Center for Electronics and Electrical Engineering
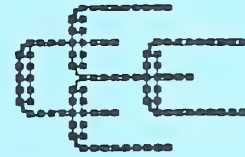
cEE

Technical Progress Bulletin

Covering Center Programs,
April 1 to June 1988,
with 1988 CEEE Events Calendar

88-2

October 1988

Stimulating America's Progress
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INTRODUCTION TO OCTOBER 1988 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the twenty-third issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology (formerly the National Bureau of Standards) Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the second quarter of calendar year 1988.

Organization of Bulletin: This issue contains abstracts for all Center papers released for publication by NIST 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 Unpublished papers appear under the subheading "Released for Publication".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 improve 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 Institute of Standards and Technology, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (301) 975-2220.

Center sponsors: The Center Programs are sponsored by the National Institute of Standards and Technology and a number of other organizations, in both the Federal and private sectors; these are identified on page 24.

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 22.

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SEMICONDUCTOR TECHNOLOGY

Silicon Materials

Released for Publication

Roitman, P., and Davis, G.E., **Selected Area Channeling Pattern and Defect Etch Study of Silicon Implanted with Oxygen,** to be published in the Proceedings of the Materials Analysis Society, Milwaukee, Wisconsin, August 8-12, 1988.

Silicon films on buried oxide layers formed by oxygen implantation have been studied using selected area channeling patterns and chemical etching. Neither technique provides the detailed information on defect morphology available from cross-sectional TEM, but both techniques appear capable of providing useful information on defect densities. Sample preparation is certainly easier for both than for TEM, and the channeling pattern approach is nondestructive. There is some promise that they can be extended in the case of lower defect densities, although it is not clear how far. The analysis of the channeling pattern data and the correlation of that analysis with film quality needs to be more firmly established.
[Contact: Peter Roitman, (301) 975-2077]

Analysis Techniques

Released for Publication

Baghdadi, A., Bullis, W.M., Croarkin, M.C., Yue-zhen, L., Scace, R.I., Series, R.W., Stallhofer, P., and Watanabe, M., **Interlaboratory Determination of the Calibration Factor for the Measurement of the Interstitial Oxygen Content of Silicon by Infrared Absorption.**

We report a world-wide interlaboratory experiment to determine the calibration factor used to calculate the interstitial oxygen content of silicon from room-temperature infrared absorption measurements. We conducted a roun robin for both the infrared and th absolute measurements on the same o equivalent specimens. The conversio coefficient for computing the oxyge content of silicon in parts per millio atomic (ppma) from a room-temperatur measurement of the absorption coeffi cient at 1107 cm^{-1} was determined to b 6.28 ± 0.18 ppma/cm^{-1}.
[Contact: Aslan Baghdadi, (301) 975 2062]

Gladden, W.K., Baghdadi, A., Slaughter S., and Duncan, W., **Semiconducto Measurement Technology: Automati Determination of the Interstitia Oxygen Content of Silicon Wafer Polished on Both Sides**, to be publishe as NIST Special Publication 400-81.

This Special Publication contains FORTRAN and a PASCAL computer progra which implement an ASTM test method fo the automatic determination of th interstitial oxygen content of silicon The programs are to be used as illustra tive examples by programmers wishing t implement the ASTM algorithm on thei computers. The publication als includes sample data that can be used t test the computer programs. The samp data are included in two forms: print, and on an MS-DOS floppy disk.
[Contact: Aslan Baghdadi, (301) 97 2062]

Roitman, P., and Davis, G.E., **Select Area Channeling Pattern and Defect Et Study of Silicon Implanted with Oxyge** to be published in the Proceedings the Materials Analysis Society, Milwa kee, Wisconsin, August 8-12, 1988.

Silicon films on buried oxide laye formed by oxygen implantation have be studied using selected area channeli patterns and chemical etching. Neith technique provides the detail information on defect morpholo available from cross-sectional TEM, b both techniques appear capable providing useful information on defe densities. Sample preparation

Analysis Techniques (cont'd.)

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[Contact: Peter Roitman, (301) 975-0977]

Dimensional Metrology

Released for Publication

Nyssonen, D., **Narrow-Angle Laser Scanning Microscope System for Linewidth Measurements on Wafers**, to be published as NISTIR 88-3808.

The integrated-circuit industry in its push to finer and finer line geometries approaching submicrometer dimensions has created a need for ever more accurate and precise feature-size measurements to establish tighter control of fabrication processes. In conjunction with the NBS Semiconductor Linewidth Metrology Program, a unique narrow-angle laser measurement system was developed. This report describes the theory, optical design, and operation of this system and includes computer software useful for characterizing the pertinent optical parameters and images for patterned thin layers. For thick layers, the physics is more complex, and only elements of the theory are included here. For more detail, the reader is referred to several related reports listed in the references.
[Contact: Robert D. Larrabee, (301) 975-2398]

Recently Published

Postek, M.T., Keery, W.J., and Larrabee, R.D., **The Relationship Between Accelerating Voltage and Electron Detection Modes to Linewidth Measure-**ment in an **SEM**, Journal of Scanning Microscopy, Vol. 10, pp. 10-18 (1988).

The basic premise underlying the use of the scanning electron microscope (SEM) for linewidth metrology in semiconductor research and production applications is that the video image acquired, displayed, analyzed, and ultimately measured accurately reflects the structure of interest. However, it has been clearly demonstrated that image distortions can be caused by the detected secondary electrons not originating at the point of impact of the primary electron beam and by the type and location of the secondary electron detector. These effects and their contributions to the actual image or linewidth measurement have not been fully evaluated. Effects due to uncertainties in the actual location of electron origination do not affect pitch (line center-to-center or similar-edge-location-to-similar-edge-location spacing) measurements as long as the lines have the same edge geometries and similar profiles of their images in the SEM. However, in linewidth measurement applications, the effects of edge location uncertainty are additive and thus give twice the edge detection error to the measured width. The basic intent of this work is to demonstrate the magnitude of the errors introduced by beam/specimen interactions and the mode of signal detection at a variety of beam acceleration voltages and to discuss their relationship to precise and accurate metrology.
[Contact: Michael T. Postek, (301) 975-2299]

Photodetectors

Released for Publication

Geist, J., **Blocked Impurity Band and Superlattice Detectors: Prospects for Radiometry**, to be published in the Proceedings of New Developments and Applications in Optical Radiometry, NPL, Teddington, United Kingdom, April 12-13, 1988.

Photodetectors (cont'd.)

Blocked Impurity Band (BIB) detectors and photomultipliers, which have been described by Petroff and Stapelbroek, may be suitable for use as high-accuracy standards for low background optical radiation measurements extending from the near ultraviolet to beyond 25 μm in the infrared. The current status of their development from the point of view of standards applications is reviewed.

Superlattice technology offers new materials properties, new degrees of freedom, and new possibilities for optical radiation detectors displaying a large range of tailorability and tunability. GaAs/AlGaAs superlattices are used to illustrate new properties, HgTe/CdTe superlattices are used to illustrate new degrees of freedom, and GaAs-doping superlattices are used to illustrate tailorability and tunability. [Contact: Jon Geist, (301) 975-2066]

Power Devices

Released for Publication

Hefner, A.R., **Analytical Modeling of Device-Circuit Interactions for the Power Insulated Gate Bipolar Transistor (IGBT)**, to be published in the Conference Record of the IEEE Industry Applications Society Annual Meeting, Pittsburgh, Pennsylvania, October 2-7, 1988.

The device-circuit interactions of the power Insulated Gate Bipolar Transistor (IGBT) for a series resistor-inductor load, both snubbered and unsnubbered, are simulated. An analytical model for the transient operation of the IGBT, previously developed, is used in conjunction with the load circuit state equations for simulations. The simulated results are compared with experimental results for all conditions. Devices with a variety of base lifetimes are studied.

