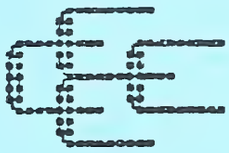
NBSIR 88-3815

Center for Electronics and Electrical Engineering



Technical Progress Bulletin

Covering Center Programs,
January to March 1988,
with 1988 CEEE Events Calendar

88-1

July 1988

U.S. Department of Commerce
National Bureau of Standards
National Engineering Laboratory
Gaithersburg, Maryland 20899

Stimulating America's Progress
1913-1988

INTRODUCTION TO JULY 1988 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the twenty-second 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 Progress Bulletin covers the first quarter of calendar year 1988.

Organization of Bulletin: This issue contains abstracts for all Center papers released for publication by NBS in the quarter and 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 under each subheading within each topic. Unpublished papers appear under the subheading "Released for Publication". Papers published in the quarter appear under the subheading "Recently Published". Following each abstract is the name and telephone number of the individual to contact for more information on the topic (usually the first author). This issue also includes a calendar of Center conferences and workshops planned for calendar year 1988 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 two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Electronics Division in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electrosystems Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information. To request a subscription or for more information on the Bulletin, write to CEEE Technical Progress Bulletin, National Bureau of Standards, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (301) 975-2220.

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 29.

Note on Publication Lists: Guides to earlier as well as recent work are the publication lists covering the work of each division. These lists are revised and reissued on an approximately annual basis and are available from the originating division. The current set is identified in the Additional Information section, page 26.

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SEMICONDUCTOR TECHNOLOGY

Silicon Materials

Released for Publication

Geist, J., Migdall, A., and Baltes, H.P., **Analytic Representation of the Silicon Absorption Coefficient in the Indirect Transition Region.**

An eleven-parameter equation is presented to describe the 298-K experimental silicon absorption coefficient data of Weakliem and Redfield from 1.05 eV to 2.7 eV. The standard deviation of the difference between one and the ratio of the values calculated from this equation to the Weakliem and Redfield experimental values for the same photon energies is 2.5 percent.
[Contact: Jon Geist, (301) 975-2066]

Recently Published

Bennett, H.S., **Indirect Energy Gap of Si: Doping Dependence**, Properties of Crystalline Silicon, Chapter 7.3, EMIS Datareview (Institute of Electrical Engineers, London, February 1988), pp. 174-181.

The doping dependence of the indirect energy gap of silicon is reviewed for the Electronic Materials Information Services (EMIS) of IEE (London). This review is a guide with commentary to assist readers in selecting which values are best for their applications. Our state of knowledge in this area is such that in many cases the intended application for the data on bandgap changes determines the appropriate values to use. Data from interpreting both electrical and optical measurements are given.
[Contact: Herbert S. Bennett, (301) 975-2081]

Analysis Techniques

Recently Published

Jach, T., Novotny, D.B., Carver, G.P., Geist, J., and Spal, R.D., **An X-Ray Monochromator Crystal Which Detects the Bragg Condition**, Nuclear Instrumentation and Methods in Physics Research, Vol. A263 (North-Holland, Amsterdam, 1988), pp. 522-524.

We have fabricated a (111) silicon x-ray monochromator crystal with a diode diffused into its surface. Without suffering any apparent degradation in its rocking-curve width at the Bragg condition, the crystal provides a dc current which changes dramatically at the diffraction of a monochromatic x-ray beam. The current change is directly attributable to extinction at the Bragg angle. It provides a new means to align the two crystals of a double-crystal x-ray monochromator using a feedback circuit.
[Contact: Donald B. Novotny, (301) 975-2699]

Dimensional Metrology

Released for Publication

Young, M., **Spatial-Filtering Microscope for Linewidth Measurements.**

High-pass filtering has been relatively little used in microscopy, yet it may have application to linewidth measurement and visualization of phase objects. I have designed and built a spatial-filtering microscope entirely of conventional microscope objectives. For linewidth measurement, the spatial filter has an optimum width that allows linewidths to be measured within a few percent. Phase lines can also be examined, but phase contrast microscopy may be more suited to weak phase objects such as integrated optical waveguides.
[Contact: Matt Young, (303) 497-3223/-5342]

Photodetectors

Released for Publication

Photodetectors (cont'd.)

Geist, J., Migdall, A., and Baltes, H.P., **Analytic Representation of the Silicon Absorption Coefficient in the Indirect Transition Region.**

An eleven-parameter equation is presented to describe the 298-K experimental silicon absorption coefficient data of Weakliem and Redfield from 1.05 eV to 2.7 eV. The standard deviation of the difference between one and the ratio of the values calculated from this equation to the Weakliem and Redfield experimental values for the same photon energies is 2.5 percent.
[Contact: Jon Geist, (301) 975-2066]

Power Devices

Released for Publication

Blackburn, D.L., **Power MOSFET Failure Revisited**, to be published in the PESC '88 Record, Proceedings of the 1988 IEEE Power Electronics Specialists Conference, Kyoto, Japan, April 11-14, 1988.

The failure of power MOSFETs during avalanche breakdown is discussed. A theory is presented that relates the failure to the temperature rise of the chip during avalanche breakdown and to a critical current for failure. It is shown that the energy that can be safely dissipated during avalanche breakdown decreases as the starting current increases or as the case temperature increases. Thus, if power MOSFETs are to be rated for their energy dissipation capability during avalanche breakdown, both the starting current and temperature must be specified, as it is these two parameters that determine the failure limits.
[Contact: David L. Blackburn, (301) 975-2068]

Integrated Circuit Test Structures

Released for Publication

Schafft, H.A., Lechner, J.A., Sabi, B., Mahaney, M., and Smith, R.C., **Statistics for Electromigration Testing**, to be published in the Proceedings of the 26th Annual Reliability Physics Symposium, Monterey, California, April 12-14, 1988.

A comprehensive statistical basis is given for the design and conduct of electromigration stress tests that allows for the efficient use of test parts, equipment, and test time. It shows how to select the size of the sample, the required control of the stress conditions, and the number of failures required before halting the test in order to characterize metallization interconnects with a quantifiable level of confidence. The results are applicable to any failure mechanism for which the failure times obey a normal or a log-normal distribution.
[Contact: Harry A. Schafft, (301) 975-2234]

Recently Published

Kim, J.S., Linholm, L.W., Barley, B.L., Hanes, M.H., and Cresswell, M.W., **A Microelectronic Test Structure for Thickness Determination of Homogeneous Conducting Thin Films in VLSI Processing**, Proceedings of the 1988 IEEE International Conference on Microelectronic Test Structures, Long Beach, California, February 22-23, 1988, pp. 34-38.

This paper describes a new test structure for use in determining the thickness of a uniform conducting film. The structure incorporates the van der Pauw cross method to determine the effective sheet resistance of a vertical, uniformly doped cross section of a polysilicon film and a bridge resistor to determine the thickness of the film. By using a composite structure, which consists of the vertical cross structure and a conventional planar cross-bridge test structure, it is possible to obtain the thickness, linewidth, and resistivity of

IC Test Structures (cont'd.)

a conducting line.
[Contact: Jin S. Kim, (301) 975-2238]

Buehler, M.G., Linholm, L.W., Tyree, V.C., Allen, R.A., Blaes, B.R., Hicks, K.A., and Jennings, G.A., **CMOS Process Monitor**, Proceedings of the 1988 IEEE International Conference on Microelectronic Test Structures, Long Beach, California, February 22-23, 1988, pp. 164-168. [Identical publication entitled **Proposed End-of-Fabrication Parametric Test Structures for the CMOS Process Monitor** will appear as Jet Propulsion Laboratory Report #D-4520.]

This document describes a proposed end-of-fabrication CMOS process monitor for VHSIC/VLSI wafer fabrication qualification. The discussion of the CMOS process monitor includes a description of the test structures, test methods, and data analysis techniques needed to acquire 26 key electrical parameters that characterize a CMOS process. This process monitor has been under development for a number of years at JPL's VLSI Technology Group and the University of Southern California/Information Sciences Institute MOSIS Project.
[Contact: Loren W. Linholm, (301) 975-2052]

Linholm, L.W., Khera, D., Reeve, C.P., and Cresswell, M.W., **A Developmental Expert System for Test Structure Data Evaluation**, Proceedings of the 1988 IEEE International Conference on Microelectronic Test Structures, Long Beach, California, February 22-23, 1988, pp. 160-163.

This paper describes a developmental expert system, rule generation techniques, a test chip, data handling methods, and statistical data reduction techniques for characterizing the performance of a 1-μm lithography process. Examples of test results and an expert system diagnosis are given.
[Contact: Loren W. Linholm, (301) 975-2052]

Schafft, H.A., and Albers, J., **Thermal Interactions Between Electromigration Test Structures**, Proceedings of the 1988 IEEE International Conference on Microelectronic Test Structures, Long Beach, California, February 22-23, 1988, pp. 132-137.

The thermal interaction between electromigration test structures on a test chip, when subjected to a high current-density stress, must be considered when making median-time-to-failure measurements.
[Contact: Harry A. Schafft, (301) 975-2234]

Suehle, J.S., and Galloway, K.F., **Test Circuit Structures for Characterizing the Effects of Localized Hot-Carrier-Induced Charge in VLSI Switching Circuits**, Proceedings of the 1988 IEEE International Conference on Microelectronic Test Structures, Long Beach, California, February 22-23, 1988, pp. 126-131.

Data are presented that were collected from test circuit structures that were hot-carrier-stressed under conditions existing in actual VLSI switching circuits. It is shown that the localized nature of hot-carrier-induced damage to n-channel MOSFETs must be considered to accurately model these data by computer circuit simulations.
[Contact: John S. Suehle, (301) 975-2247]

Device Physics and Modeling

Recently Published

Wilson, C.L., **Hydrodynamic Carrier Transport in Semiconductors with Multiple Band Minimums**, IEEE Transactions on Electron Devices, Vol. 35, No. 2, pp. 180-187 (February 1988).

