simply that very low-level analog measurements must be made at the end of a necessary system of cables and probes. Several authors have proposed building capacitance meters on the wafer, which would provide relatively high-level outputs to the external test system. A method has been chosen to improve the capability to measure capacitance on wafers directly. This improvement involved three parts of the experiment: the design of the capacitors, the design of the probe fixturing, and the instrumentation. These are discussed in turn.
[Contact: (301) 921-3625]

Schafft, H.A., Grant, T., Mandel, J., and Shott, J., **Report on an Interlaboratory Experiment**, Extended Abstract Digest of the IEEE VLSI Workshop on Test Structures, Long Beach, California, February 17-18, 1986, pp. 306-325.

An interlaboratory experiment involving 15 laboratories and associated experiments conducted at NBS are described and the results given. The twofold purpose of the experiments is 1) to assess the reproducibility of electromigration characterizations made with equivalent test structures by laboratories using their own test methods and 2) to broaden the technical base needed to develop electromigration guidelines. Specially designed test chips (NBS-42), from one metallization lot, were used in the experiments. The electromigration test structures provided to the participating laboratories are made of unpassivated, sputter-deposited Al 1%Si on oxidized Si.
[Contact: (301) 921-3801]

Schafft, H.A., and Saxena, A.N., **Electromigration Test Methodology and Characterization**, Proceedings of the Third IBM Electromigration Symposium, Poughkeepsie, New York, April 1-2, 1985, unpaged.

The accuracy of electromigration characterizations of metallizations may be affected significantly by the design of the electromigration test structure and by the conditions and procedures used in testing these structures. These effects are shown in a thermal analysis of a straight-line test structure and its packaging. The analysis uses a thermal model for an electromigration test structure from which equations are derived to calculate the temperature profile along the structure. It also uses experimental evidence to validate the thermal model and the use of a series of thermal resistance and capacitance networks to model the heat flow from the metallization through the silicon chip, package, and heat sink, and on to the oven environment.
[Contact: (301) 921-3801]

FAST SIGNAL ACQUISITION, PROCESSING, & TRANSMISSION

Waveform Metrology

Gans, W.L., **Calibration and Error Analysis of a Picosecond Pulse Waveform Measurement System at NBS,** Proceeding of the IEEE, Special Issue on Radio

Waveform Metrology, cont'd.

Measurement Methods and Standards, Vol. 74, No. 1, pp. 86-90 (January 1986).

The primary system used at the National Bureau of Standards to measure fast (picosecond-nanosecond range), repetitive, electrical pulse parameters consists of a wide-band (dc-18 GHz) sampling oscilloscope interfaced to a minicomputer. This paper describes the major calibration and analysis techniques used to reduce the effects of errors inherent in this system, both deterministic and random in nature.
[Contact: (303) 497-3538]

Laug, O.B., Stenbakken, G.N., and Leedy, T.F., **Electrical Performance Tests for Audio Distortion Analyzers**, NBS Technical Note 1219 (January 1986).

Electrical performance test procedures for audio distortion analyzers were developed by the National Bureau of Standards for the U.S. Army Communications-Electronics Command. The report provides detailed, step-by-step test procedures that are based on specifications supplied by the Army for purposes of evaluating audio distortion analyzer bid samples. Examples of data sheets and tables are also provided for recording interim and final results.

The report discusses the philosophy of each measurement procedure with a view toward providing an understanding of the basic metrology required to perform the measurements. In addition, the sources of measurement error are discussed. The primary applications and basic principles of modern audio distortion analyzers are also presented.
[Contact: (301) 921-2727]

Lawton, R.A., Riad, S.M., and Andrews, J.R., **Pulse and Time-Domain Measurements**, Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 77-81 (January 1986).

A review of the state-of-the-art and science of pulse parameter measurements is given including recent advances in the use of real-time oscilloscopes, waveform recorders, equivalent time sampling oscilloscopes, and counter-timers in the measurement of repetitive and single transient signals. Recent advances in the use of artifact waveform standards and modern signal analysis techniques to compensate for measurement distortion are highlighted. The formation and progress of an IEEE committee which is developing a performance standard for waveform recorders is also described.
[Contact: (303) 497-3339]

Cryoelectronic Metrology

Hamilton, C.A., Kautz, R.L., and Lloyd, F.L., **A Josephson Series Array Voltage Standard at One Volt**, NCSL 1985 Workshop & Symposium, Boulder, Colorado, July 15-18, 1985, pp. 71-77.

Josephson voltage standards have long been limited by their low 1- to 10-mV output level. A new method for operating 1000 or more Josephson junctions in series has produced a practical standard at the 1-V level. The junction array is in the form of a microstrip which is finline coupled to a waveguide at one end and is terminated at the other end. The whole circuit is fabricated on a (6×12)-mm silicon substrate. With applied radiation at 72 GHz, the junction array produces up to 8000 quantized levels at the voltages nhf/2e. (In the U.S. 2e/h has an assigned value of 483593.420 GHz/V_{NBS}.) By selecting the level, n, and fine tuning the frequency, f, any voltage from 0.1 to 1.2 V can be obtained. The high output voltage eliminates the need for a voltage divider and greatly reduces errors due to thermal voltages. When fully evaluated, the new standard is expected to have a precision of a few parts per billion.
[Contact: (303) 497-3740]

Cryoelectronic Metrology, cont'd.

Hamilton, C.A., Kautz, R.L., Lloyd, F.L., and Steiner, R.L., **A Practical Josephson Voltage Standard at 1 V,** IEEE Electron Device Letters, Vol. EDL-6, No. 12, pp. 623-625 (December 1985).

A series array of 1484 pairs of Josephson junctions biased by microwaves at 72 GHz is demonstrated to provide stable quantized voltages at the 1-V level. The niobium/lead-alloy junctions used in the array are not affected by thermal cycling.
[Contact: (303) 497-3740]

Kautz, R.L., and Macfarlane, J.C., **Onset of Chaos in the rf-Biased Josephson Junction**, Physical Review A, Vol. 33, No. 1, pp. 498-509 (January 1986).