For the fastest devices studied (base lifetime = 0.3 μs), the volta overshoot of the series resisto induction load circuit approaches t device voltage rating (500 V) for lo inductances greater than 1 μH. F slower devices, though, the volta overshoot is much less, and a larg inductance can therefore be switchi without a snubber circuit (e.g., 80 for a 7-μs device). In this study, t simulations are used to determine t conditions for which the differet devices can be switched safely withouta snubber protection circuit. Simulatios are also used to determine the requird values and ratings for protectin circuit components when protectin circuits are necessary.
[Contact: Allen R. Hefner, (301) 97-2071]

Recently Published

Hefner, A.R., Blackburn, D.L., ad Galloway, K.F., **A Steady-State Modl for the Insulated Gate Bipolr Transistor**, Physics of Semiconductr Devices (Proceedings of the Fourh International Workshop, Madras, Indi, December 10-15, 1987), S.C. Jain and . Radhakrishna, Eds. (World Scientifi, Singapore, 1988), pp. 22-38.

The power Insulated Gate Bipolr Transistor (IGBT) is a switching devie designed to overcome the high on-stae loss of the power MOSFET. The ICT behaves as a bipolar transistor which s supplied base current by a MOSFET. Te bipolar transistor of the IGBT has a wide base with the base contact at te collector edge of the base and s operated with its base in high-levl injection. The usual bipolar transistr models are not adequate for the IGl. This paper describes a model for te IGBT developed using ambipolar tra port.
[Contact: Allen R. Hefner, (301) 9 -2071]

Device Physics and Modeling

Released for Publication

Device Physics and Modeling (cont'd.)

Lowney, J.R., **Application of Multiscattering Theory to Impurity Bands in Si:As.**

Impurity bands in arsenic-doped silicon have been calculated for doping densities of 3.3×10^{17}, 1.2×10^{18}, and 8.0×10^{18} cm^{-3}. A multi-scattering approach is used with a model potential which provides both electronic screening and the proper bound-state energy for the isolated center. The results are in good agreement with previous calculations based on electron hopping among hydrogenic centers. An advantage of the multi-scattering approach is that it treats the conduction-band states as well, and shows the loss of these states to the formation of the impurity band. Calculations are also performed for the states associated with the binding of an extra electron to un-ionized arsenic centers, the so-called D$^-$ band. The overall results are in good agreement with the observed Mott transition in Si:As.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

Lowney, J.R., **The Effect of High Injection on the Density of States of Silicon,** to be published in the Proceedings of the IEEE Bipolar Circuits and Technology Meeting, Minneapolis, Minnesota, September 12-13, 1988.

The density of states of the conduction and valence bands of silicon has been calculated at 300 K for the case of an electron-hole plasma which occurs at high injection levels in bipolar devices.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

Mayo, S., and Lowney, J.R., **Lattice Relaxation in Silicon Doped with 4d- and 5d-Transition Metals.**

Photoionization cross-section spectra from deep centers in silicon doped with technologically important 4d- and 5d-transition elements were analyzed by the Ridley and Amato lattice coupling model to determine threshold energy and lattice relaxation parameters corresponding to optically induced transitions involving either band. The average optic phonon energy is 50 meV. Electron transitions to the conduction band from the silver, platinum, and gold acceptor centers have, respectively, threshold energies (in meV) $E_{TO} = 550$, 226, and 570. For silver and gold, the Huang-Rhys parameter S could not be determined because of a mixture of both allowed and forbidden transitions; for platinum, $S = 0.3$. Hole transitions from the valence band to the same centers are, respectively, $E_{TO} = 580$, 905, 590, and $S = 1.3$, 0.5, 0.8. Hole transitions from the valence band to the donor centers of these elements are, respectively, $E_{TO} = 340$, 320, 335, and $S = 1.2$, 1.4, 0.4. E_{TO} and S values are uncertain to within ± 5 meV and ± 0.05, respectively. Electron transition data from the donor centers of these elements to the conduction band are not available or insufficient to allow analysis of the threshold region.
[Contact: Santos Mayo, (301) 975-2045]

Insulators and Interfaces

Recently Published

Carver, G.P., Kopanski, J.J., Novotny, D.B., and Forman, R.A., **Specific Contact Resistivity of Metal-Semiconductor Contacts -- A New, Accurate Method Linked to Spreading Resistance,** IEEE Transactions on Electron Devices, Vol. 35, No. 4, pp. 489-497 (April 1988).

A new method to deduce the specific contact resistivity of metal-semiconductor contacts has been developed that allows separation of the components contributing to the total series resistance between two contacts. The principle of the method is the subtraction of the semiconductor spreading

Insulators and Interfaces (cont'd.)

resistance, deduced from a four-contact resistivity measurement, from the total two-contact resistance. This procedure requires geometrically well-defined small contacts that are accurately fabricated by lithographic methods. Using the method, accurate values were obtained for the specific contact resistivity of an aluminum-1.5% silicon alloy to p-type silicon wafers having dopant densities from 5×10^{14} to 2×10^{20} cm^{-3}. The specific contact resistivity values are lower than previously published values obtained using earlier methods in which parasitic and nonideal effects could not be quantified or eliminated. The lower values indicate that contact resistance has a less limiting effect on the performance of integrated circuits than presently believed.
[Contact: Joseph J. Kopanski, (301) 975-2089]

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 Frequency 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 at the 7-V level is typically less than ±5 ppm from 60 Hz to 2 kHz and less than ±10 ppm from 30 Hz to 15 kHz.
[Contact: Nile M. Oldham, (301) 975-2408]

Recently Published

Lawton, R.A., and Anderson, W.T., **Two-Layer Dielectric Microstrip Line Structure: SiO_2 on Si and GaAs on Si: Modeling and Measurement**, IEEE Transactions on Microwave Theory and Techniques, Vol. 36, No. 4, pp. 785-78? (April 1988).

Further development of the modeling of the two-layer dielectric stripline structure is reported by computing the scattering parameter S_{21} derived from the model and comparing the computed value with the measured value over the frequency range from 45 MHz to 25 GHz. The sensitivity of S_{21} to various parameters of the structure is also discussed. Examples of measurement and modeling of the silicon dioxide on silicon system and modeling of the gallium arsenide on silicon system are given.
[Contact: William L. Gans, (303) 497-3538]

Cryoelectronic Metrology

Released for Publication

Sauvageau, J.E., and McDonald, D.G., **Progress on a Superconducting Inductance Bolometer with Potential Photon Counting Sensitivity.**

Progress towards the development of a bolometer based on the temperature dependence of the inductance of a superconducting microstrip line is presented. Since the device is superconducting, it has no Johnson noise; it can be impedance matched to an optimized SQUID preamplifier, the quietest of all amplifiers; and its bias current is relatively unrestricted by self-heating. Thus, it is a bolometer theoretically limited only by phonon noise. If the phonon noise can be made negligible, then analysis suggests that a bolometer with an electrical noise equivalent power of about $7 \times 10^{-}$ $W/(H_z)^{1/2}$ may be feasible. Since one optical photon per second is about 7

Cryoelectronic Metrology (cont'd.)

10^{-19} W, the device has the potential for counting photons.
[Contact: Donald G. McDonald, (303) 497-5113]

Recently Published

Go, D., Hamilton, D., Lloyd, F.L., DiIorio, M.S., and Withers, R.S., **A Superconducting Analog Track-and-Hold Circuit**, IEEE Transactions on Electron Devices, Vol. 35, No. 4, pp. 498-501 (April 1988).