Carrier transport equations for analysis of semiconductor devices fabricated in materials with multiple band minimums, such as GaAs, are presented. This

Device Physics and Modeling (cont'd)

revised formulation has several advantages over previous models. Separation of the carrier transport into central and satellite components improves numerical stability in numerical simulations and allows the physical processes associated with each band to be modeled in greater physical detail. This permits processes previously neglected in hydrodynamic models, such as electron injection into insulating substrate material and deep electron traps in GaAs transistors, to be included. A model of a GaAs MESFET, which illustrates the importance of the new physical effects and achieves reasonable agreement with experiment without use of adjustable parameters, is presented as an example.
[Contact: Charles L. Wilson, (301) 975-2080]

Insulators and Interfaces

Released for Publication

Dumin, D.J., Dabral, S., Freytag, M., Robertson, P.J., Carver, G.P., and Novotny, D.B., **Ultra-Thin High Quality SOS Films for VLSI Applications**, to be published in the Proceedings of the Symposium on VLSI Technology, San Diego, California, May 10-13, 1988.

Sub-micron VLSI devices fabricated on SOI films require very thin, high-quality films. At the present time, the only way SOS films with acceptable quality have been fabricated has been to grow the silicon film and then use successive ion implantations, recrystallizations, etching, and epitaxial regrowth. The solid-phase epitaxy (SPE) and regrowth (SPEAR) and double solid-phase epitaxy processes have been used to produce high-quality 0.3-μm to 0.5-μm thick films. However, these processes certainly add to the cost of an already expensive substrate. There is need for a single epitaxial growth process that will produce high-quality SOS films.
[Contact: Donald B. Novotny, (301) 975-2699]

Dutta, P., Candela, G.A., Chandler-Horowitz, D., Marchiando, J.F., and Peckerar, M.C., **Nondestructive Characterization of Oxygen-Ion-Implanted Silicon-on-Insulator Using Multiple-Angle Ellipsometry**.

Silicon-on-insulator formed by high-dose and high-energy oxygen-ion implantation in silicon, SIMOX, has been characterized nondestructively by multiple-angle ellipsometry using a He-Ne laser at 632.8 nm. A multilayered model exhibiting two interlayers, one between the top silicon and the buried oxide and the other between the buried oxide and the substrate silicon, offers a good representation of SIMOX. The distinction between two-temperature furnace anneal (1150°C) and high-temperature rapid thermal anneal (1150°C + 1350°C) on as-implanted wafers is manifested in terms of the optical properties of these transition regions. It is shown that the agreement between the theoretical model and the experimental results improves for the high-temperature-annealed SIMOX.
[Contact: Pradip Dutta, (301) 975-2076]

Other Semiconductor Measurement Topics

Released for Publication

Bouldin, C.E., Bunker, G., McKeown, D.A., Forman, R.A., and Ritter, J.J., **Multiple Scattering in the XANES** [= X-ray Absorption Near-Edge Structure] of **Tetrahedral Ge Gases**.

X-ray absorption fine structure (XAFS) measurements of $GeCl_4$, GeH_3Cl, and GeH_4 are made. Since wide-angle multiple scattering involving H atoms is negligible, we experimentally isolate the single- and multiple-scattering terms in the XAFS of $GeCl_4$. We find that multiple scattering (MS) is nowhere dominant over single scattering (SS), although within 15 eV of the absorption edge the two are comparable

Other Semiconductor Topics (cont'd.)

in size. However, the multiple-scattering term damps out very quickly with increasing energy above the edge. Above 40 eV past the edge, the MS/SS ratio is less than 0.06. Calculations are found to be in qualitative agreement with experiment, but they overestimate the size and energy range of MS. Results suggest that XAFS data in the range $1 < k < 3$ $Å^{-1}$ can be analyzed in an SS picture in many cases, so long as good standard compounds are used, and calculations are used to estimate possible errors due to neglect of MS. Also reported is the first evidence of single scattering observed from H atoms. [Contact: Charles E. Bouldin, (301) 975-2046]

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

Released for Publication

Oldham, N.M., Hetrick, P.S., and Xiangren, Z., **A Calculable, Transportable Audio-Frequency AC Reference Standard**, to be published in the Conference Digest of CPEM-88, Tsukuba Science City, Japan, June 7-10, 1988.

A transportable ac voltage source is described, in which sinusoidal signals are digitally synthesized in the audio-frequency range. The rms value of the output waveform may be calculated by measuring the dc level of the individual steps used to generate the waveform. The uncertainty of this calculation is typically ±10 ppm from 20 Hz to 10 kHz at the 7-V level.
[Contact: Nile M. Oldham, (301) 975-2408]

Oldham, N.M., Petersons, O., and Waltrip, B.C., **Audio-Frequency Current-Comparator Power Bridge**, to be published in the Conference Digest of CPEM-88, Tsukuba Science City, Japan, June 7-10, 1988.

A system for performing active and reactive power measurements from 50 Hz to 20 kHz is described. The technique is an extension of a power bridge based on a current-comparator capacitance bridge that was originally restricted to power frequencies. A digitally synthesized dual-channel signal source provides the required voltage and current signals.
[Contact: Nile M. Oldham, (301) 975-2408]

Souders, T.M., and Hetrick, P.S., **Accurate RF Voltage Measurements Using a Sampling Voltage Tracker**, to be published in the Conference Digest of CPEM-88, Tsukuba Science City, Japan, June 7-10, 1988.

The radio-frequency (rf) voltage measurement capability of an equivalent time-sampling system is described. The frequency range investigated is 1 to 100 MHz. Over this range, the measured errors, determined by ac/dc thermal transfer, are within the stated uncertainties presently provided by NBS for thermal converter calibrations. The system offers several advantages over conventional thermal transfer techniques: ac/dc transfers are not required, loading and transmission line problems are reduced, and direct measurement of voltages from 2 V to as low as 10 mV are possible.
[Contact: T. Michael Souders, (301) 975-2406]

Recently Published

Leedy, T.F., and Bell, B.A., **Concepts for ATE Systems Calibration: Transport Standards to Achieve Traceability to National Standards**, Proceedings of the 1988 Measurement Science Conference, Long Beach, California, January 23-29, 1988, pp. 307-313.

Technical objectives are presented for a proposed transport standard to establish direct traceability of selected low-frequency electrical quantities between the National Bureau of Standards and

Waveform Metrology (cont'd.)

automatic test systems including calibration laboratories that support these automatic test systems. The transport standard would consist of precision ac and dc voltage and frequency sources and could also include more specialized measurement modules in future versions. The transport standard would allow the intercomparison of dc voltage, ac (root-mean-square) voltage, total harmonic distortion, phase, and frequency measurements made using automatic test equipment systems.
[Contact: Thomas F. Leedy, (301) 975-2410]

Petersons, O., **NBS Initiatives in TMDE/ATE Diagnostics**, Symposium Record, National Security Industrial Association Diagnostics/Prognostics Symposium, Alexandria, Virginia, October 20-21, 1987, pp. 190-193 (1988).

Advances in technology dictate that the National Bureau of Standards consider how to provide metrological support for automatic test equipment (ATE) and the area of complex systems in general. Several decades ago, standard instruments were relatively simple devices such as standard resistors, electrochemical cells for voltage, and relatively simple electromechanical indicating meters. Modern precision instruments, however, such a digital multimeters, calibrators, and waveform analyzers are very complex, computer-controlled systems having a broad spectrum of parameters including wide frequency and dynamic ranges and high speeds of operation. While complete characterization was possible and economical for the older and simpler standard instruments, this may not be true for modern measurement systems. Besides the calibration itself, consideration must be given to such items as judicious selection of a limited number of test points, test coverage, and confidence levels. These considerations relate, at least partly, to the subject of the Conference. In addition, NBS has strong interest in the diagnostics of systems that are required to produce accurate, reliable, and economical measurements. Such systems include state-of-the-art test, measurement, and diagnostic equipment (TMDE) and ATE as used by defense forces.

This presentation outlines several activities along the lines described above that are conducted at NBS, particularly in the Electrosystems Division. First, some basic tools and expertise that are applicable to TMDE and ATE diagnostics are discussed, followed by examples of applications, particularly to DoD systems and TMDE.
[Contact: Oskars Petersons, (301) 975-2400]

Turgel, R.S., **Phase Meter Calibration at NBS**, Journal of Research of the National Bureau of Standards, Vol. 93, No. 1, pp. 53-60 (January-February 1988).

To provide a phase meter calibration service, a phase angle calibration standard has been developed at NBS. This standard is a signal generator with two sinusoidal outputs and uses direct digital synthesis to generate the signals. The phase angle between the two sinusoids is determined by the input parameters in the calculation of the sets of digital values from which the analog output is synthesized. An auto-zero compensation mode corrects for residual phase differences in the two output channels. The phase resolution is better than 0.002 deg over a frequency range from 2 Hz to 5 kHz and 0.005 deg from 5 kHz to 50 kHz.

Phase meter calibration data are fitted to a linear model from which appropriate corrections for the phase meter readings can be derived. Statistical treatment of the data provides an estimate of the uncertainty of the corrected phase meter readings relative to the phase angle calibration standard.
[Contact: Raymond S. Turgel, (301) 975-2420]

Waveform Metrology (cont'd.)

Turgel, R.S., Laug, O.B., and Leedy, T.E., **Electrical Performance Tests for True-RMS Voltmeters**, NBSIR 88-3736 (March 1988).

Electrical performance test procedures for a true root-mean-square (rms) voltmeter were developed by the National Bureau of Standards for the U.S. Army Communications-Electronics Command. The report provided detailed, step-by-step test procedures that are based on the specifications supplied by the Army for the purpose of evaluating the bid samples of this type of instrument. Examples are provided of the data sheets and tables for recording of interim data and the final results.

This report discusses the philosophy underlying each of the measurement procedures from a point of view of the basic metrology required to perform the measurements. In addition, the sources of measurement error are discussed.
[Contact: Raymond S. Turgel, (301) 975-2420]

Cryoelectronic Metrology

Released for Publication

Hu, Q., Mears, C.A., Richards, P.L., and Lloyd, F.L., **Measurement of Integrated Tuning Elements for SIS Mixers with a Fourier Transform Spectrometer**.