The onset of chaos in the radiofrequency-biased (rf-biased) Josephson junction is studied through numerical simulations. It is shown that the chaotic region predicted by the method of Melnikov spans only a narrow region of rf amplitudes and consists of weakly chaotic solutions which maintain phase lock with the rf bias. The experimentally observed threshold of chaos is shown to coincide with the onset of unlocked chaotic behavior at higher rf amplitudes.
[Contact: (303) 497-3991 or -3988]

Raisanen, A.V., McGrath, W.R., Richards, P.L., and Lloyd, F.L., **Broad-Band RF Match to a Millimeter-Wave SIS Quasi-Particle Mixer,** IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-33, No. 12, pp. 1495-1500 (December 1985).

An integrated superconducting microstrip is shown to be a convenient, flexible, and well-characterized matching element for a superconductor-insulator-superconductor (SIS) quasi-particle heterodyne mixer. The resonant interaction (Fiske modes) between the Josephson oscillations of a voltage-biased junction and the microstrip provides a convenient method for determining the electrical length of the microstrip line. An open-circuited microstrip stub that reflects a parallel inductance across the junction is used to broaden the bandwidth of the radiofrequency match of a 30- to 40-GHz SIS mixer. Measurements with Pb-alloy junctions in a full-height wavelength mixer with fixed mechanical tuning give an instantaneous bandwidth of 10 to 15 percent with a double sideband mixer noise temperature $T_M(DSB) = 10 \pm 2.5$ K.
[Contact: Frances L. Lloyd (303) 497-3254]

Antenna Metrology

Lewis, R.L., and Newell, A.C., **An Efficient and Accurate Method for Calculating and Representing Power Density in the Near-Zone of Microwave Antennas,** NBSIR 85-3036 (December 1985).

An algorithm is presented for calculating near-zone and Fresnel-region fields in front of microwave antennas from discrete numerical values of the radiated plane-wave spectrum (complex far-field pattern). That is, the near fields are calculated by numerically integrating the plane-wave spectrum representation of the field. The crux of the analysis consists of handling a numerical instability which arises from integrating discrete data. A criterion is developed for limiting the integration domain in order to exclude highly oscillatory regions of the integrand. In turn, this leads to restricting the applicable output range over which the field can be computed. With the numerical instability problem thus resolved, fast Fourier transform techniques are used to assure efficient numerical integration over a large (but restricted) output range. The results are conveniently presented as relative power-density contours in planes formed by the longitudinal coordinate axis and

Antenna Metrology, cont'd.

one transverse coordinate axis. The algorithm is capable of extremely high accuracy, which is demonstrated by comparing predicted and measured near-fields for two distinct antennas, along with a comparison against an exact theoretical model. In the case of circularly symmetric excitation models for electrically large antenna apertures, the predicted relative near-zone power-density contour plots turn out to be a function of only the relative aperture distribution. Nomographs for obtaining absolute near-zone power densities are presented for a few typical aperture-distribution functions.
[Contact: (303) 497-5196]

Muth, L.A., **Interelement Interactions in Phased Arrays: Theory, Methods of Data Analysis, and Theoretical Simulations,** NBS Technical Note 1091 (December 1985).

We review theoretically the effects of multiple reflections and mutual impedances in array environments and study possible methods of far-field pattern data analysis to recover interaction effects. We use theoretical expressions derived earlier to calculate in a two-element linear array the mutual-impedance matrix and effective excitations of elements as functions of interelement separation and n_{max}, the maximum mode number in the radiation pattern of the elements. Generalizations to two- and three-dimensional arrays are discussed.
[Contact: (303) 497-3603]

Newell, A.C., Stubenrauch, C.F., and Baird, R.C., **Calibration of Microwave Antenna Gain Standards,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 129-132 (January 1986).

Techniques for precision calibration of microwave antenna gain standards are described with discussions of applicability and associated uncertainties. Included are the three-antenna, extrapolation, swept-frequency, and near-field techniques.
[Contact: (303) 497-3743]

Yaghjian, A.D., and Wittmann, R.C., **The Receiving Antenna as a Linear Differential Operator: Application to Spherical Near-Field Scanning,** IEEE Transactions on Antennas and Propagation, Vol. AP-33, No. 11, pp. 1175-1185 (November 1985).

The general receiving antenna is represented as a linear differential operator converting the incident field and its spatial derivatives at a single point in space to an output voltage. The differential operator is specified explicitly in terms of the multipole coefficients of the antenna's complex receiving pattern. When the linear operator representation is applied to the special probes used in spherical near-field measurements, a probe-corrected spherical transmission formula is revealed that retains the form, applicability, and simplicity of the nonprobe-corrected equations. The new spherical transmission formula is shown to be consistent with the previous transmission formula derived from the rotational and translational addition theorems for spherical waves.
[Contact: Ronald C. Wittmann (303) 497-3326]

Noise Metrology

Wait, D.F., **The Impact of Automation on NBS Noise Temperature Measurements,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 117-120 (January 1986).

The accuracy of calibrating a thermal noise source using the National bureau of Standards' automated radiometer and cryogenic primary noise standards is typically ±2 percent, compared with ±3

Noise Metrology, cont'd.

percent for corresponding services that used manual radiometers and hot primary standards. Using the automated radiometer, a noise source can typically be calibrated at three frequencies in the time a manual radiometer requires to calibrate one. The automated radiometer contains a six-port reflectometer, and noise sources with reflection coefficients as great as 0.3 can be tolerated without significantly affecting the calibration accuracy. This makes it practical to use a single broad-band, coaxial noise standard from 0.03 to 14 GHz. The six-port reflectometer also makes it possible to calibrate sources with connectors different from those of the primary standard with almost no additional degradation in accuracy.
[Contact: (303) 497-3610]

Microwave Metrology

Hoer, C.A., **Multiple Network Analyzers,** McGraw-Hill Yearbook of Science and Technology, pp. 289-292 (1986).