A superconducting analog track-and-hold circuit has been designed, fabricated, and tested.   Experimental results demonstrate a 1.2-GHz bandwidth and a 25-dB dynamic range. Model calculations indicate that an optimized circuit with a critical current density of 10,000 A/cm^2 can achieve a 4-GHz bandwidth and a 35-dB dynamic range.
[Contact: Diane Go, (303) 497-3770]

Antenna Metrology

Released for Publication

Francis, M.H., Repjar, A.G., and Kremer, D.P., **Antenna Measurements for Millimeter Waves at the National Bureau of Standards**, to be published in the Proceedings of the Antenna Measurement Techniques   Association   Meeting, Atlanta,   Georgia,   September   12-16, 1988.

For the past two years, the National Bureau of Standards (NBS) has been developing the capability to perform on-axis gain and polarization measurements at millimeter-wave frequencies from 33 to 65 GHz.   This paper discusses the error analysis of antenna measurements at these frequencies.   The largest source of error is insertion loss measurements. In order to make accurate insertion loss measurements, flanges on antennas need to be flat and perpendicular to the waveguide axis to within approximately 0.001 cm (0.0005 in.).   In addition, waveguide screws need to be tightened with a device that supplies constant torque.   For antennas with gains less than about 25 to 30 dB (probes), NBS can measure on-axis gains to within an uncertainty of 0.14 dB in the 33- to 50-GHz frequency band and within 0.16 dB in the 55- to 65-GHz frequency band using the three-antenna technique on the extrapolation range. For antennas with larger gains, NBS can measure on-axis gains to within an uncertainty of 0.21 dB in the 33- to 50-GHz frequency band and within 0.24 dB in the 55- to 65-GHz band using the planar near-field technique. NBS is continuing development of its measurement capabilities,   including   measuring   probe correction   coefficients   required   in planar near-field processing, in order to provide accurate pattern measurements at these frequencies.
[Contact: Michael H. Francis, (303) 497-5873]

Recently Published

Muth, L.A., **Displacement Errors in Antenna Near-Field Measurements and Their Effect on the Far Field**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 5, pp. 581-591 (May 1988).

The effects of probe displacement errors in the near-field measurement procedure on the far-field spectrum are studied. Expressions   are   derived   for   the displacement   error   functions   that maximize the fractional error in the spectrum both for the on-axis and off-axis   directions.   The x-y and z-displacement errors in planar scanning are studied first, and the results are then generalized to errors in spherical scanning. Some simple near-field models are used to obtain order-of-magnitude estimates for the fractional error as a function of relevant scale lengths of the near field, defined as the lengths over which significant variations occur.
[Contact: Lorant A. Muth, (303) 497-3603]

Noise Metrology

Recently Published

Wait, D.F., Daywitt, W.C., and Counas, G., **Intercomparison of NBS Noise Calibration Services**, Digest of the 1988 Conference on Precision Electromagnetic Measurements, Tsukuba, Japan, June 7-10, 1988, p. 209.

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 percent.
[Contact: David F. Wait, (303) 497-3610]

Microwave & Millimeter-Wave Metrology

Released for Publication

Counas, G.J., and Yates, B.C., **Measurement of Adapter Loss, Mismatch, and Efficiency Using the Dual Six-Port** to be published as NISTIR 88-3096.

A noise measurement system is being developed for the Air Force which uses coaxial cryogenic and ambient noise temperature standards to determine the noise temperature of the device under test. When the device under test has a different connector than those on the noise standards, an adapter has to be used. Adapter loss and complex reflection coefficient must be compensated for, or noise measurement accuracy is affected. A technique has been developed which uses a dual six-port measurement system to determine the mismatch, loss, and ultimately the efficiency of the adapter used. This enables correction of measurement results and allows measurements to be made with an adapter with no degradation of accuracy. The method of evaluating adapters is described, and instructions for its use are provided.

[Contact: George J. Counas, (303) 4973664]

Recently Published

Hoer, C.A., **An Equivalent Circuit for Imperfect Transmission Line Connectors**, Digest of the 1988 Conference on Precision Electromagnetic Measurements, Tsukuba, Japan, June 7-10, 1988, pp. 264-265.

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**, Digest of the 1988 Conference on Precision Electromagnetic Measurements, Tsukuba, Japan, June 7-10, 1988, p. 263.

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

Drapela, T.J., **Interlaboratory Comparison of Far-Field Methods for Determining Mode Field Diameter Using Both Gaussian and Petermann Definitions**, to be published as an NIST Special Publication.

ptical Fiber Metrology (cont'd.)

n interlaboratory comparison of easurement methods for mode field iameter (MFD) was conducted, using both he Gaussian and Petermann definitions f MFD. Both dispersion-shifted and nshifted single-mode optical fibers ere measured at wavelengths of 1300 nm nd 1550 nm. Petermann results gave ignificantly better agreement between easurement methods than Gaussian, ithout exception.
Contact: Timothy J. Drapela, (303) 97-5858]

ranzen, D.L., Young, M., Cherin, A., Head, E., Hackert, M., Raine, K., and Baines, J., **Numerical Aperture of Multimode Fibers by Several Methods: Resolving Differences**.

n industry-wide study among members of he Electronic Industries Association as conducted to document differences etween three numerical aperture easurement methods. Results on twelve ultimode graded index fibers indicate hat systematic differences exist among ommonly used far-field and index rofile techniques. Differences can be xplained by a wavelength-dependent actor and choice of definitions. onversion factors may be used to relate he various methods.
Contact: Douglas L. Franzen, (303) 97-3346/-5342]

ose, A.H., Day, G.W., Lee, K.S., Tang, D., Vesser, L.R., Paptheofanis, B.J., and Whitesel, H.K., **Optical Fiber Sensors for the Measurement of Electro-magnetic Quantities**, to be published in the Sensors, The Journal of Machine Perception (Proceedings of the Sensors Expo 1988), Chicago, Illinois, September 12-16, 1988.

ensors used for the measurement of both ulsed and ac current, voltage, and agnetic field are described. Design onsiderations, including the choice of omponents and configurations, and erformance achievements are discussed.

In this paper, several sensor configurations are described which are presently being used to measure current, voltage, and magnetic fields in environments where electromagnetic interference is a problem. The current and magnetic-field sensors are based on the Faraday effect either in single-mode optical fiber or in bulk glass or polycrystalline materials. The voltage sensors are based on the linear electro-optic (Pockels) effect in cubic crystalline materials.
[Contact: Allen H. Rose, (303) 497-5599]

Tang, D., and Day, G.W., **Progress in the Development of Miniature Optical Fiber Current Sensors**, to be published in the Proceedings of the IEEE Lasers and Electro-Optic Society Annual Meeting, Santa Clara, California, November 2-4, 1988.

Recent improvements in fiber annealing technology has allowed the substantial reduction of size and increase in the number of turns of fiber current-sensing coils. Coils as small as 7-mm diameter have been successfully annealed. Coils with more than 100 turns and diameters of 1 or 3 cm are routinely produced. The linear birefringence of such coils is small enough that Faraday rotation is not measurably diminished. Increased loss as a result of annealing is minimal.
[Contact: Gordon W. Day, (303) 497-5204]

Electro-Optic Metrology

Released for Publication

Gallawa, R.L., and Tu, Y., **Analysis of Circular Bends in Planar Optical Waveguides**.