Planar lithographed quasi-optical mixers can profit from the use of integrated tuning elements to improve the coupling between the antenna and the superconductor-insulator-superconductor (SIS) mixer junctions. We have used a Fourier transform spectrometer with an Hg-arc lamp source as a radio-frequancy (rf) sweeper to measure the frequency response of such integrated tuning elements. The SIS junction connected to the tuning element served as the direct detector for the spectrometer. This relatively quick, easy experiment can give enough information over a broad range of millimeter and submillimeter wavelengths to test both design concepts and success in fabrication. One type of tuning element, an inductive wire connected in parallel with a series array of five SIS junctions across the terminals of a bow-tie antenna, shows a resonant response peak at 100 GHz with a 30% bandwidth. This result is in excellent agreement with theoretical calculations based on a simple inductance-capacitance circuit. It also agrees very well with the rf frequency dependence of the mixer gain measured using the same structure. The other type of tuning element, an open-circuited stub connected in parallel with a single SIS junction across the terminals of a bow-tie antenna, exhibits multiple resonances at 110, 220, and 336 GHz, with bandwidths of 9 to 15 GHz. This result is in good agreement with theoretical calculations based on an open-circuited stub with small loss and small dispersion. The position and the bandwidth of the resonance at 110 GHz also agrees with the rf frequency dependence of the mixer gain measured using similar structures.
[Contact: Frances L. Lloyd, (303) 497-3254]

Kautz, R.L., **Thermally Induced Escape: The Principle of Minimum Available Noise Energy**.

The average time required for thermally induced escape from a basin of attraction increases exponentially with inverse temperature in proportion to exp (E_A/kT) in the limit of low temperature. A minimum principle states that the activation energy E_A is the minimum available noise energy required to execute a state-space trajectory which takes the system from the attractor of the noise-free system to the boundary of its basin of attraction and that the minimizing trajectory is the most probable low-temperature escape path. This principle is applied to the problem of thermally induced escape from two attractors of the dc-biased Josephson junction, the zero-voltage

Cryoelectronic Metrology (cont'd.)

state and the voltage state, to determine activation energies and most probable escape paths. These two escape problems exemplify the classical case of escape from a potential well and the more general case of escape from an attractor of a nonequilibrium system. Monte Carlo simulations are used to verify the accuracy of the activation energies and the most probable escape paths derived from the minimum principle.
[Contact: Richard L. Kautz, (303) 497-3391/-3988]

Laser Metrology

Released for Publication

Scott, T.R., **Review of NBS Laser Power and Energy Measurements.**

The National Bureau of Standards (NBS) maintains a set of electrically calibrated calorimeters designed and used for laser energy measurements. These calorimeters are used as national reference standards for the calibration of optical power and energy meters. Based on the standard calorimeters and associated measurement systems, NBS offers laser power and energy measurement services to the public at a variety of laser wavelengths and power ranges. The uncertainties associated with these measurements have recently been reevaluated.
[Contact: Thomas R. Scott, (303) 497-3651]

Pulse Power Metrology

Released for Publication

McComb, T.R., Hughes, R.C., Lightfoot, H.A., Schon, K., Schulte, R., McKnight, R.B., and Zhang, Y.X., **International Comparison of HV Impulse Measuring Systems.**

Present standards for qualifying high-voltage (HV) impulse measuring systems by unit-step-response parameters are complex and difficult to apply, and some systems, which have response parameters within the limits of the standards, have unacceptable errors. This paper takes the first step in providing a simplified method based on simultaneous measurements of an HV impulse by a reference system and the system under test. Comparative measurements have been made in four national laboratories and the relative differences are reported. The results are discussed, and the further work which is required is outlined.
[Contact: William E. Anderson, (301) 975-2423]

Antenna Metrology

Released for Publication

Baird, R.C., Newell, A.C., and Stubenrauch, C.F., **A Brief History of Near-Field Measurements of Antennas at the National Bureau of Standards.**

The National Bureau of Standards (NBS) played a pioneering role in the development of practical planar near-field antenna measurement techniques. This paper presents a brief history of that role, which began with theoretical studies to determine corrections for diffraction in a microwave measurement of the speed of light. NBS contributions to the development of nonplanar near-field measurement theory and practice are also described.
[Contact: Ramon C. Baird, (303) 497-3131]

Camell, D.G., Larsen, E.B., and Anson, W.J., **NBS Calibration Procedures for Horizontal Dipole Antennas (25 to 1000 MHz)**, to be published in the Symposium Record of the 1988 IEEE International Symposium on Electromagnetic Compatibility, Seattle, Washington, August 2-4, 1988.

The theoretical basis and test procedures for horizontally polarized dipole calibrations at the National Bureau of Standards are described. Two different

Antenna Metrology (cont'd.)

techniques and two different test sites are used for these measurements. The standard antenna method uses the calculation of a field strength level, from the response of a simple half-wave dipole, to calibrate an antenna. This method is used at an open-field site in the frequency range 25 to 1000 MHz. The standard field method applies the theoretical gain equations of waveguides to determine the field strength level. This latter method is used in an anechoic chamber in the frequency range 200 to 1000 MHz. Procedures for both techniques are explained and measurement setups are illustrated. Measurement uncertainties are discussed.
[Contact: Dennis G. Camell, (303) 497-3214]

Recently Published

Hill, D.A., and Francis, M.H., **Out-of-Band Response of Antenna Arrays**, IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-29, No. 4, pp. 282-288 (November 1987). [Also appeared in the Proceedings of the 1987 IEEE International Symposium on Electromagnetic Compatibility, Symposium Record, August 25-27, 1987, Atlanta, Georgia, pp. 435-438. An expanded version appeared as NBSIR 86-2037 (June 1986).]

The response of antenna arrays to out-of-band frequencies has been analyzed using the effective aperture approach. An average value of effective aperture can be obtained by averaging the incidence angle and the polarization of the incident field. Far-field patterns have also been calculated by treating the array element excitations as random variables. The randomness in the element excitations causes a decrease in directivity and an increase in sidelobe level.
[Contact: David A. Hill, (303) 497-3472]

Lewis, R.L., **Spherical-Wave Source-Scattering Matric Analysis of Coupled Antennas; A General System Two-Port Solution**, IEEE Transactions on Antennas and Propagation, Vol. AP-35, No. 12, pp. 1375-1380 (December 1987).

Expressions are given for the coupling between two antennas in terms of each antenna's spherical-wave source-scattering matrix. A comparison with the "classical" scattering matrix representation is given in sufficient detail to permit conversion back and forth between the source-scattering matrix and the classical scattering matrix. The paper concludes with expressions for the transmission formulas, showing two different expressions corresponding to reversing the direction of propagation. However, if both antennas are reciprocal with equal characteristic waveguide impedances, then the two-port scattering matrix is a symmetric matrix.
[Contact: Richard L. Lewis, (303) 497-5196]

Lewis, R.L., and Wittmann, R.C., **Improved Spherical and Hemispherical Scanning Algorithms**, IEEE Transactions on Antennas and Propagation, Vol. AP-35, No. 12, pp. 1381-1388 (December 1987).

A probe-corrected spherical-scanning algorithm has been developed which is applicable when the antenna under test radiates negligibly into its rear hemisphere. Compared to an efficient version of the best previously published full-sphere scanning algorithm, it is found that our hemispherical scanning algorithm is over three and a half times more efficient. Improvements have also been made to full-sphere scanning, with the result that our new spherical scanning algorithm is twice as efficient as the best previous full-sphere algorithm. We also show that our new formulations constitute an exact inversion of the band-limited spherical-coordinate representation of the received signal (i.e., no aliasing errors are introduced).

Antenna Metrology (cont'd.)

[Contact: Richard L. Lewis, (303) 497-5196]

Noise Metrology

Released for Publication

Daywitt, W.C., **Design Considerations for an Accurate Coaxial Noise Standard.**

This summary outlines the important aspects of the design and construction, and the output noise temperature calculation, of a cryogenic thermal noise standard. The coaxial standard operates up to 12.4 GHz.
[Contact: William C. Daywitt, (303) 497-3720]

Wait, D.F., Daywitt, W.C., and Counas, G., **Intercomparison of NBS Noise Calibration Services.**

New, less restrictive thermal noise calibration services recently established in the frequency range of 2 to 12.4 GHz overlap prior NBS services and provide an opportunity for intercomparison. The agreement between old and new calibration systems is better than 0.4%.
[Contact: David F. Wait, (303) 497-3610]

Microwave and Millimeter-Wave Metrology

Released for Publication

Hill, D.A., **Reflection Coefficient of a Waveguide with Slightly Uneven Walls.**

First-order results are derived for the reflection coefficient of a waveguide with slightly uneven walls. Specific analytical and numerical results are given for rectangular waveguides and coaxial transmission lines. Simple upper bounds are given for reflection coefficients in terms of the maximum deviation of the waveguide. For typical tolerances, the reflection coefficients are very small ($<10^{-3}$), but the results are important in precise six-port measurements.
[Contact: David A. Hill, (303) 497-3472]

Hoer, C.A., **An Equivalent Circuit for Imperfect Transmission Line Connectors.**

An exact equivalent circuit for a pair of transmission line connectors is developed. New reference planes are chosen in such a way that all imperfections in the connector pair can be lumped into one connector or the other. This makes it possible to compensate for imperfections in test port connectors when calibrating network analyzers.
[Contact: Cletus A. Hoer, (303) 497-3705]

Holt, D.R., **Determination of Scattering Parameters from Precision Coaxial Air-Line Standards.**

Scattering parameter expressions are developed for the principal mode of a coaxial air line. Dimensional variations in the inner and outer conductors and skin effect are included in the model. An error analysis reveals that accuracy of the scattering parameters is primarily dependent on the precision of the measurements of conductor radii.
[Contact: Donald R. Holt, (303) 497-3574]

Optical Fiber Metrology

Released for Publication

Oates, C.W., and Young, M., **Profile Inhomogeneity in Multimode-Graded Index Fibers.**

We have measured the profile parameter of multimode-graded index fibers and found that it may vary azimuthally by 0.15 or more.
[Contact: Matt Young, (303) 497-3223/-5342]

Electro-Optic Metrology

Released for Publication

Electro-Optic Metrology (cont'd.)