This section discusses the theoretical basis and operational considerations for multiport network analyzers, which are linear passive microwave networks used to measure complex reflection coefficient and power. Methods for measuring these quantities at a fixed frequency have long been known and use, for instance, bridge or slotted-line techniques. In recent years very wide-band systems (covering perhaps a 10:1 range of frequency) have been developed. To make measurements on such systems one frequency at a time by manual methods is prohibitively time-consuming. Automatic network analyzers, using wide-band tunable sources and receivers under computer control, have been developed, enabling measurements to be made more rapidly. They are, however, complex and expensive, and more recently the use of multiport couplers has resulted in simpler systems.
[Contact: (303) 497-3705]

Hoer, C.A., **Summary of the NBS Calibration Services and Systems,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 32-35 (January 1986).

This paper gives a brief summary of the calibration services available at the National Bureau of Standards for attenuation, phase shift, impedance, power, and voltage at radiofrequency and microwave frequencies.
[Contact: (303) 497-3705]

Judish, R.M., **Quality Control of Measurements - Measurement Assurance,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 23-25 (January 1986).

The ability to relate individual measurements to nationally accepted standards is a requirement of traceability. This paper discusses a perspective in which the goals of traceability are viewed in terms of performance requirements on measurement quality as reflected in a statement of uncertainty.
[Contact: (303) 497-3380]

Kamper, R.A., **Uncertainty Charts for RF and Microwave Measurements,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 27-32 (January 1986).

The scope of the calibration services for electrical quantities in the range of frequency from 0 to 100 GHz that are available from the National Bureau of Standards is discussed briefly in a historical context. Some plans for improved services that will be available in the near future are noted. Charts showing the variation of uncertainty with magnitude over the full range of the respective calibration services are presented.
[Contact: (303) 497-3535]

Microwave Metrology, cont'd.

Kamper, R.A., **Uncertainty Charts for RF and Microwave Measurements,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 27-32 (January 1986).

The scope of the calibration services for electrical quantities in the range of frequency from 0 to 100 GHz that are available from the National Bureau of Standards is discussed briefly in a historical context. Some plans for improved services that will be available in the near future are noted. Charts showing the variation of uncertainty with magnitude over the full range of the respective calibration services are presented.
[Contact: (303) 497-3535]

Reeve, G.R., and Miller, C.K.S., **Current NBS Metrology Capabilities and Limitations at Millimeter Wave Frequencies,** Precision Measurements Association Newsnotes (9681 Business Center Drive, Rancho Cucamonga, CA 91730), Vol. II, pp. 55-67 (1985).

The National Bureau of Standards (NBS) establishes national artifact standards and provides a metrology base for U.S. industry and technology. NBS has not established all of the required metrology in the millimeter-wave frequency range to meet the needs of industry or government for this technology. This paper describes the technical demands of responding to the metrological challenges posed by millimeter-wave technology. A description of current capabilities at NBS is given for those parameters and frequencies where measurement services exist. The physical basis for selected novel standards, such as the 94-GHz thermal noise standard, is described to illustrate the changes required from lower frequency designs and the challenges that had to be overcome. Limitations in services and in concepts of standards for providing these services are described to indicate the degree of research that must be undertaken to satisfy future industrial needs in this evolving technology.
[Contact: (303) 497-3557]

Sladek, N.J., and Jesch, R.L., **Standardization of Coaxial Connectors in the IEC,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 14-18 (January 1986).

This paper reviews the requirements and standardization of coaxial connectors in the United States. It details the standardization of coaxial connectors within the International Electrotechnical Commission (IEC) Subcommittee SC46D "Connectors for RF Cables." A list of published IEC connector standards and a list of IEC standards under consideration are included.
[Contact: Robert L. Jesch (303) 497-3496]

Weidman, M., **Finline Diode Six-Port: Fundamentals and Design Information,** NBS Technical Note 1090 (December 1985).

The preliminary design and testing of a planar circuit six-port having diode detectors is described. The planar circuit medium was chosen to be finline, and all preliminary work was done in WR-42 waveguide (18 to 26.5 GHz). The finline substrate was alumina, and initially commercial beam-lead diodes were bonded to the finline metallization. The goal is to design an integrated circuit which could be fabricated on one chip (with diode detectors) and used as part of a six-port network analyzer in the waveguide bands above 18 GHz. Initial designs proved to be unsatisfactory because of high losses and reflections. Most of the problems have been solved, and a usable integrated finline circuit is a good possibility for a millimeter wave six-port.
[Contact: (303) 497-3210]

Laser Metrology

Case, W.E., and Sanders, A.A., **Laser Power and Energy Measurements and the NBS Laser Measurement Assurance Program (MAP)**, Proceedings of the IEEE Instrumentation and Measurement Technology Conference, Tampa, Florida, March 20-22, 1985, pp. 281-285.

This paper describes the national standards for laser power and energy measurements maintained by the National Bureau of Standards and how the measurement services based on these standards are disseminated. Particular emphasis is devoted to the procedures and instrumentation used in these measurements. The Laser Measurement Assurance Program (MAP) is discussed in detail. The paper also presents a detailed procedure for the user to choose proper instrumentation and procedures to implement a measurements program in the laboratory.
[Contact: Aaron A. Sanders (303) 497-5341]

Johnson, E.G., Jr., **Direct Measurement of the Electric Field of a Laser Pulse-Theory**, NBS Technical Note 1084 (August 1985).

We consider realizing an electric field measuring apparatus by using optical processing, tapered optical fibers, and a pair of detectors at the end of each optical fiber. Using an appropriate computer-generated optical filter, we show it is possible to discriminate among a set of orthonormal modes used to represent the spatial features of the electric field with a signal-to-noise ratio of at least 100 to 1. If the positioning accuracies for various parts of the apparatus are properly set up, it is expected that the signal-to-noise ratio could be about 1000. The purpose of the tapered and graded-index fibers is to select the fundamental propagating mode in a fiber and to attenuate the other modes. The existence of these fibers allows the precise determination of the strength of each of the orthonormal modes being used as the spatial basis of the electric field before the optical processing. The detectors then measure the strength of each fundamental mode. There are 36 such modes for the apparatus under discussion--six for the x-dimension and six for the y-dimension. Propagation of the laser pulse is assumed to be along the z-axis. We use two detectors for each mode so that the polarization is determined.