Waveguides with circular bends are analyzed using a conformal transformation in conjunction with the WKB method of dealing with the nonuniform refractive index that results from the transformation. The result is a

Electro-Optic Metrology (cont'd.)

prediction of the operational parameters
of the bent guide, including the loss.
The transformation allows an intuitive
understanding of the cause of the loss.
[Contact: Robert L. Gallawa, (303) 497-
3761]

Hale, P.D., and Day, G.W., **Stability of
Birefringent Linear Retarders (Wave-
plates).**

The effects of changes in temperature,
wavelength, and direction of propagation
(angle of incidence) on the retardance
of zero-order, multiple-order, compound
"zero-order", and temperature-compen-
sated waveplates are described in
detail. A disagreement in the litera-
ture regarding the properties of a
compound "zero-order" waveplate is
resolved by showing that with respect to
temperature and wavelength, it behaves
like a true zero-order waveplate, but
with respect to angle of incidence, it
behaves like a multi-order waveplate. A
previously proposed temperature-
compensated design is shown to suffer
from the same directional limitations.
A new design for a retarder consisting
of one element of a positive uniaxial
crystal and one element of a negative
uniaxial crystal is proposed. The
retardance of such a waveplate would be
much less sensitive to the direction of
propagation, but somewhat more sensitive
to temperature, than a typical compound
zero-order waveplate.
[Contact: Gordon W. Day, (303) 497-
5204]

Hickernell, R.K., Larson, D.R., and
Phelan, R.J., **Electrically Calibrated
Photothermal Deflection Measurement for
Separating Channel Waveguide Loss
Mechanisms**, to be published as an NIST
Special Publication.

Electrical calibration of the photother-
mal deflection effect permits us to
distinguish absorption from scattering
contributions to total propagation loss
in channel waveguides. In the calibra-

tion technique, the resistive heating of
a thin-film metal strip deposited on the
substrate mimics the absorption of
guided light. The technique is
illustrated by experimental results from
ion-exchanged glass waveguides.
[Contact: Robert K. Hickernell, (303)
497-3455]

Larson, L.E., Larson, D.R., and Phelan,
R.J., **System for Measuring Optical
Waveguide Intensity Profiles**, to be
published as NISTIR 88-3092.

A computer-controlled system to measure
the intensity profile of optical
waveguides has been developed.
Knowledge of the intensity profile
provides an indication of the shape of
the waveguide and, therefore, the degree
to which light can be coupled to the
guide from an optical fiber. This
report describes the construction and
operation of this system.
[Contact: Donald R. Larson, (303) 497-
3440]

Lee, K.S., **Electromagnetic Wave
Propagation Through Anisotropic Crystals
Possessing Multiple Birefringences, and
Compensation Techniques for Bulk-Type
Optical Sensors with Multiple Birefrin-
gences.**

The expression for the dielectric tensor
of an anisotropic crystal with multiple
perturbation is derived. Starting from
Maxwell's equations and the expression
for the dielectric tensor, electromag-
netic wave propagation through anisotro-
pic crystals possessing multiple
birefringences is studied using both
normal-mode formalism and coupled-mode
theory. A 2-by-2 transmission matrix
formalism is extended to anisotropic
crystals possessing multiple birefrin-
gences in order to find compensation
schemes for optical sensors employing
the crystal. It is shown that compensa-
tion techniques utilizing two analyzers
can eliminate the effects of both
unwanted linear birefringences and
unwanted circular birefringences on the
stability of the ac bulk-type optical

Electro-Optic Metrology (cont'd.)

sensor. The condition (here referred to as the quenching condition), under which the compensation methods become important, is derived for both the voltage sensor and the current sensor. Also, from coupled-mode theory applied to wave propagation in anisotropic crystals possessing multiple birefringences, the complex coupling constants are obtained.
[Contact: Kyung S. Lee, (303) 497-5170]

Complex Testing

Released for Publication

Stenbakken, G.N., and Starzyk, J.A., **Diakoptic and Large Change Sensitivity Analysis**.

This paper presents an approach for the analysis of large circuits based on the use of the large change sensitivity technique applied to decomposed networks. As a result of this approach, a simple, compact notation for the solution vector is derived. The method is applicable to nonlinear analog networks with hierarchical decomposition simulated by inserted ideal switches. A simple illustrative example is given.
[Contact: Gerard N. Stenbakken, (301) 975-2440]

Other Fast Signal Topics

Released for Publication

Geyer, R.G., **Dielectric Mixing Rules for Background Test Soils**, to be published as NISTIR 88-3095.

The bulk or effective dielectric constant of any background test medium whether naturally occurring or synthetic) determines the electromagnetic visibility of buried objects. Heuristic mixing rules are considered that allow the prediction of complex dielectric behavior in linear, homogeneous, isotropic, and lossy multi-phase soil mixtures. Measurement results in bio-electromagnetic and microwave remote sensing suggest a refractive mixing model as that being most suited for dry soils or soil-water mixtures.
[Contact: Richard G. Geyer, (303) 497-5852]

Hill, D.A., **Near-Field Detection of Buried Dielectric Objects**.

The plane-wave, scattering-matrix method is used to compute the response of a detector to a buried dielectric scatterer. Specific numerical results are generated for a UHF dipole detector swept over a buried dielectric cube. The maximum response is obtained when the detector is located at the air-earth interface, and the response decays rapidly with detector height. The sweep curves are symmetrical in the horizontal direction and have a null for the detector directly over the object. An experimental curve for a free-space environment has the same qualitative features.
[Contact: David A. Hill, (303) 497-3472]

Vanzura, E.J., **Creating CSUBs Written in FORTRAN That Run in BASIC**, to be published in the Proceedings of the INTEREX Technical Computer Users Conference, Orlando, Florida, August 7-12, 1988.

CSUBs are compiled subprograms created using the Pascal operating system which run in the BASIC environment. A new technique is described in which programs written in FORTRAN can be turned into CSUBs. Thus, powerful, well-documented FORTRAN routines become accessible to the BASIC-language programmer. I/O and variable interfacing are discussed, and a comprehensive example is provided.
[Contact: Eric J. Vanzura, (303) 497-5752]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Power Systems Metrology (cont'd.)

Misakian, M., **Characterizing Electrical Parameters Near ac and dc Power Lines**, to be published in the Proceedings of the U.S.-Japan Seminar on Electrical Engineering (National Science Foundation), Honolulu, Hawaii, August 1-4, 1988.

During the early 1970s, reports appeared in the literature which raised questions regarding possible biological effects from exposure to power frequency lines and in substations. In response to the concerns generated by these reports, numerous bioeffects studies were initiated in the United States by government and private agencies; the studies continue to this day. In the mid-1970s, there were no standards which provided guidance for the measurement of fields near power lines or for the calibration of instrumentation used for such measurements. Today, an ANSI/IEEE standard exists for measurements of electric and magnetic fields near ac power lines, and an IEC standard exists for measuring power frequency electric fields. In addition, an IEEE standard is currently being prepared for the measurement of dc electric fields and ion-related parameters near dc power lines. This paper briefly surveys the instrumentation currently in use for characterizing fields near ac power lines, and the electric field, ion current density, and monopolar charge density near dc power lines.
[Contact: Martin Misakian, (301) 975-2416]

Olthoff, J.K., Van Brunt, R.J., Wang, Y., Champion, R.L., and Doverspike, L.D., **Collisional Electron Detachment Cross Sections for SF_6^-, SF_5^-, and F^- in SF_6: Implication for Interpretations of Existing Ion Transport and Breakdown Probability Data**.

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 reported and indicate the necessity to re-examine ion-conversion rates determined in SF_6 from drift-tube data. 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 detachment thresholds implied by analysis of breakdown-probability data for SF_6. The model indicates that at high pressure, measured detachment coefficients appear to depend primarily upon ion-conversion and direct detachment rates for processes involving F^-.
[Contact: James K. Olthoff, (301) 975-2427]

Phelps, A.V., and Van Brunt, R.J., **Electron Transport, Ionization, Attachment, and Dissociation Coefficients in SF_6 and Its Mixtures**.

An improved set of electron collision cross sections is derived for SF_6 and used to calculate transport, ionization, attachment, and dissociation coefficients for pure SF_6 and mixtures of SF_6 with N_2, O_2, and Ne.