Day, G.W., Lee, K.S., Rose, A.H., Veeser, L.R., Papatheofanis, B.J., and Whitesel, H.K., **Optical Fiber Sensors for Electromagnetic Quantities**, to be published in the Proceedings of the Fiber Optics Conference 88, McLean, Virginia, March 22-25, 1988; and the Proceedings of the Instrument Society of America Annual Conference, Albuquerque, New Mexico, May 2-6, 1988.

Several sensors used for the measurement of both pulsed and ac current, voltage, and magnetic field are described. Design considerations, including the choice of components and configurations, and performance achievements are discussed.
[Contact: Gordon W. Day, (303) 497-5204]

Hickernell, R.K., Larson, D.R., Phelan, R.J., Jr., and Larson, L.E., **Waveguide Loss Measurement Using Photothermal Deflection**, to be published in the Proceedings of the Topical Meeting on Integrated and Guided Wave Optics (IGWO'88), Sante Fe, New Mexico, March 25-April 1, 1988.

Photothermal deflection (PTD) is introduced as a technique for measuring propagation loss in optical channel waveguides. A probe laser beam is deflected by the thermally induced refractive-index gradient due to the absorption of guided pump light. The technique is noncontact and is applicable to a wide range of channel waveguide geometries and materials, including buried guides. Scattering centers and unguided background light affect the measurement only indirectly, since the PTD signal depends on the gradient of the local temperature and not the light intensity directly.

The pump beam from a HeNe laser of 633-nm wavelength was mechanically chopped and coupled into potassium, ion-exchanged, glass waveguides. The probe beam, also of 633-nm wavelength, was focused on the substrate surface, and its deflection was measured by a silicon bicell using lock-in detection. Our measurements of the PTD signal as a function of the probe spot position agree with similar measurements performed on bulk materials by other researchers. Scans of the PTD signal as a function of distance along the waveguide yielded propagation loss measurements with lower uncertainty than scans of the scattered light intensity. The PTD technique should be useful in the study of waveguide loss mechanisms.
[Contact: Robert K. Hickernell, (303) 497-3455]

Lee, K.S., and Day, G.W., **Effect of Multiple Internal Reflections on the Stability of Electro-Optic and Magneto-Optic Sensors.**

The effects of multiple internal reflections are evaluated analytically. Response functions showing changes in shape as a function of optical path length are computed. The variation in sensitivity is obtained as a function of the reflectance of the sensing element and is found to be significant (several tenths of a percent) even when the reflectance is reduced to 0.1%.
[Contact: Kyung Lee, (303) 497-5170]

Complex Testing

Recently Published

Petersons, O., **NBS Initiatives in TMDE/ATE Diagnostics**, Symposium Record, National Security Industrial Association Diagnostics/Prognostics Symposium, Alexandria, Virginia, October 20-21, 1987, pp. 190-193 (1988).

Advances in technology dictate that the National Bureau of Standards consider how to provide metrological support for automatic test equipment (ATE) and the area of complex systems in general. Several decades ago, standard instruments were relatively simple devices such as standard resistors, electrochemical cells for voltage, and relatively

Complex Testing (cont'd.)

simple electromechanical indicating meters. Modern precision instruments, however, such a digital multimeters, calibrators, and waveform analyzers are very complex, computer-controlled systems having a broad spectrum of parameters including wide frequency and dynamic ranges and high speeds of operation. While complete characterization was possible and economical for the older and simpler standard instruments, this may not be true for modern measurement systems. Besides the calibration itself, consideration must be given to such items as judicious selection of a limited number of test points, test coverage, and confidence levels. These considerations relate, at least partly, to the subject of the Conference. In addition, NBS has strong interest in the diagnostics of systems that are required to produce accurate, reliable, and economical measurements. Such systems include state-of-the-art test, measurement, and diagnostic equipment (TMDE) and ATE as used by defense forces.

This presentation outlines several activities along the lines described above that are conducted at NBS, particularly in the Electrosystems Division. First, some basic tools and expertise that are applicable to TMDE and ATE diagnostics are discussed, followed by examples of applications, particularly to DoD systems and TMDE.
[Contact: Oskars Petersons, (301) 975-2400]

Other Fast Signal Topics

Released for Publication

Hill, D.A., **Fields of Horizontal Currents Located Above the Earth.**

The plane-wave spectrum technique is used to derive the fields of horizontal currents located in a horizontal plane above the earth. The far field is derived asymptotically, and the near field is computed by two-dimensional fast Fourier transform. Specific numerical results are presented for a pair of oppositely directed dipoles, and the results have application to detection of buried objects. When the antenna is located at low heights, the field is enhanced in the earth and decreased in air.
[Contact: David A. Hill, (303) 497-3472]

Hill, D.A., **Magnetic Dipole Excitation of a Long Conductor in a Lossy Medium.**

Formulations for the excitation of currents on an infinitely long conductor by electric or magnetic dipoles of arbitrary orientation are presented. The conductor can be either insulated or bare to model ungrounded or grounded conductors. Specific calculations are presented for a vertical magnetic dipole source because this source produces the appropriate horizontal polarization and could be used in a borehole-to-borehole configuration. Numerical results for the induced current and secondary magnetic field indicate that long conductors produce a strong anomaly over a broad frequency range. The secondary magnetic field decays slowly in the direction of the conductor and eventually becomes larger than the dipole source field.
[Contact: David A. Hill, (303) 497-3472]

Young, M., **Fresnel Lenses Display Inherent Vignetting.**

Some of the light refracted by a facet of a Fresnel lens impinges on the axial (or horizontal) portion of the facet and is directed away from the focal point. Loss of this light may be significant in applications where precise radiometric measurements are necessary.
[Contact: Matt Young, (303) 497-3223/-5342]

Recently Published

Bell, B.A., Stenbakken, G.N., Flynn,

Other Fast Signal Topics (cont'd.)

D.R., Evans, D.J., Burnett, E.D., Nedzelnitsky, V., and Eberhardt, K.R., **Evaluation of a Copy Prevention Method for Digital Audio Tape Systems**, NBSIR 88-3725 (February 1988).

The National Bureau of Standards in response to requests from the U.S. Congress tested a system designed to prevent unauthorized copying by digital audio tape (DAT) recorders of suitably encoded audio recordings. The system, designed by CBS Records, filters out a narrow range of frequencies from the spectrum of the original sound in the region of 3840 Hz, thereby encoding the material with a "notch" in the frequency spectrum so that a DAT recorder equipped with the system's decoding circuitry can sense the presence of a prescribed notch in the spectrum and inhibit recording.

The congressional questions and the NBS conclusions are:
1. Does the copy prevention system achieve its purpose?
NBS Conclusion: The system does not achieve its stated purpose.
2. Does the system diminish the quality of the prerecorded material into which the notch is inserted?
NBS Conclusion: The system's encoder alters the original electrical signal. For some listeners for some selections, this results in a discernible difference between prerecorded notched and unnotched material.
3. Can the system be bypassed and, if so, how easily?
NBS Conclusion: The copy prevention system can be bypassed easily.
[Contact: Barry A. Bell, (301) 975-2402]

Jesch, R.L., **Fixed and Base Station FM Transmitters**, National Institute of Justice, NIJ Standard-0201.01 (September 1987).

This document establishes minimum performance requirements and methods of test for fixed and base station frequency-modulated (FM) transmitters. The standard applies primarily to the law enforcement community, and as such covers the four frequency bands, 25 to 50 MHz, 150 to 174 MHz, 400 to 512 MHz, and 806 to 866 MHz. This standard supersedes NILECJ-STD-0201.00, Fixed and Base Station FM Transmitters.
[Contact: Ramon L. Jesch, (303) 497-3496]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Fenimore, C., **The Thermal-Expansive Growth of Prebreakdown Streamers in Liquids**, to be published in the Proceedings of the 1988 IEEE International Symposium on Electrical Insulation, Boston, Massachusetts, June 6, 1988.

The growth of electrically conductive, low-density regions has been observed in dielectric breakdown in a variety of liquids. This phenomenon motivates the development of the present theory for coupling thermal effects with fluid mechanical effects in the dynamics of elongated, impulsively driven bubbles. The model explicitly describes the time-dependent dimensions of a growing ellipsoidal bubble. The parameters of the model are the external pressure in the liquid, the density of energy which is deposited impulsively in the liquid, and the length over which energy is deposited.

In previous work, we have developed a model for such effects associated with the growth of a bubble about an arc in a liquid. In the case of the prebreakdown streamer, the geometry is not as simple as for an arc, and the evolution of the bubble is found in ellipsoidal coordinates. The effect of pressure is to shorten the time scale of the bubble dynamics. Even in the case when the bubble may not be spatially resolved, the time to recollapse can be es-

Power Systems Metrology (cont'd.)

tablished from visual data. Calculations based on the model are shown to be consistent with experimental results on the collapse of the streamer.
[Contact: Charles Fenimore, (301) 975-2428]

Hebner, R.E., **Measurement of Electrical Breakdown in Liquids**, to be published in the Proceedings of the NATO Advanced Study Institute on the Liquid State and Its Electrical Properties, Sintra, Portugal, July 5-17, 1987.

The continuing development of light sources, high-speed cameras, and high-speed electronic measuring systems have made it possible to study the breakdown process in increasing detail. The four measurements described are high-speed photography of the breakdown process, measurement of the voltage and current, optical spectroscopy, and the measurement of acoustic emission. After a battery of measurement techniques has been developed, understanding of the breakdown process is gained by changing the system in known ways and determining the effect of these changes on the measured results. Parameters which have been investigated include types of liquids, chemical additives, particle density, pressure, viscosity, and the rate of rise of the applied voltage. These investigations have led to the identification of four modes of growth when the streamer initiates at a cathode and three modes when it initiates at an anode.
[Contact: William E. Anderson, (301) 975-2423]

Misakian, M., **DC Electric Field Effects During Measurements of Monopolar Charge Density and Net Space Charge Density Near HVDC Power Lines.**

The influence of a dc electric field on the measurement of monopolar charge densities using an aspirator-type ion counter and the measurement of net space charge density using a Faraday cage or filter are examined. Optimum configurations which minimize the effect of the electric field are identified for each type of instrumentation.
[Contact: Martin Misakian, (301) 975-2426]

Misakian, M., **Measurement of Electrical Parameters Near AC and DC Power Lines**, to be published in the Proceedings of the IEEE Instrumentation and Measurement Technology Conference, San Diego, California, April 19-22, 1988.