This paper presents the conflicts in the design and gives a solution. The complete evaluation requires assembly of the proposed apparatus to assess final accuracy.
[Contact: (303) 497-3234]

Rasmussen, A.L., and Sanders, A.A., **Documentation of the NBS APD and PIN Calibration Systems for Measuring Peak Power and Energy of Low-Level 1.064 μm Laser Pulses**, NBSIR 85-3032 (December 1985).

National Bureau of Standards APD (avalanche) and PIN silicon photodiode transfer standards are documented for a calibration service to measure 1.064-μm laser pulses from ~10^{-8} to ~10^{-4} W peak power and ~10^{-16} to ~10^{-11} J energy. A modulated cw (continuous-wave) measurement system generating known low-level pulses is described. Calibration support equipment, systematic and random errors, and computer programs and calibration data are also described.
[Contact: (303) 497-5367 or -3616]

Rasmussen, A.L., and Sanders, A.A., **Transfer Standards for Energy and Peak Power of Low-Level 1.064 Micrometer Laser Pulses and Continuous Wave Laser Power**, Optical Engineering, Vol. 25, No. 2, pp. 277-285, (February 1986).

For the first time, traceable transfer standards have been developed for measuring 1.064-μm laser pulses with duration of about 10 to 100 ns, peak power density of about 10^{-8} to 10^{-4} W/cm^2, and energy density of about 10^{-16} to 10^{-11} J/cm^2. These power and energy transfer standards use avalanche (APD) and PIN

Laser Metrology, cont'd.

silicon photodiode detectors, respectively. They are stable and have total uncertainties of about 10%. The system for calibrating them and other devices consists of a cw (continuous-wave) Nd:YAG laser beam acousto-optically modulated to provide low-level laser pulses of known peak power and energy. With pulse height analyzer readout, the PIN transfer standard system records each pulse, from which the mean pulse energy and laser stability may be evaluated. With integrating voltmeter readout, this system can measure energy or average power. These pulsed and cw measurement techniques can be extended to the visible and other near-infrared wavelengths.
[Contact: (303) 497-5367 or -3616]

Simpson, P.A. and Sanders, A.A., **Pulse Considerations for Low-Level Laser Receivers**, to be published in the Proceedings of the Measurement Science Conference, Irvine, California, January 22-24, 1986.

Laser target designators and rangefinders use low-level receivers to detect the light reflected from the target. Present testing procedures for the receivers often use the measurement of the total energy of a light pulse which is generated with a pulsed LED (light-emitting diode). These procedures can be subject to significant error unless certain precautions are observed. Two new fast detectors of pulse shape with high sensitivity and extended wavelength range are described. These detectors can be used with low-level transfer standards for next generation laser target designator and rangefinder systems.
[Contact: (303) 497-3789]

Optical Fiber Metrology

Danielson, B.L., **Optical Time-Domain Reflectometer Specifications and Performance Testing**, Appl. Optics, Vol. 24, No. 15, pp. 2313-2322 (August 1, 1985).

From a researcher's as well as a user's point of view, it is highly desirable to adopt a common basis for specifying optical time-domain reflectometer performance parameters. This paper proposes some procedures and test methods which permit these devices to be characterized in a consistent way. Passive test fixtures are also described which may facilitate measurements of dynamic range and other reflectometer properties (the reflectometers addressed in this paper are used to characterize optical fibers and fiber installations).
[Contact: (303) 497-5620]

Day, G.W., McFadden, J.D.O., Veeser, L.R., Chandler, G.I., and Cernosek, R.W., **Optical Fiber Sensors for the Measurement of Pulsed Electric Currents**, NATO AGARD Conference, Guided Optical Structures in the Military Environment, Istanbul, Turkey, Sept. 23-27, 1985, Preprint 383, pp. 8-1 to 8-9.

Recent progress in the design of fiber sensors for pulsed electric currents is reviewed. Several of the most useful sensor configurations are described and compared. Models are used to predict the transfer function of these sensors, their sensitivity to non-ideal fiber properties, particularly linear birefringence, and methods for overcoming these problems. Other recent research is examined to suggest the prospect for sensors with improved sensitivity and stability.
[Contact: (303) 497-5204]

Franzen, D.L., **Determining the Effective Cutoff Wavelength of Single-Mode Fibers: An Interlaboratory Comparison**, Journal of Lightwave Technology, Vol. LT-3, No. 1, pp. 128-134 (February 1985).

The National Bureau of Standards, in cooperation with the Electronic Industries Association, conducted an interlaboratory measurement comparison among six fiber manufacturers to deter-

Optical Fiber Metrology, cont'd.

mine the effective cutoff wavelength of single-mode fibers. Measurement techniques based on transmitted power were used to determine cutoff wavelength on four fibers designed for single-mode operation at 1300 nm. NBS also contributed results using a spectral near-field technique. One-standard-deviation measurement spreads for the various techniques range from 6 to 12 nm. With the appropriate data analysis, single-bend attenuation and power-step methods give the same results. Both techniques are easily implemented as extensions to the usual spectral attenuation measurement.
[Contact: (303) 497-3346]

Franzen, D.L., **An Interlaboratory Measurement Comparison Among Fiber Manufacturers to Determine the Effective Cut-Off Wavelength and Mode Field Diameter of a Single Mode Fiber,** Technical Digest of the Conference on Optical Fiber Communication and the 3rd International Conference on Optical Fiber Sensors, San Diego, California, February 11-14, 1985, p. 36.