These SF_6 cross sections differ from the previously published set primarily at very low and at high electron energies. At energies below 0.03 eV, the attachment cross section is adjusted to fit recent electron swarm experiments, while the elastic momentum transfer cross section is increased to the theoretical limit. At high energies, an allowance is made for the excitation of highly excited levels as observed in electron-beam experiments. The cross section sets used for the admixed gases have previously been published. Electron kinetic energy distribution computed from numerical solutions of the electron-transport (Boltzmann) equation

Power Systems Metrology (cont'd.)

using the two-term, spherical harmonic expansion approximation are used to obtain electron transport and reaction coefficients as functions of E/N and the fractional concentration of SF_6. Here E is the electric field strength, and N is the gas number density. Attachment rate data for low concentrations of SF_6 in N_2 are used to test the attachment cross sections. Particular attention is given to the calculation of transport and reaction coefficients at the critical $E/N = (E/N)_c$ at which the ionization and attachment rates are equal.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Zhang, Y., McKnight, R.H., and Hebner, R.E., **Interactions Between Two Dividers Used in Simultaneous Comparison Measurements.**

A revised international standard for the measurement of lightning and front-chopped lightning impulses is presently under consideration. This standard states that the accuracy of the measuring systems used is to be determined by comparison to reference systems maintained by appropriate national laboratories. Investigations have been made of the interactions between two systems configured for simultaneous measurements and of methods for minimizing these interactions. Unit step responses were measured for different configurations, and a model developed to predict divider response. Simultaneous measurements were made of full and chopped lightning impulses using different divider systems to determine the effects of divider interactions on measurements.
[Contact: Robert E. Hebner, (301) 975-2403]

Recently Published

Van Brunt, R.J., and Kulkarni, S.V., **New Method for Measuring the Stochastic Properties of Corona and Partial Discharge Pulses**, Conference Record of the 1988 IEEE International Symposium on Electrical Insulation, Boston, Massachusetts, June 7, 1988, pp. 233-237.

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) 975-2425]

Superconductors

Released for Publication

Bray, S.L., Goodrich, L.F., and Dube, W.P., **Battery Powered Current Supply for Superconductor Measurements.**

In order to measure the critical current of superconductors, a high output current supply is required. In addition to high current capability, the supply should be designed to reduce ground loop problems, respond linearly to an input control signal, and minimize output noise. A current supply having these qualifications has been constructed and tested. Although the supply was originally designed for testing conventional superconductors, it has been successfully used in measurements on the high-critical-temperature ceramic superconductors as well. The supply can produce 1000-A output current with a noise level of approximately 0.05 A peak-to-peak. In addition to its normal operation as a controllable dc current source, two other specialized modes of

Superconductors (cont'd.)

operation have been developed and
tested. In one mode, the supply is used
as a source of dc-biased ac currents for
testing the effect of dc-power-supply
ripple on critical-current measurements.
In the other mode, the supply is used in
conjunction with a larger and noisier
current source to form a hybrid supply.
In the hybrid system, the smaller supply
is used to increase the current output
while greatly reducing the noise output
of the larger supply. The specifics of
all designs, modes of operation, and
performance results are given.
[Contact: Loren F. Goodrich, (303) 497-
3143]

Ekin, J.W., Peterson, R.L., and Bray,
S.L., **Effect of Small Coherence Length
on the Critical Current of High-T_c
Superconductors: Pinning, Weak Links,
Conduction Anisotropy, and Contact
Resistivities**, to be published in the
Proceedings of the Materials Research
Society International Meeting on
Advanced Materials, Tokyo, Japan, 1989.

The coherence length ξ of high-T_c
superconductors is about an order of
magnitude smaller than for conventional
superconductors. This intrinsic
difference has profound consequences for
the transport properties of high-T_c
superconductors. Because the pinning
effectiveness of defects of average size
$\langle D \rangle$ is greatest for $\langle D \rangle/\xi = 1$ and
decreases rapidly for $\langle D \rangle/\xi < 1$, atomic
scale defects are ineffective as pinning
sites in conventional superconductors,
but play an important role in high-T_c
superconductors. Unfortunately, the
small coherence length also makes atomic
scale defects effective tunneling
barriers in high-T_c superconductors.
Thus, from the practical standpoint of
producing high transport critical
current J_c in high-T_c superconductors,
the conventional problem of pinning
force enhancement is replaced by weak-
link minimization. The transport J_c is
nearly independent of the angle between
the applied magnetic field and the

average transport current direction,
indicating highly convoluted percolation
paths in these materials. Conduction
anisotropy is a secondary factor, but
emerges as a prime determinant of
transport J_c in the absence of weak link
effects. The effect of conduction
anisotropy on transport J_c is described
in terms of a current-transfer model. A
method used to achieve contact resis-
tivities in the 10^{-10} Ω-cm^2 range is
summarized.
[Contact: John W. Ekin, (303) 497-5448]

Goldfarb, R.B., Ried, D.L., Kreilick,
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 percent.
[Contact: Ronald B. Goldfarb, (303)
497-3650]

Katayama-Yoshida, H., Hirooka, T.,
Oyamada, A., Okabe, Y., Takahashi, T.,
Sasaki, T., Ochiai, A., Suzuki, T.,
Mascarenhas, A.J., Pankove, J.I.,
Ciszek, T., Deb, S.K., Goldfarb, R.B.,
and Li, Y., **Oxygen Isotope Effect in
the Superconducting Bi-Sr-Ca-Cu-O
System**.

An oxygen isotope effect is observed in
mixed-phase Bi-Sr-Ca-Cu-O superconduc-
tors when ^{18}O is substituted for ^{16}O.
The isotope substitution is confirmed by
Raman scattering. The superconducting
transition temperature T_c, measured by
electrical resistivity and magnetic
susceptibility, is lowered by 0.34 ±
0.03 K for the higher T_c (approximately
110-K) phase and by 0.33 ± 0.04 K for
the lower T_c (approximately 75-K) phase.
The results suggest a measurable
contribution to the superconductivity

perconductors (cont'd.)

om phonons in the two-dimensional CuO_2
anes.
ontact: Ronald B. Goldfarb, (303)
7-3650]

reland, J., Goodrich, L.F., Ekin,
.W., Capobianco, T.E., and Clark,
.F., **Break Junctions** I, to be
blished as NISTIR 88-3090.

asurements of the tunneling current-
ltage characteristics of break
nctions in conventional superconduc-
rs can be used to determine their
perconducting energy gap as a function
 energy. These results agree with
ose previously obtained using
aditional oxide tunneling barriers.
eak junctions in some exotic supercon-
ctors, on the other hand, have
omalous current-voltage characteris-
cs compared to BCS theory predic-
ons. Energy gaps and the Josephson
fect measurement for the new high T_c
terials YBaCuO (T_c = 93 K) and
SrCuO (T_c = 36 K) indicate that the
mples are inhomogeneous with varying
 functions depending on the location
 the tunneling contact within the
eak junction fracture. Break junction
ta for these materials are within the
rong coupling limits of BCS theory.
ontact: John Moreland, (303) 497-
+1]

, R., Beall, J.A., Ekin, J.W.,
elson, A.J., Kazmerski, L.L., Mason,
.R., Swartzland, A.B., and McConnell,
.D., **Surface Analysis of Interfacial**
roperties for Thin Film and Bulk
$Ba_2Cu_3O_7$, to be published in the
roceedings of the Second Conference on
perconductivity and Applications,
ffalo, New York, April 18-20, 1988.

ger electron spectroscopy (AES) has
en used to characterize the surface
l grain boundary chemistry of thin-
m $YBa_2Cu_3O_7$ and the interface
mistry between In and Ag contacts to
k $YBa_2Cu_3O_7$ before and after the
ndard post-deposition annealing.

Compositional variations at grain
boundaries as well as substrate effects
have been related to the observed
nonlinear tailing in the resistivity vs.
temperature curves. In addition, AES
analysis of the contact/$YBa_2Cu_3O_7$
interfacial chemistry is used to explain
the large variations in contact resis-
tances observed for these technological-
ly important materials.
[Contact: Ronald H. Ono, (303) 497-
3762]

Peterson, R.L., **Bean Model Extended to**
Magnetization Jumps.