This presentation surveys the instrumentation, calibration procedures, measurement techniques, and measurement standards which can be used for characterizing (1) fields near ac power lines and (2) electric field strength, ion current density, monopolar charge density, and net space charge near dc power lines.
[Contact: Martin Misakian, (301) 975-2426]

Misakian, M., and McKnight, R.H., **DC Electric Field Effects During Measurements of Monopolar Charge Density and Net Space Charge Density.**

The influence of a dc electric field on the measurement of monopolar charge densities using an aspirator-type ion counter and the measurement of net space charge density using a Faraday cage or filter is examined. Optimum configurations which minimize the effect of the electric field are identified for each type of instrumentation.
[Contact: Martin Misakian, (301) 975-2426]

Moore, W.J.M., So, E., Miljanic, P.N., Oldham, N.M., and Bergeest, R., **An International Comparison of Power Meter Calibrations Conducted in 1987**, to be published in the Conference Digest of CPEM-88, Tsukuba Science City, Japan, June 7-10, 1988.

The results of an intercomparison of power meter calibrations conducted during 1987 between the National

Power Systems Metrology (cont'd)

Research Council, Ottawa (Canada), the National Bureau of Standards, Gaithersburg (U.S.A.), and the Physikallsch-Technische Bundesanstalt, Braunschweig (Federal Republic of Germany), using a time-division multiplier watt-converter developed at the Institut Mihailo Pupin, Belgrade (Yugoslavia), are discussed. The measurements were made at 120 V, 5 A, 50 and 60 Hz, at power factors of 1.0, 0.5 lead and lag, and 0.0 lead and lag. An agreement between laboratories of better than 20 parts in a million is indicated.
[Contact: Nile H. Oldham, (301) 975-2408]

Olthoff, J.K., **Collisional Electron Detachment Cross Section Measurements for SF_6^-, SF_5^-, and F^- in SF_6: Implications for Interpretations of Existing Ion Transport and Breakdown Probability Data**, to be published in the Proceedings of the 9th International Conference on Gas Discharges and Their Applications, Venice, Italy, September 19-23, 1988.

Collisional electron detachment cross sections for SF_6^-, SF_5^-, and F^- on SF_6 target gas have been measured for relative (center-of-mass) energies in the range of 3 to 250 eV. Apparent thresholds for direct detachment are observed at 90 eV for SF_6^- and SF_5^-, and at 8 eV for F^-. Cross sections for ion conversion processes that compete with detachment are also reported. The measured cross sections are used in a theoretical model which invokes detachment from long-lived energetically unstable states of collisionally excited SF_6^- to explain the pressure dependence of previously measured detachment coefficients and the high apparent detachment thresholds implied by analysis of breakdown probability data for SF_6. The present results also indicate the necessity to re-examine ion conversion rates determined in SF_6 from drift-tube data.
[Contact: James K. Olthoff, (303) 497-2427]

Pace, M.O., Wintenberg, A.L., Blalock, T.V., Foust, J.V., Kelley, E.F., Nehmadi, M., and Hebner, R.E., **Measurement of Partial Discharges in Hexane Under DC Voltage.**

Partial discharges in liquid hexane are observed at the tip of a needle-sphere electrode system subjected to dc high voltage. A sensitive amplifier monitors the partial discharge current and activates a circuit which operates a high-speed, high-magnification photography system. The initiation and growth of the partial discharges is being photographed and correlated with the current supplied to the partial discharge. The initiation of the random phenomena is photographed by the use of an image-preserving optical delay.
[Contact: Edward F. Kelley, (301) 975-2424]

Van Brunt, R.J., and Kulkarni, S.V., **New Method for Measuring the Stochastic Properties of Corona and Partial Discharge Pulses**, to be published in the Proceedings of the 1988 IEEE International Symposium on Electrical Insulation, Boston, Massachusetts, June 7, 1988.

A new computer-based method for measuring the statistical characteristics of corona or partial discharge pulses is described. The method allows direct measurement of a set of conditional probability distributions that reveal correlations among successive pulse amplitudes, pulse time intervals, and between pulse amplitudes and time intervals. Application of the method to an investigation of ultraviolet sustained negative corona (Trichel) pulses in air has shown the existence of strong correlations between pulse amplitude and time interval as well as between amplitudes of successive pulses. The observed correlations appear to be consistent with existing models for Trichel pulse formation.
[Contact: Richard J. Van Brunt, (301)

Power Systems Metrology (cont'd.)

975-2425]

Van Brunt, R.J., and Kulkarni, S.V., **Stochastic Properties of Negative Corona (Trichel) Pulses in SF_6/O_2 Mixtures**, to be published in the Proceedings of the 9th International Conference on Gas Discharges and Their Applications: Venice, Italy, September 19-23, 1988.

The statistical probability distributions of discharge pulse amplitude, $p_o(q)$, pulse time interval, $p_o(\Delta t)$, and pulse amplitude for a given time separation, Δt, from the previous pulse, $p_1(q|\Delta t)$ have been measured for Trichel-type negative point-plane corona in SF_6/O_2 gas mixtures as functions of point-to-plane voltage and mixture ratio. The results reveal significant, previously unrecognized correlations among the amplitudes and time intervals of successive discharge pulses which are consistent current theoretical descriptions of the phenomenon. As the SF_6 content in SF_6/O_2 mixtures is increased, the growth of negative corona pulses diminishes as reflected in lower mean pulse amplitudes and the pulses appear more randomly in time; i.e., there is a broadening of the pulse time-interval distributions.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Recently Published

Martzloff, F.D., **Power Quality Measurements: Bringing Order Out of Chaos**, Energy Technology XV -- Repowering America (Proceedings of the Energy Technology Conference, Washington, DC, February 17-19, 1988) (Government Institutes, Inc., Maryland), pp. 947-959.

The quality of the power supplied to sensitive electronic equipment is an important issue. Quantifying this quality, however, is difficult under the present state of nonexistent or uncoordinated standards concerning two related questions: (1) what levels of power quality are required for what types of loads, and (2) what measurement techniques are required to determine reliably the level of disturbances that reduce quality. Development of standards by the consensus process and voluntary compliance, although a slow process, is a mechanism for reaching technically sound and cost-effective solutions. Several standards projects are in progress, but need industry-wide support to become the generally accepted basis for valid and useful measurements of power quality.
[Contact: Francois D. Martzloff, (301) 975-2409]

Sieck, L.W., and Van Brunt, R.J., **Rate Constants for F^- Transfer from SF_6 to Fluorinated Gases and SO_2. Temperature Dependence and Implications for Electric Discharge in SF_6**, Journal of Physical Chemistry, Vol. 92, No. 3, pp. 708-713 (1988).

The reactivity of SF_6^- towards SO_2, SOF_2, SO_2F_5, SOF_4, SF_4, and SiF_4 has been investigated using the technique of pulsed-electron-beam, high-pressure mass spectrometry. With the exception of the $SF_6^- + SiF_4$ reaction, all of the pairs exhibited a negative temperature coefficient in that the rate constants for F^- transfer decreased substantially with increasing temperature. The reaction $SF_6^- + SiF_4 \rightarrow SiF_5^- + SF_5$ was found to proceed with a rate constant of $5.6 \pm 0.8 \times 10^{-10}$ $cm^3/mol\text{-}s$ throughout the temperature range studied (298 to 510 K), which corresponds to a collision efficiency of unity. The other reactions were found to approach unit collision efficiency only at reduced temperatures (<300 K).
[Contact: Richard J. Van Brunt, (301) 975-2425]

Superconductors

Released for Publication

Goldfarb, R.B., Ried, D.L., Kreilick,

Superconductors (cont'd.)

T.S., and Gregory, E., **Magnetic Evaluation of Cu-Mn Matrix Material for Fine-Filament Nb-Ti Superconductors.**

Copper-manganese alloys have been proposed as matrix material for the reduction of coupling losses in fine-filament Nb-Ti superconductor wires. Magnetization and susceptibility measurements show that adverse magnetic effects arising from the spin-glass properties of this matrix are minimal for concentrations of Mn up to at least 4%.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Goodrich, L.F., **Development of Standards for Superconductors**, to be published as NBSIR 88-3088.

A cooperative program with the Department of Energy, the National Bureau of Standards, other national laboratories, and private industry is in progress to develop standard measurement practices for use in large-scale applications of superconductivity. Research for the period January 1986 through December 1987 is described. This report contains the results of critical-current studies on the effect of power supply current ripple, measurements on single strands extracted from cables, a round robin on a large NbTi monolithic conductor, and a Nb_3Sn round robin. Several useful current supply circuits have been developed. The reduction coupling losses in multifilamentary NbTi conductors has been addressed by a study of the magnetic properties of matrix material consisting of dilute alloys of Mn in Cu. In addition, the technique of vibrating-sample magnetometry is shown to be adaptable to the measurement of coupling losses in addition to hysteresis losses in multifilamentary conductors.
[Contact: Loren F. Goodrich, (303) 497-3143]

Moreland, J., Beall, J.A., Ono, R.H., and Clark, A.F., **Recent Tunneling Measurements of 90 K Superconductors at NBS**, to be published in the Proceedings of Materials Research Society Spring Meeting, Symposium K, High-T_c Superconductors, Reno, Nevada, April 5-9, 1988.

Several tunneling measurements on oxide superconductors have been made at NBS in the last year. These include break junction tunneling measurements of the energy gap, break junction superconducting point contacts, and the operation of a break junction point contact radio-frequency superconducting quantum interference device (SQUID) above 77 K. Until recently, these tunneling experiments have been limited to bulk samples cut from sintered pellets and a few small single crystals. We present here further results on thin films of $YBa_2Cu_3O_x$ (YBCO) using squeezable electron tunneling (SET) junctions. In contrast to the break junction tunneling experiments on bulk samples, where quite often tunneling spectra are without energy gap features, the spectra for thin-film SET junctions are rich with structure.
[Contact: John Moreland, (303) 497-3641]

Moreland, J., Clark, A.F., Damento, M.A., and Gschneider, Jr., K.A., **Single Crystal $HoBa_2Cu_3O_x$ Break Junctions**, to be published in the Proceedings of the International Conference on High Temperature Superconductors - Materials and Mechanisms of Superconductivity, Interlaken, Switzerland, February 29-March 4, 1988.