An interlaboratory measurement comparison to determine an effective cutoff wavelength and mode field diameter of a single-mode fiber was conducted by the National Bureau of Standards in cooperation with the Electronic Industries Association (EIA). Participants included NBS, several U.S. manufacturers, and some foreign laboratories. The purpose of the comparisons was to gather information on interlaboratory agreement when the same measurement techniques are used and to determine offsets between different techniques. The various procedures tested (three transmission methods for determining cut-off wavelength and four methods [transverse offset, near-field, far-field, and variable aperture far-field] for determining mode field diameter) are currently pending before the EIA and represent current practice for manufacturers. Interlaboratory agreement and systematic offsets between methods are discussed.
[Contact: (303) 497-3346 or -5342]

Franzen, D.L., and Day, G.W., **Fiber Optics Emphasis on Single Mode - Conference Report,** NBS Journal of Research, Vol. 9, No. 1, p. 49 (January-February 1985).

The third biennial Symposium on Optical Fiber Measurements, sponsored by NBS in cooperation with the IEEE Optical Waveguide Communications Committee and the Optical Society of America, drew some 300 attendees to Boulder October 2-3, 1984 to hear 25 contributed papers, several invited papers, and to attend two workshops on the general subject of optical fiber measurements. This short note identifies several highlights of the Symposium.
[Contact: (303) 497-3346 or -5342]

Franzen, D.L., and Srivastava, R., **Determining the Mode-Field Diameter of Single-Mode Optical Fiber: An Interlaboratory Comparison,** Journal of Lightwave Technology, Vol. LT-3, No. 5, pp. 1073-1077 (October 1985).

The National Bureau of Standards, in cooperation with the Electronic Industries Association, conducted an interlaboratory measurement comparison among fiber manufacturers. Evaluated were transverse splice offset, near-field, far-field, and variable aperture far-field methods for determining mode-field diameter. Measurements were performed on five single-mode fibers at both 1300- and 1550-nm wavelengths. At 1300 nm, agreement was fairly good with the average one standard deviation being 0.15 μm for mode-field diameters in the 8- to 11-μm range. Distinct systematic differences among various techniques were observed at 1550 nm where mode distributions are not as Gaussian.
[Contact: (303) 497-3346 or -5342]

Maisonneuve, J.M., Churoux, P., and Gallawa, R.L., **Use of Mode Transfer Matrices in L.A.N. Loss Evaluation,** Proc. SPIE - International Society of

Optical Fiber Metrology, cont'd.

Optical Engineering (P.O. Box 10, Bellingham, WA 98227-0010), Vol. 559, pp. 182-185 (1985) [Conference, San Diego, California, August 19-23, 1985].

A method using Mode Transfer Matrices to characterize step-index fiber components and predict local area network (LAN) power budget is presented. The results show this method is well adapted to describing modal power distribution variations.
[Contact: Robert L. Gallawa (303) 497-3761]

Shao, Y., Alvarez, R., Weimer, C., and Gallawa, R.L., **Pulse Spectrum Analysis Method of Measuring Fiber Bandwidth**, Proc. SPIE - The International Society for Optical Engineering (P.O. Box 10, Bellingham, WA 98227-0010), Vol. 559, pp. 207-210 [Conference, San Diego, California, August 19-23, 1985].

A system for measuring optical fiber bandwidth utilizing the pulse spectrum analysis method (PSA) has been established. This paper discusses problems inherent to that system such as signal-to-noise ratio and off-peak error. Included are the results of bandwidth measurements for telecommunication grade fibers. Finally, the PSA method is compared to other bandwidth measurement methods.
[Contact: Robert L. Gallawa (303) 497-3761]

Shao, Y., and Gallawa, R.L., **Some Issues in Optical Fiber Bandwidth Measurements**, Proceedings of the IEEE Instrumentation and Measurement Technology Conference, Tampa, Florida, March 20-22, 1985, pp. 228.

The measurement of optical fiber bandwidth, using methods in common use in the fiber community, is discussed along with difficulties and variabilities encountered.
[Contact: Robert L. Gallawa (303) 497-3761]

Other Fast Signal Topics

Judish, R.M., **Quality Control of Measurements - Measurement Assurance**, Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 23-25 (January 1986).

The ability to relate individual measurements to nationally accepted standards is a requirement of traceability. This paper discusses a perspective in which the goals of traceability are viewed in terms of performance requirements on measurement quality as reflected in a statement of uncertainty.
[Contact: (303) 497-3380]

Kamper, R.A., **Uncertainty Charts for RF and Microwave Measurements**, Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 27-32 (January 1986).

The scope of the calibration services for electrical quantities in the range of frequency from 0 to 100 GHz that are available from the National Bureau of Standards is discussed briefly in a historical context. Some plans for improved services available in the near future are noted. Charts showing the variation of uncertainty with magnitude over the full range of the respective calibration services are presented.
[Contact: (303) 497-3535]

Ku, H.H., and Judish, R.M., **Fundamentals of Error Analysis**, Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 25-27 (January 1986).

This paper discusses the process of assessing the uncertainty of measurement results through error analysis. We restrict the discussion to sources of errors, measurement errors, modeling errors, and calibration errors in the context of physical experiments.
[Contact: Robert M. Judish (303) 497-3496]

Other Fast Signal Topics, cont'd.

Sladek, N.J., and Jesch, R.L., **Standardization of Coaxial Connectors in the IEC,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 14-18 (January 1986).

This paper reviews the requirements and standardization of coaxial connectors in the United States. It details the standardization of coaxial connectors within the International Electrotechnical Commission (IEC) Subcommittee SC46D "Connectors for RF Cables." A list of published IEC connector standards and a list of IEC standards under consideration are included.
[Contact: Robert L. Jesch (303) 497-3496]

Erratum

The wrong abstract appeared in the June 1986 issue of the Technical Progress Bulletin [NBSIR 86-3344-2] for the following published paper. The correct abstract follows the citation.