The Bean model of magnetization in hard
superconductors is extended to include
the trains of magnetization jumps seen
at low temperature in moderate-to-high
magnetic fields. As in the original
Bean model, no particular mechanisms for
flux pinning or dynamics are invoked.
The model correctly accounts for the
general dependence of the size of the
magnetization jumps on sample size and
critical current density. The data
together with the model show that the
shielding fields are approximately equal
after each jump.
[Contact: Robert L. Peterson, (303)
497-3750/-3227]

Recently Published

Ekin, J.W., Panson, A.J., and Blanken-
ship, B.A., **Effect of Oxygen Annealing**
on Low-Resistivity Contact for High-T_c
Superconductors, Proceedings of the
Materials Research Society 1988 Spring
Meeting, Symposium K, Reno, Nevada,
April 5-8, 1988, Vol. 99, pp. 283-286.

A method for making low-resistivity
contacts to high-T_c superconductors has
been developed, consisting of depositing
noble metal contact pads (silver or
gold) on a clean superconductor surface
at low temperatures (<150°C). After
annealing the silver contact pads in
oxygen at intermediate temperatures
(≤500°C) for 1 h, contact resistivities
less than 2×10^{-8} Ω-cm^2 at 76 K are
obtained, about six orders of magnitude

Superconductors (cont'd.)

less than for indium-solder contacts. Before annealing, the contact resistivities are still very low, in the 10^{-6} to 10^{-5} $\Omega\text{-cm}^2$ range at 76 K, which would be useful when contacts with low fabrication temperatures are required. The voltage-current characteristics of the contacts are strongly nonlinear after annealing, having a superconducting transition character. This is ascribed to the critical current of the superconducting material being exceeded at the contact interface. External connections to the contact pads have been made using both solder and thermosonic wire-bonding techniques. [Contact: John W. Ekin, (303) 497-5448]

Goodrich, L.F., **Development of Standards for Superconductors**, NBSIR 88-3088 (February 1988).

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 have 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]

Goodrich, L.F., Bray, S.L., and Clark A.F., **Current-Ripple Effect** **Superconductive dc Critical-Curren Measurements**, Advances in Cryogen Engineering Materials, Vol. 34, p 1019-1026 (1988).

The effect of current ripple or noise dc critical-current measurements w systematically studied. Measurement were made on multifilamentary Nb superconductors. A low-noise, batter powered current supply was required this study in order to make the pure critical-current measurements. Also, electronic circuit that simulates superconductor's general current-volta characteristic was developed and used an analysis tool. In order to mal critical-current measurements in whi current ripple was present, the batter supply was modified to allow t introduction of controlled amounts of ripple. In general, ripple in a currer supply becomes more significant abo 500 A, because effective filtering difficult. The effect of current ripp is a reduction in the measured critical current; however, ripple sufficient amplitude can result arbitrary measurement results. T results of this work are general ar quantitatively applicable to t evaluation of critical-current data ar measurement systems. A theoretica model was developed to further suppor and explain the ripple effect. unexpected benefit of this work was tha it led to a more precise method fo general critical-current data acquisi tion. Problems common to all large conductor critical-current measurement are discussed. [Contact: Loren F. Goodrich, (303) 497 3143]

Magnetic Materials & Measurements

Recently Published

Fickett, F.R., **Transverse Magnetoresi tance of Oxygen-Free Copper**, IE Transactions on Magnetics, Vol. 24, N 2, pp. 1156-1158 (March 1988).

gnetic Materials (cont'd.)

cent studies on the magnetoresistance
   copper with residual resistance
tios (RRR) in the range 100 to 1000
ing cold work and irradiation as
rameters modifying RRR show a large
read in the appropriate region of the
hler plot. This spread is much larger
an that found in our earlier work on
ry pure copper in which we used
mperature as the main variable. We
port results of 4-K magnetoresistance
asurements on a large number of
mples of copper from various sources
d in various states of cold work,
rain, and reanneal. A new look is
ken at the Kohler plot as a method for
edicting magnetoresistive behavior.
ontact: Frederick R. Fickett, (303)
7-3785]

her Electrical Systems Topics

Recently Published

psik, F.I., Kelley, E.F., and Martz-
off, F.D., **A Review of Candidate
ethods for Detecting Incipient Defects
ue to Aging of Installed Cables in
uclear Power Plants**, NBSIR 88-3774
lay 1988).

veral types of test methods have been
pposed for detecting incipient
fects due to aging in cable insulation
stems, none offering certainty of
tecting all possible types of defects.
he methods constitute direct detection
a defect in the cable; other methods
tect changes in electrical or non-
ctrical parameters from which
ferences can be drawn on the integrity
the cable. The paper summarizes the
st year of a program conducted at the
tional Bureau of Standards to assess
potential of success for in-situ
ection of incipient defects by the
t promising of these methods.
ntact: Francois D. Martzloff, (301)
-2409]

CTROMAGNETIC INTERFERENCE

Radiated Electromagnetic Interference

Released for Publication

Crawford, M.L., and Ladbury, J.M.,
**Shielding Effectiveness Measurements of
Cables and Connectors Using a Mode-
Stirred Chamber**, to be published in the
Proceedings of the 1988 IEEE EMC
International Symposium, Seattle,
Washington, August 1-5, 1988.

The mode-stirred method for measuring
the shielding effectiveness (SE) of
cables and connectors as specified in
MIL-STD-1344A Method 3008 is examined.
Problems encountered in applying the
method are identified and recommenda-
tions are provided to improve the
measurement results. These include
chamber design, type and placement of
transmitting and reference receiving
antenna, determination and correction
for VSWR of the reference antenna and
equipment under test, and the measure-
ment approach to use at specified test
frequencies. Design and measurement
setups for a small mode-stirred chamber
suitable for performing SE measurements
in the frequency range from 1 to 18 GHz
with dynamic ranges up to 130 dB are
given along with SE measurement results
of some sample equipment.
[Contact: Myron L. Crawford, (303) 497-
5497]

Cruz, J.E., and Larsen, E.B., **Alterna-
tive Techniques for Some Typical MIL-
STD-461/462 Types of Measurements**, to
be published as NIST Technical Note
1320.

Most testing for MIL-STD-461/462 is
performed in a shielded enclosure
(screenroom) which leads to uncertainty
in the measurement of emissions from
electronic equipment, or the suscep-
tibility of equipment to electromagnetic
radiation. Possible alternative
techniques for improved measurements in
a screenroom have been developed by the
National Bureau of Standards. These
techniques are covered in this report.

Radiated EMI (cont'd.)

This report presents antenna factors
determined in a screenroom which was
partially loaded with radio-frequency
absorbing material, using the two-
antenna insertion-loss technique. These
antenna factors are compared with the
antenna factors obtained in an unloaded
screenroom, a fully loaded screenroom
(anechoic chamber), and at an open-field
site. In addition, measurements at the
eight corners of a cube were made in the
partially loaded and fully loaded
screenrooms to determine the field
deviation at the eight corners of the
cube with respect to its center. Also,
measurement improvements are quantified
for the electric-field strength beneath
a single-wire transmission line, in a
partially loaded screenroom. Finally,
electric-field measurements were made on
top of the grounded table in a partially
loaded screenroom to determine the field
strength variation above the table.
[Contact: Jose E. Cruz, (303) 497-3763]

Kanda, M., and Orr, R.D., **Generation of
Standard Electromagnetic Fields in a
TEM Cell**, to be published as NIST
Technical Note 1319.