Tunneling spectra of $HoBa_2Cu_3O_x$ single crystals using the break junction method show energy gap features. These features are variable from junction to junction possibly due to an anisotropic gap function. The I-V curves show the peculiar square law dependence of the current on voltage seen in many tunneling measurements of polycrystalline samples of 90-K superconductors. This may be an indication of an inherent "granularity" built into the supercon-

Superconductors (cont'd.)

ducting matrix of a single crystal.
[Contact: John Moreland, (303) 497-3641]

Moreland, J., and Hirabayashi, H., **18th International Conference on Low Temperature Physics (LT-18)**.

This note discusses results presented relating to superconductivity, especially superconductivity above liquid-nitrogen temperature at the 18th International Conference on Low Temperature Physics (LT-18), held in Kyoto, Japan, August 20-26, 1987. Over 1600 persons from 36 countries attended LT-18, with papers presented in areas including superconductivity, magnetism, heavy-electron systems, density waves, thermometry, cryogenic techniques, liquid helium 3 and helium 4 and superfluid properties, critical phenomena, polarized systems, metals, and semiconductors. About 200 of the contributed papers (20% of the total) were on high-critical-temperature superconductors, and there was a special symposium on this topic.
[Contact: John Moreland, (303) 497-3641]

Recently Published

Chen, D.-X, Goldfarb, R.B., Nogues, J., and Rao, K.V., **Magnetic Susceptibility of Sintered and Powdered Y-Ba-Cu-O** (Original title: Susceptibility Measurements of a Sintered and Powdered Y-Ba-Cu-O Superconductor), Journal of Applied Physics, Vol. 63, No. 3, pp. 980-983 (1 February 1988).

The real and imaginary parts of magnetic ac susceptibility of a sintered Y-Ba-Cu-O superconductor were measured as functions of temperature. The susceptibility may be separated into two contributions, one sensitive and the other relatively insensitive to the magnitude of the measuring field. The former is partially suppressed upon coarsely crushing the sample. It is completely suppressed after finely powdering, whereupon the susceptibility curves become insensitive to the magnitude of the measuring field. Several models might be consistent with the results.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Ekin, J.W., **Transverse Stress Effect on Multifilamentary Nb_3Sn Superconductor**, Advances in Cryogenic Engineering Materials, Vol. 34, pp. 547-552 (Plenum Publishing Corporation, 1988).

A large reversible degradation of the critical current of multifilamentary Nb_3Sn superconductors has been observed under application of uniaxial compressive stress at 4 K applied transverse to the conductor axis. In bronze-process multifilamentary Nb_3Sn, the onset of significant degradation occurs at about 50 MPa. The intrinsic effect of transverse stress on the upper critical field is about ten times greater than for axial stress. Although transverse stress on the Nb_3Sn filaments is less than axial stress, it will need to be considered in the internal stress design of large magnets. The effect scales with conductor thickness and consequently will place limits on conductor dimensions and the spacing between distributed reinforcement in large magnets.
[Contact: John W. Ekin, (303) 497-5448]

Goodrich, L.F., Bray, S.L., and Clark, A.F., **Current-Ripple Effect on Superconductive DC Critical Current Measurements**, Advances in Cryogenic Engineering Materials, Vol. 34, pp. 1019-1026 (1988).

The effect of sample current power supply ripple on the measurement of dc critical current is reported. Measurements were made on multifilamentary NbTi superconductors. Ripple in a current supply becomes more significant above 500 A because effective filtering becomes more difficult. The presence of

Superconductors (cont'd.)

current ripple reduces the measured dc critical current. Ripple can also directly affect the voltmeter used for the measurements, because it has to operate with a noisy input. The quantitative effect of current ripple was studied using a battery current supply instrumented to allow the creation of ripple current with variable frequency and amplitude. Problems common to all large conductor critical current measurements are discussed.
[Contact: Loren F. Goodrich, (303) 497-3143]

Moreland, J.M., Ekin, J.W., Goodrich, L.F., Capobianco, T.E., and Clark, A.F., **Electron Tunneling Measurements in LaSrCuO and YBaCuO**, Proceedings of Symposium S, 1987 Spring Meeting of the Materials Research Society, Anaheim, California, April 23-24, 1987, pp. 273-275 (1988).

The break junction technique whereby vacuum tunneling occurs within the fracture of a bulk sample is used to study the LaSrCuO and YBaCuO perovskite superconductors. Structure in the current-versus-voltage characteristics is reminiscent of previous quasiparticle curves obtained for BCS superconducting materials. Some curves have anomalous qualities, including large dips in the junction conductance with increasing voltage just above a well-defined tunneling gap edge, linearly increasing junction conductance with applied bias, along with features occurring near voltage intervals following a 1, 3, 5 pattern.
[Contact: John M. Moreland, (303) 497-3641]

Moreland, J.M., Goodrich, L.F., Ekin, J.W., Capobianco, T.E., and Clark, A.F., **Anomalous Behavior of Tunneling Contacts in Superconducting Perovskite Structures**, Advances in Cryogenic Engineering Materials, Vol. 34, pp. 625-632 (Plenum Publishing Corporation, 1988).

Our break junction results for electron tunneling spectroscopy of the perovskite superconductors La-Sr-Cu-O and Y-Ba-Cu-O are similar to those obtained using thin-film, scanning tunneling microscopy, and point-contact methods. Energy gap structures are sometimes observed in the measured current-voltage characteristics. More often, however, the characteristics are anomalous when compared to previous tunneling studies of BCS superconductors. The anomalies include linearly increasing conductance with voltage, large deviations in junction conductance above the gap edge, and junction diode action. We discuss some possible explanations for these observations.
[Contact: John M. Moreland, (303) 497-3641]

Other Electrical Systems Topics

Released for Publication

Martzloff, F.D., **A Review of Candidate Methods for Detecting Incipient Defects Due to Aging of Installed Cables in Nuclear Power Plants**, to be published in the Proceedings of the Workshop on Power Plant Cable Condition Monitoring, San Francisco, California, February 16-18, 1988; and as NBSIR 88-3791.

Several types of test methods have been proposed for detecting incipient defects due to aging in cable insulation systems, none offering certainty of detecting all possible types of defects. Some methods apply direct detection of a defect in the cable; other methods detect changes in electrical or nonelectrical parameters from which inferences can be drawn on the integrity of the cable. The paper summarizes the first year of a program conducted at the National Bureau of Standards to assess the potential of success for in-situ detection of incipient defects by these methods.
[Contact: Francois D. Martzloff, (301) 975-2409]

ELECTROMAGNETIC INTERFERENCE

Radiated Electromagnetic Interference

Released for Publication

Camell, D.G., Larsen, E.B., and Anson, W.J., **NBS Calibration Procedures for Horizontal Dipole Antennas (25 to 1000 MHz)**, to be published in the Symposium Record of the 1988 IEEE International Symposium on Electromagnetic Compatibility, Seattle, Washington, August 2-4, 1988.

The theoretical basis and test procedures for horizontally polarized dipole calibrations at the National Bureau of Standards are described. Two different techniques and two different test sites are used for these measurements. The standard antenna method uses the calculation of a field strength level, from the response of a simple half-wave dipole, to calibrate an antenna. This method is used at an open-field site in the frequency range 25 to 1000 MHz. The standard field method applies the theoretical gain equations of waveguides to determine the field strength level. This latter method is used in an anechoic chamber in the frequency range 200 to 1000 MHz. Procedures for both techniques are explained and measurement setups are illustrated. Measurement uncertainties are discussed.
[Contact: Dennis G. Camell, (303) 497-3214]

Driver, L.D., and Kanda, M., **An Optically Linked Electric and Magnetic Field Sensor for Poynting Vector Measurements in the Near Fields of Radiating Sources.**

A unique, single-element antenna-sensing scheme is described which can simultaneously measure the electric, magnetic, and time-dependent Poynting vectors of electromagnetic (EM) fields. The electric and magnetic responses of the antenna sensor are separated by a 0°/180° hybrid junction. The resulting two radio-frequency voltages, along with relative phase and frequency information, are transmitted to a remotely located vector analyzer by a pair of well-matched fiber optic downlinks. The remote receiver displays: (1) the electric dipole response, (2) the magnetic loop response, and (3) the time phase difference between the two. This information is sufficient to determine the time-dependent Poynting vector. Both a theoretical analysis and a discussion of the experimental measurements performed are presented, which describe the capabilities and performance of a working prototype of the antenna measurement scheme. The results demonstrate that a three-axis (isotropic) version of this system could be used to measure the near-fields of EM sources, as well as to completely describe the resultant flow of energy.
[Contact: Lanny D. Driver, (303) 497-3911]

Kanda, M., and Driver, L.D., **An Optically Linked Electric and Magnetic Field Sensor for Poynting Vector Measurements in the Near Field of Radiating Sources.**

An improved, single-element antenna-sensing technique is described which can simultaneously measure the electric (E) field, magnetic (H) field, and time-dependent Poynting vector of electromagnetic (EM) fields. Two radio-frequency voltages are produced which, along with relative phase and frequency information, are transmitted to a remotely located vector analyzer by a pair of matched fiber optic downlinks.
[Contact: Motohisa Kanda, (303) 497-5320]

Ma, M.T., **Theory and Measurements of Unintentional Radiators.**

By characterizing an unknown emitter with equivalent vector electric- and magnetic-dipole moments, we formulate a theoretical basis to express the radiation properties of such an emitter in terms of these unknown dipole moments. Power and relative phase

Radiated EMI (cont'd.)

measurements from appropriate ports of a transverse electromagnetic cell, when the emitter is placed at the cell's center, are proven to be sufficient to determine quantitatively the unknowns and, therefore, the radiation characteristics.
[Contact: Mark T. Ma, (303) 497-3800]

Randa, J.P., Kanda, M., Melquist, D.G., Sega, R.M., and Norgard, J.D., **High Frequency Electric-Field Probe Development**, to be published in the Proceedings of the EMC EXPO'88 Conference, Washington, D.C., May 10-12, 1988.