Young, M., **The Scratch Standard is Only a Cosmetic Standard,** Laser Focus/Electro-Optics, pp. 138-140 (November 1985). [An identical paper appeared in the Proceedings of the Conference on Laser Induced Damage in Optical Materials, Boulder, Colorado, October 28-30, 1985.]

In this paper, I present a history of the scratch and dig standard and show that this standard has since its inception been recognized as a cosmetic standard and not as an objective or performance standard. In addition, I attempt to dispel the myth that the scratch standard was changed during the 1960s and show that scratch number cannot be related to scratch width. Finally, I describe a preliminary experiment that suggests that the scratch standards have not aged with time and are, in fact, extremely stable.
[Contact: (303) 497-3223 or -5342]

ELECTRICAL SYSTEMS

Power Systems Metrology

FitzPatrick, G.J., Forster, E.O., Kelley, E.F., and Hebner, R.E., **Streamer Initiation in Liquid Hydrocarbons,** 1985 Annual Report, IEEE Conference on Electrical Insulation and Dielectric Phenomena, Amherst, New York, Oct. 20-24, 1985, pp. 27-32.

Using 93X magnification and a framing rate of 2×10^7 frames/s, the initiation of prebreakdown streamers in toluene, isooctane, and a white oil has been photographed. The initial growth from a negative point electrode was a thin pencil-like structure, having a growth rate of 2 to 3×10^4 cm/s, which subsequently branched into a tree-like structure. Positive streamers were found to develop into a more filamentary structure than negative streamers. Under nominally identical conditions, a positive streamer may grow, then disappear; may grow to bridge the gap; or may grow to a certain length, then persist.
Contact: Robert E. Hebner (301) 921-3121]

Fulcomer, P.M., **NBS Ambient Magnetic Field Meter for Measurement and Analysis of Low-Level Power Frequency Magnetic Fields in Air,** NBSIR 86-3330 (December 1985).

This report describes a portable, battery-powered magnetic fieldmeter which has been developed to provide improved accuracy in the measurement and analysis of low-level and ambient power-frequency magnetic fields. Accurate measurement of such fields is becoming increasingly important as public concern grows over the possibility that exposure to such fields may produce effects on human health. Included in the report are a description of the instrumentation, a circuit analysis, a discussion of the calibration procedures together with an uncertainty analysis, and some sample measurement results. The instrumentation enables measurement of power-

Power Systems Metrology, cont'd.

frequency magnetic field in air with an overall uncertainty of less than one percent over a range from 50 nanotesla (500 microgauss) to 200 microtesla (2 gauss) and an overall uncertainty of less than two percent down to 2 nanotesla (20 microgauss). It also enables the percentage of each harmonic present in the field to be determined to an uncertainty of less than three percent.
[Contact: (301) 921-3121]

Hebner, R.E., **Research for Electric Energy Systems -- An Annual Report,** NBSIR 86-3316 (March 1986).

This report documents the technical progress in the five investigations which make up the project "Support of Research Projects for Electrical Energy Systems," Department of Energy Task Order Number 137, funded by the U.S. Department of Energy's Office of Energy Systems Research and performed in the Electrosystems Division of the U.S. National Bureau of Standards.
[Contact: (301) 921-3121]

Kamper, R.A., **Uncertainty Charts for RF and Microwave Measurements,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 27-32 (January 1986).

The scope of the calibration services for electrical quantities in the range of frequency from 0 to 100 GHz that are available from the National Bureau of Standards is discussed briefly in a historical context. Some plans for improved services that will be available in the near future are noted. Charts showing the variation of uncertainty with magnitude over the full range of the respective calibration services are presented.
[Contact: (303) 497-3535]

Pulse Power Metrology

Day, G.W., McFadden, J.D.O., Veeser, L.R., Chandler, G.I., and Cernosek, R.W., **Optical Fiber Sensors for the Measurement of Pulsed Electric Currents,** NATO AGARD Conference, Guided Optical Structures in the Military Environment, Istanbul, Turkey, Sept. 23-27, 1985, Preprint 383, pp. 8-1 to 8-9.

Recent progress in the design of fiber sensors for pulsed electric currents is reviewed. Several of the most useful sensor configurations are described and compared. Models are used to predict the transfer function of these sensors, their sensitivity to non-ideal fiber properties, particularly linear birefringence, and methods for overcoming these problems. Other recent research is examined to suggest the prospect for sensors with improved sensitivity and stability.
[Contact: (303) 497-5204]

Magnetic Materials and Measurements

Fulcomer, P.M., **NBS Ambient Magnetic Field Meter for Measurement and Analysis of Low-Level Power Frequency Magnetic Fields in Air,** NBSIR 86-3330 (December 1985).

This report describes a portable, battery-powered magnetic fieldmeter which has been developed to provide improved accuracy in the measurement and analysis of low-level and ambient power-frequency magnetic fields. Accurate measurement of such fields is becoming increasingly important as public concern grows over the possibility that exposure to such fields may produce effects on human health. Included in the report are a description of the instrumentation, a circuit analysis, a discussion of the calibration procedures together with an uncertainty analysis, and some sample measurement results. The instrumentation enables measurement of power-frequency magnetic field in air with an overall uncertainty of less than one percent over a range from 50 nanotesla (500 microgauss) to 200 microtesla (2 gauss) and an overall uncertainty of

Magnetic Materials, etc., cont'd.

less than two percent down to 2 nanotesla (20 microgauss). It also enables the percentage of each harmonic present in the field to be determined to an uncertainty of less than three percent.
[Contact: (301) 921-3121]

Goldfarb, R.B., Rao, K.V., and Chen, H.S., **New Magnetic Phase Diagram of the Amorphous Pd-Fe-Si Ferroglass Alloy System**, Journal of Magnetism and Magnetic Materials, Vol. 54-57, pp. 111-112 (1986).