This paper documents the facilities and
procedures employed by the National
Bureau of Standards to calibrate radio-
frequency electric-field probes using a
transverse electromagnetic (TEM) cell.
The advantages, limitations, and
physical characteristics of TEM cells
are presented. Impedance, field
uniformity, and mode structure, critical
aspects of a cell as a standard field
enclosure, are discussed. The paper
concludes with sections on setup and
measurement procedures for users,
uncertainty in the standard field, and
statistical control of the calibration
system. Copies of key references are
included to provide ready access to the
details of topics summarized in the
text.
[Contact: Motohisa Kanda, (303) 497-
5320]

Koepke, G.H., Ma, M.T., and Bensema
W.D., **Theory and Measurements c
Radiated Emissions Using a TEM Cell**.

The transverse electromagnetic cel
(TEM) is widely used to evaluate th
electromagnetic characteristics c
electrically small devices. This pape
reviews the theoretical basis for
technique to quantify the radiate
emissions from any such device in th
cell. The technique is well suited t
an automated test system, provided th
mechanical motions required can l
controlled by a computer. The difficul
ties associated with these mechanica
motions are discussed and possibl
solutions are proposed. The measuremen
technique is also expanded to includ
multiple-frequency sources in additic
to single-frequency sources.
[Contact: Galen H. Koepke, (303) 49
5766]

Recently Published

Hill, D.A., **A Circular Array for Plan
Wave Synthesis**, IEEE Transactions c
Electromagnetic Compatibility, Vol. 3(
No. 1, pp. 3-8 (February 1988).

We analyze a circular array of electri
line sources for generating a unifor
plane wave in the interior region of th
array. Identical results for th
synthesized element weightings a
obtained using matrix inversion or
Fourier series technique. A physic;
optics approximation for the elemer
weightings is also presented, but
yields a much poorer result for th
synthesized field. The angle of arriva
of the plane wave can be scanned I
recalculating the element weighting;
and the quality of the field
maintained. Frequency scanning is al;
possible, but the number of arr;
elements limits the maximum frequency.
[Contact: David A. Hill, (303) 49
3472]

Kanda, M., and Driver, L.D., **An Opti
cally Linked Electric and Magneti
Field Sensor for Poynting Vecto**

diated EMI (cont'd.)

easurements in the Near Field of adiating Sources, Digest of the 1988 onference on Precision Electromagnetic easurements, Tsukuba, Japan, June 7- 0, 1988, pp. 32-33.

improved, single-element antenna- nsing technique is described which can multaneously measure the electric (E) eld, magnetic (H) field, and time- pendent Poynting vector of electromag- tic (EM) fields. Two radio-frequency ltages are produced which, along with lative phase and frequency informa- on, are transmitted to a remotely ated vector analyzer by a pair of tched fiber optic downlinks. ontact: Motohisa Kanda, (303) 497- 0]

M.T., Theory and Measurements of nintentional Radiators, Digest of the 88 Conference on Precision Electro- gnetic Measurements, Tsukuba, Japan, ne 7-10, 1988, pp. 30-31.

characterizing an unknown emitter th equivalent vector electric- and gnetic-dipole moments, we formulate a eoretical basis to express the liation properties of such an emitter terms of these unknown dipole ents. Power and relative phase surements from appropriate ports of a nsverse electromagnetic cell, when emitter is placed at the cell's ter, are proven to be sufficient to ermine quantitatively the unknowns , therefore, the radiation charac- istics. ntact: Mark T. Ma, (303) 497-3800]

da, J.P., Kanda, M., Melquist, D.G., ga, R.M., and Norgard, J.D., High equency Electric-Field Probe Develop- nt, Proceedings of the International nference on Electromagnetic Com- tibility (EMC EXPO'88), Washington, C., May 10-12, 1988, pp. T15.31- 5.37.

ious 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]

Vanzura, E.J., Automated system for Electromagnetic Field Generation and Immunity Testing, Proceedings of the 1988 IEEE Instrumentation/Measurement Technology Conference, San Diego, California, April 19-22, 1988, pp. 3- 10.

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 polariza- tions 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 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

Radiated EMI (cont'd.)

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]

Vanzura, E.J., and Adams, J.W., **Electromagnetic Fields in Loaded Shielded Rooms**, Test and Measurement World, pp. 72ff (November 1987).

This paper describes a computer-controlled feedback system that can maintain field strength levels within moderate bounds inside a partially loaded shielded room. These levels are relatively uniform over a large enough volume to allow radiated immunity testing of moderate-sized objects. The frequency range depends on the characteristics of the transmit antenna; we used 50 to 200 MHz, which is a difficult range to cover because of limitations of other EMC susceptibility test facilities.

The measurement system consists of a computer, signal generator, amplifier, biconical antenna, and an isotropic probe system.
[Contact: Eric J. Vanzura, (303) 497-5752]

Wilson, P.F., **A Comparison Between Near-Field Shielding-Effectiveness Measurements Based on Coaxial Dipoles and on Electrically Small Apertures**, IEEE Transactions on Electromagnetic Compatibility, Vol. 30, No. 1, pp. 23-

28 (February 1988).

The near-field shielding effectivenes of a material may be measured by placin it between two closely spaced dipole (electric or magnetic) and noting th resulting insertion loss. An alterna tive approach is to cover an electrical ly small aperture with the test materia and to measure the resulting loade aperture polarizability (electric c magnetic), as is done in a dual TE cell. Expressions are developed herei which relate these two configurations.
[Contact: Perry F. Wilson, (303) 497 3842]

Wu, D.I., and Chang, D.C., **The Effect c a Large Rotating Scatterer in Rectangular Cavity**, NBS Technical Not 1317 (March 1988).

In a mode-stirred chamber, the field i the cavity is perturbed with a stirrer i.e., a rotating scatterer, in such way that it is uniformly random. I this report, we investigate the ke factor which governs the effectivenes of a stirrer. By examining th fundamental properties associated with perturbing body in a cavity, we fir that the key to effective fiel perturbation lies in the shifting c eigenmode frequencies. When the size c the perturbing body becomes large, th shifting may be large enough that th new perturbed modes no longer resembl the original unperturbed modes. I effect, as this body rotates, differer perturbed modes may be excited, thu introducing randomness into the systen We illustrate this phenomenon b examining a 2D cavity with a 1 perturbing body. Using the transmis sion-line-matrix method, the shifting c eigenfrequencies and the variation c the magnitude of the fields fc different stirrer sizes are computec From this analysis, useful insights ar drawn which include an analogy betwee the action of a large stirrer and frequency modulator.
[Contact: Doris Wu, (303) 497-3214]

nducted Electromagnetic Interference

Released for Publication

rtzloff, F.D., **Coupling, Propagation, nd Side Effects of Surges in an ndustrial Building**, to be published in he Proceedings of the IEEE/IAS Annual eeting, Pittsburgh, Pennsylvania, ctober 3-6, 1988.

asurements were made in an industrial ilding to determine the propagation aracteristics of surges in the ac wer wiring of the facility. The rges, of the unidirectional or the ng-wave types described in ANSI/IEEE 2.41-1980, were injected at one point the system, and the resulting surges riving at the other points were asured. The results show how idirectional surges couple through ansformers and produce a ring-wave mponent in the response of the system. unexpected side effect of the surges, plied to the power lines only, was parent damage suffered by the data ne input components of some computer- iven printers in the building. ontact: Francois D. Martzloff, (301) 5-2409]

rtzloff, F.D., **Surge Testing: Don't id Yourself, Don't Kill Yourself**, to e published in the EMC Technology and nterference Control News (August 988).

creasing awareness of the sensitivity electronics to surge effects has led a proliferation of surge suppressors the market. Confronted with a fficult choice, some users are aluating the performance of these vices by surge testing. However, the chniques involved in these tests are fferent from typical electromagnetic mpatibility (EMC) testing because of e single-shot nature of the event and ause of the potential personal ards involved in surge testing. This icle presents a brief overview of ge testing, focusing on the tech- ues required in performing valid

tests under safe conditions. [Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., and Leedy, T.F., **Electrical Fast Transient Tests: Applications and Limitations**, to be published in the Proceedings of the IEEE Conference, Dallas, Texas, September 12, 1988 (Petroleum and Chemical Industry Committee).