Various designs have been considered for electric-field probes for the frequency range 26 to 110 GHz. A fiber optic temperature sensor to detect the heating of a resistive strip was designed, built, and tested. With increased sensitivity, this design may be capable of operating to above 100 GHz.
[Contact: James P. Randa, (303) 497-3150]

Reeve, G.R., **Proficiency Testing for MIL-STD 462 NVLAP Laboratories**, to be published in the Proceedings of the EMC EXPO'88 Conference, Washington, D.C., May 10-12, 1988.

Some of the difficulties in obtaining accurate results using MIL-STD 462 test procedures are reviewed. Several measuring standard devices whose characteristics have been determined accurately are presented that could be used for verification of test results along with their application to proficiency testing for NVLAP certification.
[Contact: Gerome R. Reeve, (303) 497-3557]

Vanzura, E.J., **Automated System for Electromagnetic Field Generation and Immunity Testing**, to be published in the 1988 IEEE Instrumentation/ Measurement Technology Conference, San Diego, California, April 19-22, 1988.

An interactive computer-controlled system has been constructed for radiated immunity measurements. It can set up a desired unperturbed field strength at a point in space and simultaneously measure field strengths and polarizations at up to ten different positions. Field mapping experiments have been performed with the system in an anechoic chamber, a partially loaded shielded room, and an unloaded shielded room. Results confirm dramatic improvement in spatial field uniformity as more absorber is used. If the unperturbed fields in a specified test volume do not deviate more than a desired amount for any frequency of interest, meaningful immunity tests can be performed. An equipment under test (EUT) is placed into the test volume and its response to radiation is measured using current probes and a spectrum analyzer. Such an experiment requires many mid-experiment calculations, making automation highly desirable because of significant time savings.

Our frequency range of interest is 50 to 200 MHz because this is a particularly difficult frequency band in which to perform reliable immunity tests. By measuring the field variations in a test zone, systematic uncertainty limits due to spatial field deviations can be estimated more accurately. This allows testing in an anechoic chamber below what is normally considered its lowest usable frequency. If an anechoic chamber is not available, a partially loaded shielded room can be used, with the necessary requirement that specifications on spatial field uniformity be relaxed.

This measurement system can be used in conjunction with many other facilities, such as a tranverse electromagnetic cell, an open-field site (ground screen) or a reverberating chamber, and can be used to test at frequencies from the low kilohertz up to 2 GHz.
[Contact: Eric J. Vanzura, (303) 497-5752]

Radiated EMI (cont'd.)

Wilson, P.F., and Ma, M.T., **Techniques for Measuring the Electromagnetic Shielding Effectiveness of Materials: Part II -- Near-Field Source Simulation.**

Shielding effectiveness relates to the ability of a material to reduce the transmission of propagating fields in order to electromagnetically isolate one region from another. Because the shielding capability of a complex material is difficult to predict, it often must be measured. Two measurement approaches based on near-field source simulation are studied, namely, the use of the dual TEM cell and an apertured TEM cell in a reverberating chamber. In each case, we consider the system frequency range, test sample requirements, test field type, dynamic range, measurement time required, analytical background, and present data taken on a common set of materials.
[Contact: Mark T. Ma, (303) 497-3800]

Wilson, P.F., Ma, M.T., and Adams, J.W., **Techniques for Measuring the Electromagnetic Shielding Effectiveness of Materials: Part I -- Far-Field Source Simulation.**

Shielding effectiveness relates to the ability of a material to reduce the transmission of propagating fields in order to electromagnetically isolate one region from another. Because the shielding capability of a complex material is difficult to predict, it often must be measured. A number of far-field source simulation measurement approaches are studied, including the use of coaxial transmission-line holders and a time-domain system. In each case, we consider the system frequency range, test sample requirements, test field type, dynamic range, measurement time required, analytical background, and present data taken on a common set of materials.
[Contact: Mark T. Ma, (303) 497-3800]

Wilson, P.F., Ondrejka, A.R., and Ma, M.T., **ESD Radiated Electromagnetic Fields -- Theory and Experiment**, to be published in the Symposium Record of the 1988 IEEE International Symposium on Electromagnetic Compatibility, Seattle, Washington, August 2-4, 1988.

Electrostatic discharge (ESD) can be a serious threat to electronic equipment. To date, metrology efforts have focused primarily on ESD-associated currents in order to develop test simulators. Significantly less work has been done on the ESD-radiated fields. This paper examines the fields problem, both theoretically and experimentally. Measurements indicate that the electric fields can be quite significant (>150 V/m at a distance of 1.5 m), particularly for relatively low-voltage sparks (<6 kV). A theoretical dipole model for the ESD spark is developed to compute the radiated fields if the required current waveform can be modeled based on measurements. The agreement between theory and experiment is good. The model may be used to predict the fields for a wide range of possible discharge configurations.
[Contact: Mark T. Ma, (303) 497-3800]

Wu, D.I., and Chang, D.C., **The Effect of a Large Rotating Scatterer in a Rectangular Cavity**, to be published as NBS Technical Note 1317.

In a mode-stirred chamber, the field in the cavity is perturbed with a stirrer, i.e., a rotating scatterer, in such a way that it is uniformly random. In this report, we investigate the key factor which governs the effectiveness of a stirrer. By examining the fundamental properties associated with a perturbing body in a cavity, we find that the key to effective field perturbation lies in the shifting of eigenmode frequencies. When the size of the perturbing body becomes large, the shifting may be large enough that the new perturbed modes no longer resemble the original unperturbed modes. In effect, as this body rotates, different

Radiated EMI (cont'd.)

perturbed modes may be excited, thus introducing randomness into the system. We illustrate this phenomenon by examining a 2D cavity with a 1D perturbing body. Using the transmission-line-matrix method, the shifting of eigenfrequencies and the variation on the magnitude of the fields for different stirrer sizes are computed. From this analysis, useful insights are drawn which include an analogy between the action of a large stirrer and a frequency modulator.
[Contact: Doris I. Wu, (303) 497-3214]

Wu, D.I., and Chang, D.C., **A Hybrid Representation of the Green's Function in an Over-Moded Rectangular Cavity.**

A hybrid ray-mode representation for the Green's function in a rectangular cavity is developed using the finite Poisson summation formula. In order to obtain a numerically efficient scheme for computing the field generated by a point source in a large rectangular cavity, the conventional modal representation of the Green's function is modified in such a way that all the modes near resonance are retained, while the truncated remainder of the mode series is expressed in terms of a weighted contribution of rays. For a large cavity, the contribution of rays from far-away images becomes small; therefore, the ray sum can be approximated by one or two dominant terms without a loss of numerical accuracy. To illustrate the accuracy and the computational simplification of this ray-mode representation, numerical examples are included with conventional mode series (summed at the expense of long computation time) serving as a reference.
[Contact: Doris I. Wu, (303) 497-3842]

Recently Published

Adams, J.W., Ondrejka, A.R., and Medley, H.W., **Time-Domain System for Identification of the Natural Resonant Frequencies of Aircraft Relevant to Electromagnetic Compatibility Testing**, NBSIR 87-3077 (November 1987).

A method for measuring the natural resonant frequencies of a structure is described. The measurement involves radiating an aircraft with an impulsive electromagnetic field and receiving the echo reflected from this aircraft. Resonances are identified by using a mathematical algorithm based on Prony's method to operate on the digitized reflected signal. The measurement system consists of special transverse electromagnetic horns, pulse generators, a time-domain system, and an implementation of Prony's algorithm. The frequency range covered is 5 to 250 MHz; this range is determined by antenna and circuit characteristics.

The use of this system is shown, and measured data from several different helicopters are presented in different forms. These different forms are needed to determine which of the resonant frequencies are real and which are false. The false frequencies are byproducts of Prony's algorithm.
[Contact: John W. Adams, (303) 497-3328]

Cavcey, K.H., and Friday, D.S., **Aircraft Field Degradation and Electromagnetic Compatibility**, NBSIR 88-3083 (January 1988).

This paper discusses the first tests undertaken to study the problem of field degradation in army aircraft (helicopters and one fixed-wing airplane) due to the deterioration of electronic and electrical systems. The electromagnetic compatibility of such systems was investigated by passive measurement of each aircraft as a collection of radio-frequency sources. Methods for detection of these sources were developed that included sensitivity to both stationary and nonstationary noise that existed.

The collected data were studied to see

Radiated EMI (cont'd.)

if there existed any obvious factors derived from the data that one could use to correct potential problems that might affect flight safety. Emphasis was placed upon making such test methods appropriate, inexpensive, and easily performed by army field personnel. In addition, applications to quality control or acceptance testing, as related to the Environmental Stress Screening program, were examined.
[Contact: Kenneth H. Cavcey, (303) 497-3995]

Crawford, M.L., Koepke, G.H., and Ladbury, J.M., **EMR Test Facilities, Evaluation of Reverberating Chamber Located at RADC, Griffiss AFB, Rome, New York**, NBSIR 87-3080 (December 1987).

This report describes measurement procedures and results obtained from evaluating the reverberating chamber facility located at the Rome Air Development Center (RADC), Griffiss Air Force Base, Rome, New York. The facility was developed by the RADC for use in measuring and analyzing the electromagnetic susceptibility/ vulnerability of weapon systems and the shielding effectiveness of enclosures and shielding materials. A brief description of the facility, including the instrumentation used for performing its evaluation and calibration by the National Bureau of Standards, is given. Measurements described include: (1) evaluation of the chamber's transmitting and receiving antennas' voltage standing-wave ratios; (2) measurement of the chamber's insertion loss or coupling efficiency versus frequency; (3) measurement of the chamber's tuner effectiveness; (4) determination of the electric- (E-) field uniformity in the chamber's test zones versus frequency; (5) determination of the absolute amplitude calibration of the test E-fields in the chamber based upon the reference antenna's received power measurements and calibrated dipole probe antenna measurements; (6) comparison of reference standard equipment under test responses to test fields established inside the RADC reverberating chamber and the NBS anechoic chamber; and (7) evaluation of the performance characteristics of the reverberating chamber excited by pulsed radio frequency (rf) at selected discrete frequencies as a function of pulse width (0.2 to 20 μs) and the chamber's quality factor (Q). Conclusions indicate that the chamber can be used at frequencies down to approximately 150 MHz for continuous-wave (cw) testing, and for rf pulsed immunity testing with pulse widths as short as 0.3 μs by using rf absorber loading. Immunity testing to pulsed rf fields, however, has some inherent limitations that are discussed in the report. Estimates of the cw measurement uncertainties derived empirically from the test results are given.
[Contact: Myron L. Crawford, (303) 497-5497]

Randa, J., Kanda, M., and Melquist, D., **Possible Designs for Electric-Field-Strength Probes for Millimeter Waves**, NBSIR 88-3084 (February 1988).