The magnetic phase diagram of amorphous $Pd_{80-x}Fe_xSi_{20}$ is examined for values of x between 5 and 22. We use the peak in the imaginary component of ac susceptibility to determine the ferromagnetic-like to spin-glass transition temperatures T_{fg}. It is found that the T_{fg} curve is strongly field dependent and increases monotonically with increasing Fe concentration, even around x = 22.
[Contact: (303) 497-3650]

Superconductors

Fickett, F.R., **Investigation of a Practical Superconductor with a Copper Matrix, Annual Report and Final Summary of Project 255**, International Copper Research Association (708 Third Avenue, New York, NY 10017) (1985).

In this report we summarize the work performed on four INCRA projects covering a span of about six years. The main goal of the work was to investigate the in-situ superconductors, those produced by the relatively rapid cooling of a melt containing essentially non-miscible components. The component with the higher melting point precipitates out as small particles during the cooling. Subsequent drawing of the resulting boule results in fine filaments of this material (the superconductor) in the lower-melting matrix (usually oxygen-free copper or a copper-tin alloy).
[Contact: (303) 497-3785]

Goodrich, L.F., Minervini, J.V., Clark, A.F., Fickett, F.R., Ekin, J.W., and Pittman, E.S., **Development of Standards for Superconductors - Interim Report**, NBSIR 85-3027 (January 1985).

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 January 1982 through December 1983 is reported. The major effort was the procurement, selection, and certification of the first superconducting wire for critical current measurements as a Standard Reference Material (SRM 1457). Other work reported here includes effect of geometry on current transfer, lap-joint resistance, and ac losses.
[Contact: (303) 497-3143]

ELECTROMAGNETIC INTERFERENCE

Adams, J.W., and Vanzura, E., **Shielding Effectiveness Measurements of Plastics**, NBSIR 85-3035 (January 1986).

Measurement of shielding effectiveness of plastic materials with respect to electromagnetic radiation poses serious problems due to the insulating nature of many plastics. A method of making these measurements using a flanged coaxial holder overcomes some of the difficulties.
[Contact: (303) 497-3328]

Kanda, M., Larsen, E.B., Borsero, M., Galliano, P.G., Yokoshima, I., and Nahman, N.S., **Standards for Electromagnetic Field Measurements**, Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 120-128 (January 1986).

This paper describes the methodology for

Electromagnetic Interference, cont'd.

standard electromagnetic field measurements using anechoic chambers, open sites, guided-wave structures, and probes as transfer standards.
[Contact: (303) 497-5320]

Larsen, E.B., **Calibration and Meaning of Antenna Factor and Gain for EMI Antennas**, Directory and Design Guide of the Control of EMI, Item 1986, pp. 114ff (1986) [Robar Industries, Inc., 20 Clipper Road, West Conshohocken, PA 19428-2721].

The National Bureau of Standards offers a calibration service for field strength meters and electromagnetic interference (EMI) antennas in the frequency range of 10 kHz to 10 GHz. The antennas most commonly used are loops for magnetic fields from 10 kHz to 50 MHz, monopoles for vertically polarized electric fields from 30 kHz to 300 MHz, and dipoles or related antennas for electric fields from 20 MHz to 10 GHZ. The majority of calibrations consist of determining the "antenna factor" (K) or "realized" gain (G_{re}), which permits the use of a 50-Ω receiver (tunable radiofrequency voltmeter) with the calibrated antenna to make measurements of radiated emissions. A receiver with attached antenna can also be calibrated as a system to measure the field strength directly.

There are three common independent techniques for calibrating an antenna to make field strength measurements. These are: (a) standard antenna method, (b) standard field method, and (c) insertion loss method. All three techniques lead to a calibrated gain or antenna factor - which are related to each other in a reciprocal fashion. In practice, however, the gain of an antenna is most commonly measured by comparing its output in a locally generated field to that of a "standard" receiving antenna, whose gain is accurately known. This approach is called a "relative" gain measurement. If the gain is determined without using another antenna having known gain, the procedure is called an "absolute" gain measurement. The three techniques for determining absolute gain and antenna factor are described.
[Contact: (303) 497-3540]

Ma, M.T., Kanda, M., Crawford, M.L., and Larsen, E.B., **Measuring Electromagnetic Interference, Part I: Open-Field Sites and TEM Cells**, Test and Measurement World, pp. 72ff (February 1986) [condensation of a portion of **A Review of Electromagnetic Compatibility/Interference Measurement Methodologies**, Proceedings of the IEEE, Vol. 73, No. 3, pp. 388-411 (March 1985)].

Measuring radiated electromagnetic power is essential to demonstrate conformance to various electromagnetic interference/compatibility (EMI/EMC) regulations and specifications. A number of methods are available -- open-field sites, transverse electromagnetic (TEM) cells, reverberating chambers, and anechoic chambers. Selection of a suitable technique requires a knowledge of the strengths and limitations of each. Proper interpretation of measured results then requires an intimate knowledge of the characteristics of the chosen site or facility.

Following a general introduction to the subject of testing for EMI/EMC, this first article in a three-part series discusses 1) measurements and problems using open-field sites and 2) measurements on small electrical equipment and devices in TEM cells for radiated susceptibility and radiated emission testing.
[Contact: (303) 497-3800]

Ma, M.T., and Koepke, G.H., **Measurements of Unintentional Electromagnetic Emissions**, Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 110-111 (January 1986).

A summary of a new method for determining the radiation characteristics of leakage from electronic equipment or

Electromagnetic Interference, cont'd.

other unintentional radiators of interference is presented. The theoretical background and specific measurement procedures for the method using a transverse electromagnetic cell are outlined. The theory and measurements have been verified in referenced work by the results of a simulated theoretical example and an experiment using a spherical dipole radiator. A reference is also given for mathematical analysis of the uncertainties in the final, extracted results when the experimental data are degraded by the background noise and measurement imperfections.
[Contact: (303) 497-3800]

Phelan, R.J., Jr., Larson, D.R., and Simpson, P.A., **A Sensitive, High Frequency Electromagnetic Field Probe Using a Semiconductor Laser in a Small Loop Antenna,** Proc. SPIE - International Society of Optical Engineering (P.O. Box 10, Bellingham, WA 98227-0010), Vol. 566, pp. 300-306 (1985) [Conference, San Diego, California, August 20-23, 1985].