The Technical Committee TC 65 of the International Electrotechnical Commission (IEC) has promulgated a new document (IEC 801-4) requiring demonstration of the immunity of industrial process control equipment to fast transients occurring in power and data lines. These fast transients contain high-frequency components, intuitively expected to suffer greater attenuation than the lower-frequency components as they propagate along the lines. Quantifying this intuitive expectation provides a perspective on the severity of the situation and helps in defining realistic test requirements. To that end, this paper describes specific measurements conducted for typical low-voltage power line configurations; modeling of the attenuation provides a tool for understanding the significance of the line parameters and extends the usefulness of results to general cases. [Contact: Francois D. Martzloff, (301) 975-2409]

Recently Published

Martzloff, F.D., and Levinson, L.M., **Surge-Protective Devices** [original title ... and Zinc Varistor Technology], in Electronic Ceramics-- Properties, Devices, and Applications, L.M. Levinson, Ed., Chapter 5 (Marcel Dekker, Inc., New York, 1988), pp. 275-305.

A tutorial description of surge-protective devices and their applications and requirements is given, comparing the three basic technologies: crowbars, varistors, and avalanche

Conducted EMI (cont'd.)

diodes.   The   varistor   material   is
described in detail from the electronic
ceramics   point   of   view.   Thirty
references are given.
[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 Technol-
ogy: A Bibliography of NBS Publica-
tions, 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,
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 ellip-
sometrically derived thickness and
refractive index of a silicon dioxide
film on silicon.   Available for sale to
the public through the NIST 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

Recently Issued SRMs (cont'd.)

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

October 26-28, 1988 (Boulder, CO)

Twentieth Symposium on Optical Materials for High Power Lasers (Boulder Damage Symposium). In addition to the NIST, 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 NIST 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]

June 12-15, 1989 (Gaithersburg, MD)

International Conference on Narrow Gap **Semiconductors and Related Materials.** Jointly sponsored by the National Institute of Standards and Technology along with the U.S. Air Force Office of Scientific Research, the American Physical Society, the U.S. Office of Naval Research, Texas Instruments, and the University of North Texas, this conference is the first in the narrow gap field since 1981. The scope of the conference includes such topics as crystal growth and new materials; two-dimensional physics; surfaces and interfaces; superlattices and hetero-structures; transport; impurities and defects; optical properties; nonlinear optical effects; device physics; lattice properties; and hot or nonequilibrium carrier effects. [Contact: David G. Seiler, (301) 975-2081]

September 11-13, 1989 (Garmisch-Partenkirchen, FDR)

VLSI and GaAs Chip Packaging Workshop. The IEEE CHMT Society and the National Institute of Standards and Technology are co-sponsoring the Eighth VLSI Packaging Workshop. Topics to be discussed include VLSI package design; integrated package design; multichip module design; WSI packaging; package

CEEE Calendar (cont'd.)

thermal design; package electrical design; GaAs IC packaging; VLSI package interconnection options; VLSI package materials and die-attach solutions; and failure mechanism and quality of VLSI packages. All attendees are expected to be specialists working in the field and to participate in discussions. [Contact: George G. Harman, (301) 975-2097]

December 7-8, 1989 (Gaithersburg, MD)

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

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  Naval Ocean Systems Center; Weapons Support Center/Crane; Naval Weapons Station; Office of Naval Research; Naval Sea Systems Command; Naval Postgraduate School; Naval Ship Research Development Center; Naval Air Systems Command; Naval Research Laboratory; Aviation Logistics Center/Patuxent; Naval Explosive Ordnance
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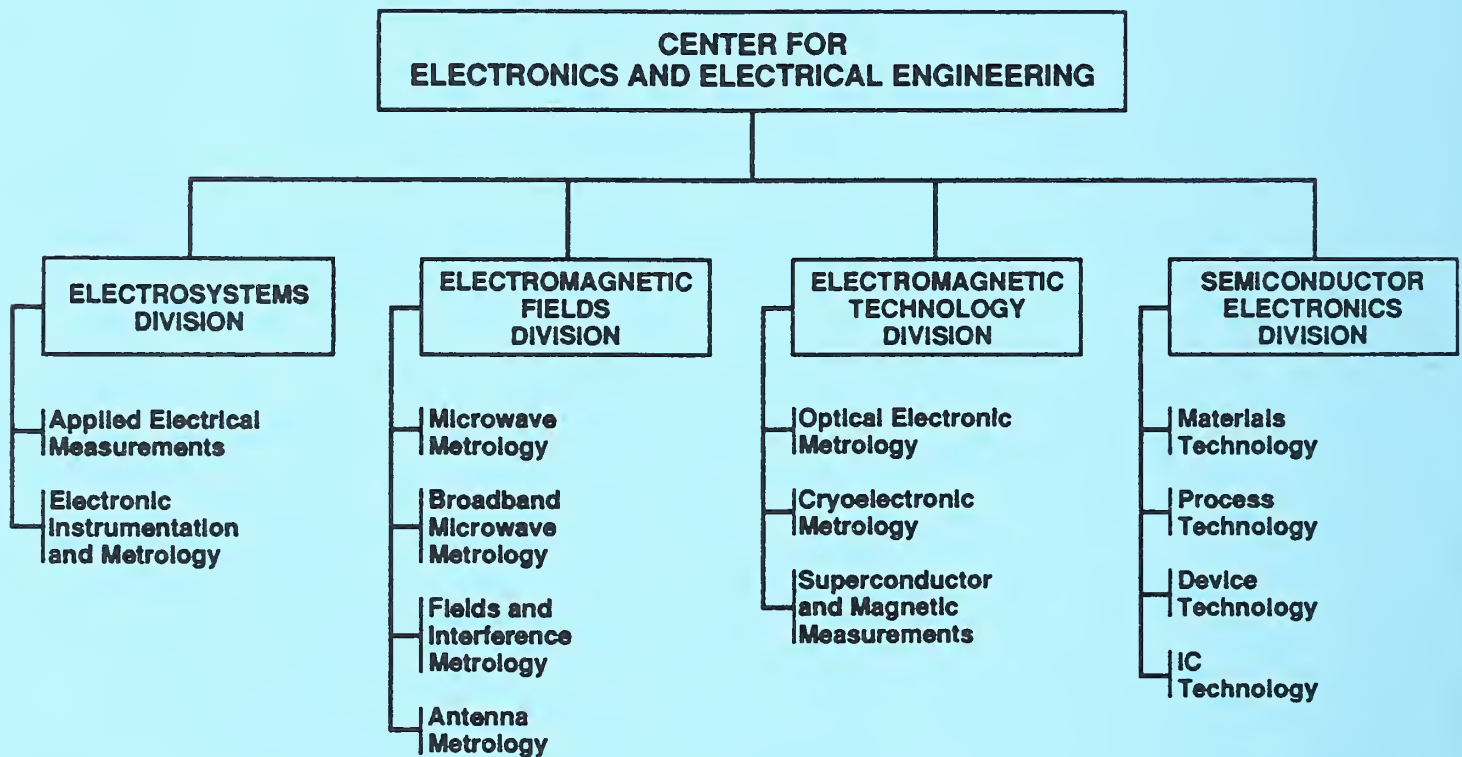Nuclear Regulatory Commission
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JPPLEMENTARY NOTES

.l technical information included in this document has been approved for publication
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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

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bliography or literature survey, mention it here)*

lis is the twenty-third issue of a quarterly publication providing information on
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itional Bureau of Standards) Center for Electronics and Electrical Engineering.
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Y WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

tennas; electrical engineering; electrical power; electromagnetic interference;
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