Various designs are considered for electric-field probes for the frequency range from 26 to 110 GHz. Two particular designs are investigated in some detail. A resistively tapered dipole antenna with a diode detector shows promise for frequencies up to about 40 GHz. The second design is based on a fiber-optically sensed temperature sensor to detect the heating of a resistive strip. If its sensitivity can be increased significantly, this design may be capable of operating to frequencies above 100 GHz.
[Contact: James P. Randa, (303) 497-3150]

Wilson, P.F., Ondrejka, A.R., Ma, M.T., and Ladbury, J.M., **Electromagnetic Fields Radiated From Electrostatic Discharges Theory and Experiment**, NBS Technical Note 1314 (February 1988).

Radiated EMI (cont'd.)

The fields radiated by electrostatic discharges (ESD) are studied both theoretically and experimentally. The ESD spark is modeled theoretically as an electrically short, time-dependent, linear dipole situated above an infinite ground plane. Experimentally, sparks of varying voltages are generated by a commercially available simulator and used to excite a number of targets including: (1) the extended inner conductor of a coaxial cable mounted in a ground plane, (2) direct discharges to a ground plane, (3) indirect radiation from a large metal plate, (4) a metal chair over a ground plane, and (5) a metal trash can. Results show that relatively low-voltage sparks (2 kV to 4 kV) excite the strongest radiated fields. This suggests that the spark fields can pose a significant interference threat to electronic equipment into the gigahertz range.
[Contact: Mark T. Ma, (303) 497-3800]

Conducted Electromagnetic Interference

Recently Published

Martzloff, F.D., **Power Quality Measurements: Bringing Order Out of Chaos**, Energy Technology XV -- Repowering America (Proceedings of the Energy Technology Conference, Washington, DC, February 17-19, 1988) (Government Institutes, Inc., Maryland), pp. 947-959.

The quality of the power supplied to sensitive electronic equipment is an important issue. Quantifying this quality, however, is difficult under the present state of nonexistent or uncoordinated standards concerning two related questions: (1) what levels of power quality are required for what types of loads, and (2) what measurement techniques are required to determine reliably the level of disturbances that reduce quality. Development of standards by the consensus process and voluntary compliance, although a slow process, is a mechanism for reaching technically sound and cost-effective solutions. Several standards projects are in progress, but need industry-wide support to become the generally accepted basis for valid and useful measurements of power quality.
[Contact: Francois D. Martzloff, (301) 975-2409]

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: Kathryn A. Gibson, (303) 497-3132]

Kline, K.E., and DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NBS Publications**, NBSIR 87-3074 (June 1987).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NBS in the period from January 1970 through December 1986. A few earlier references that are directly related to the present work of the Division are included.
[Contact: Sarabeth Moynihan, (303) 497-3678]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division Publications, NBS list of Publications 94 (January 1988).**

This bibliography covers publications of the Electrosystems Division, Center for Electronics and Electrical Engineering,

Lists of Publications (cont'd.)

NBS, and of its predecessor sections for the period January 1963 to January 1988. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology, NBS List of Publications** 72 [a bibliography of NBS publications concerning semiconductor measurement technology for the years 1962-1987] (March 1988).

This bibliography 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 1987. An index by topic area and a list of authors are provided.
[Contact: E. Jane Walters, (301) 975-2050]

RECENTLY ISSUED STANDARD REFERENCE MATERIALS

The Semiconductor Electronics Division announces the release of a new Standard Reference Material (SRM) for **ellipsometrically derived thickness and refractive index of a silicon dioxide film on silicon.** Available for sale to the public through the NBS Office of Standard Reference Materials [for orders, (301) 975-6776], SRM 2530 is separately available for three oxide thicknesses: 50 nm (2530-1), 100 nm (2530-2), and 200 nm (2530-3).

This SRM was developed to respond to industry needs to evaluate the accuracy of ellipsometers, but may also be used as aid in the calibration of various other optical and mechanical thickness monitoring instruments.

Each SRM consists of a 76-mm (3-in.) diameter silicon wafer on which a uniform silicon dioxide layer was grown, patterned, and partially covered with chromium. The certified values were determined from measurements made using the highly accurate ellipsometer developed in the Division and are the ellipsometric parameters delta, Δ, and psi, ψ, at a wavelength of $\lambda = 632.8$ nm. The SRMs are also certified for the derived values of thickness and refractive index of its silicon dioxide layer determined by using a two-layer model consisting of a silicon dioxide layer on a thin silicon-rich oxide interlayer. [Contact: George A. Candela, (301) 975-2086]

1988 CEEE Calendar

August 23-26 (Vail, CO)

Laser Measurements Short Course. This course will emphasize the concepts, techniques, and apparatus used in measuring laser parameters and will incorporate a visit to the NBS laser measurement laboratories. Attendees will be assumed to have knowledge equivalent to a degree in physics or electrical engineering; some experience in the use of lasers is desirable.

Major topic areas include: optics for laser measurements, attenuation techniques, laser operation, basic laser power/energy standards, laser power-/energy measurement techniques, pulse measurements, transfer standards, beam-profile measurements, diode lasers, laser measurements for optical communications, statistics and error analyses, and laser safety. Instructors will be drawn from NBS, industry, and other government agencies. [Contact: Office of Conference Services, (303) 492-5151; for technical information, Douglas L. Franzen, (303) 497-3346]

September 12-14, 1988 (San Jose, CA)

VLSI and GaAs Chip Packaging Workshop. This Workshop is co-sponsored by the Components, Hybrids, and Manufacturing Technology Society of IEEE and NBS; attendees are expected to be knowledgeable in the field and to participate in

CEEE Events (cont'd.)

discussions. Topic areas include: VLSI and wafer-scale package design (characterization and implementation, cost and performance-driven solutions); package thermal design (characteristics, results, and issues); package interconnection options (wire bonding, TAB, flip chip, or optical); GaAs IC packaging (high-speed packaging considerations); package electrical issues (reduction of parasitics, improvements in electrical performance, reduction in line resistance); integrating package design (from die to system, including assembly and test issues); VLSI package materials advancements; die-attach solutions for large chips; and new failure mechanisms in VLSI packaging. [Contact: George G. Harman, (301) 975-2097]

September 20-21, 1988 (Boulder, CO)

Symposium on Optical Fiber Measurements. This symposium is intended to provide a forum for the lightwave communications community to discuss and possibly resolve measurement problems related to optical fiber, sources, detectors, switches, couplers, modulators, and other components. The symposium is sponsored by NBS, in cooperation with the Institute of Electrical and Electronics Engineers' Optical Communications Committee, and the Optical Society of America. Eight technical sessions are scheduled, including presentations relating to optical time-domain reflectometry return loss, polarization, losses, transmission modes, cut-off wavelength, geometry, and refractive index. [Contact: Douglas L. Franzen, (303) 497-3346]

October 26-28, 1988 (Boulder, CO)

Twentieth Symposium on Optical Materials for High Power Lasers (Boulder Damage Symposium). In addition to the NBS, this symposium is sponsored by the American Society for Testing and Materials, the Air Force Office of Scientific Research, the Office of Naval Research, the Defense Advanced Research Projects Agency, and the Department of Energy. It serves as the principal forum for the exchange of information on the physics and technology of materials for high-power lasers. Topics to be discussed include new materials, bulk damage phenomena, surface and thin-film damage, design considerations for high-power systems, and fundamental mechanisms of laser-induced damage. [Contact: Aaron A. Sanders, (303) 497-5341]

February 7-9, 1989 (San Diego, CA)

IEEE Semiconductor Thermal and Temperature Measurements Symposium. This fifth annual **SEMI-THERM** symposium is sponsored by the Components, Hybrids, and Manufacturing Technology Society of IEEE in cooperation with NBS and constitutes an international forum for the presentation of new developments relating to generation and removal of heat within semiconductor devices, measurement of device temperatures, and the simulation of device and system thermal behavior. Major SEMI-THERM topic areas include: thermal measurements; simulation, computation, and software; thermal characterization; and applications.

The program includes keynote speakers, technical presentations, tutorial sessions, workshops, and an exhibit. In addition, the Semiconductor Equipment and Materials Institute (SEMI) and the Joint Electron Devices Engineering Council (JEDEC) have scheduled in conjunction with SEMI-THERM several Standards Committee Task Force meetings, to which attendees are invited. [Contact: Frank F. Oettinger, (301) 975-2054]

September 11-13, 1989 (Munich, FDR)

VLSI and GaAs Chip Packaging Workshop. [Contact: George G. Harman, (301) 975-2097]

December 7-8, 1989 (Gaithersburg, MD)

CEEE Events (cont'd.)

Power Semiconductor Devices Workshop. [Contact: David L. Blackburn, (301) 975-2068]

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NBS-114A (REV. 2-8C)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET** *(See instructions)*	1. PUBLICATION OR REPORT NO. NBSIR 88-3815	2. Performing Organ. Report No.	3. Publication Date July 1988

4. TITLE AND SUBTITLE

Center for Electronics and Electrical Engineering Technical Progress Bulletin Covering Center Programs, January to March 1988, with 1988 CEEE Events Calendar

5. AUTHOR(S)

E. Jane Walters, compiler

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899

7. Contract/Grant No.

8. Type of Report & Period Covered

January-March 1988

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

10. SUPPLEMENTARY NOTES

All technical information included in this document has been approved for publication previously.

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This is the twenty-second 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 Progress Bulletin covers the first quarter of calendar year 1988. Abstracts are provided by technical area for both published papers and papers approved by NBS for publication.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

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

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☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

33

15. Price

$11.95

USCOMM-DC 6043-P80