Using a loop antenna in series with a semiconductor laser, an optically coupled electromagnetic field probe has demonstrated sensitivities better than 3 $\mu V/(m \cdot Hz^{1/2})$. The outside dimensions of the probe are equal to $5.7 \times 5.7 \times 1.3$ cm^3. It can be used to measure fields with frequencies as high as 2 GHz. The dynamic range is estimated to exceed 6 orders of magnitude for incident microwave powers.
[Contact: (303) 497-3696 or -5342]

Randa, J., and Kanda, M., **Directional Scanning of Complex Electromagnetic Environments,** IEEE Transactions on Antennas and Propagation, Vol. AP-33, No. 12, pp. 1413-1416 (December 1985) [a shortened version of this paper appeared in the Proceedings of the 1985 International Symposium on Antennas and Propagation, Kyoto, Japan, August 20-22, 1985, pp. 899-902].

As radiofrequency and microwave sources (both intentional and inadvertent) multiply, the electromagnetic (EM) environment in which electronic devices (and people) must function becomes increasingly complicated, while at the same time its characterization becomes more important. In order to completely characterize an EM environment without knowledge of the radiating sources, the sampling theorem requires that systematic measurements of the amplitude and phase of the field be made throughout the volume at spacings of no more than one-half wavelength of the highest frequency present. Implementing this number of measurements is often impossible and seldom convenient. There is a need for practical techniques which would determine useful properties of an EM environment from relatively few measurements. One recent suggestion for such a technique is to use directional measurements at a single point in conjunction with a plane-wave expansion of the field. This paper reports the formulation of the technique and the results of a simulation using it.
[Contact: (303) 497-3150]

Wilson, P.F., Adams, J.W., and Ma, M.T., **Measurement of the Electromagnetic Shielding Capabilities of Materials,** Proceedings of the IEEE, Special Issue on Radio Measurement Methods and Standards, Vol. 74, No. 1, pp. 112-115 (January 1986).

Electromagnetic shielding is typically measured in terms of insertion loss, that is, the reduction in the fields coupled between a transmitter and a receiver which results from interposing the shield material. Although the insertion loss concept is simply stated, questions arise when one attempts to interpret specific insertion loss measurements. Insertion loss data depend not only on the inherent shielding effectiveness of the material, but also on the antenna types used for the measurement, the incident field distribution, the sample size, a possible contact impedance between the

Electromagnetic Interference, cont'd.

test material and its mount, and other factors. For a given sample of shield material, varying these factors can lead to a large range of possible measured insertion loss values. Both the above considerations and existing shielding effectiveness measurement systems are discussed briefly in this paper. The emphasis is on potential difficulties encountered in making even relative comparisons of results and on the importance of understanding how the measurement system used affects the data.
[Contact: (303) 497-3842]

ADDITIONAL INFORMATION

Lists of Publications

Gibson, K.A., Page, J.M., and Miller, C.K.S., **A Bibliography of the NBS Electromagnetic Fields Division Publications**, NBSIR 85-3040 (February 1986).

This bibliography lists publications of the National Bureau of Standards' Electromagnetic Fields Division for the period from January 1984 through September 1985, with selected earlier publications from the Division's predecessor organizations.
[Contact: (303) 497-3132]

Sorrells, J.R., Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division's Publications**, NBS List of Publications 94 (January 1986).

This bibliography lists the publications of the Electrosystems Division, Center for Electronics and Electrical Engineering, NBS, and of its predecessor sections for the period January 1968 through December 1985. A brief description of the Division's technical program is given in the introduction.
[Contact: (301) 975-2413]

Kline, K.E., and DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NBS Publications**, NBSIR 86-3048 (June 1986).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NBS in the period from January 1970 through December 1985. A few earlier references that are directly related to the present work of the Division are included.
[Contact: (303) 497-3678]

Walters, E.J., **Semiconductor Measurement Technology; List of Publications -- 1962-1984**, NBS List of Publications 72 (March 1985).

This list of publications contains reports of work performed at the National Bureau of Standards in the field of Semiconductor Measurement Technology in the period from 1962 through December 1984.
[Contact: (301) 975-2050]

RECENTLY ISSUED STANDARD REFERENCE MATERIALS

The first practical superconducting standard reference material (SRM) has been released by the Electromagnetic Technology Division to the NBS Office of Standard Reference Materials for sale to the public. The certified parameter of SRM 1457, Superconducting Critical Current -- NbTi Wire, is critical current at magnetic fields of 2, 4, 6, and 8 tesla at a temperature of 4.2 K and an electric field criterion of 0.2 μV/cm. Information is given to permit the user to determine critical current for temperatures in the range 3.90 to 4.24 K and electric field criteria from 0.05 to 0.2 μV/cm.

SRM 1457 consists of a 2.2-m length of a multifilimentary, niobium-titanium, copper-stabilized wire, wound in a single layer on a spool having a core diameter of 8.7 cm. The wire is evaluated for 34 parameters relating to current, voltage, magnetic field, temperature, Recently Issued SRMs, cont'd.

strain, and physical specimen characteristics.

In conjunction with ASTM Standard Test Method B714-82, D-C Critical Current of Composite Superconductors, the new SRM is intended to provide means for calibrating apparatus used to measure key parameters of superconductor products and thus should be useful to buyers and sellers of superconductors, users of superconducting equipment, and researchers in superconducting technology.

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This is the eighth issue of a quarterly publication providing information on the technical work of the National Bureau of Standards Center for Electronics and Electrical Engineering. This issue of the Center for Electronics and Electrical Engineering Technical Publication Announcements covers the first quarter of calendar year 1986. Abstracts are provided by technical area for papers published this quarter.

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antennas; electrical engineering; electrical power; electromagnetic interference; electronics; instrumentation; laser; magnetics; microwave; optical fibers; semiconductors; superconductors

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