

IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT

A PUBLICATION OF THE IEEE INSTRUMENTATION AND MEASUREMENT SOCIETY



JUNE 2011

VOLUME 60

NUMBER 6

IEIMAO

(ISSN 0018-9456)

REGULAR PAPERS

Algorithms, Artificial Intelligence, SOFT Computing, and Informatics

Coarse Alignment of a Ship's Strapdown Inertial Attitude Reference System Using Velocity Loci. . . . *P. M. G. Silson* 1930

A/D and D/A Conversion, Analog, and Digital Instrumentation

Design of a 12-Bit 2.5 MS/s Integrated Multi-Channel Single-Ramp Analog-to-Digital Converter for Imaging Detector Systems *W. Gao, D. Gao, C. Hu-Guo, and Y. Hu* 1942

Analog and Digital Data, Image, and Signal Processing

B-Spline Approximation Using an EKF for Signal Reconstruction of Nonlinear Multifunctional Sensors. *X. Wang, G. Wei, and J.-W. Sun* 1952

Electronic Tongue System for Water Sample Authentication: A Slantlet-Transform-Based Approach *P. K. Kundu, A. Chatterjee, and P. C. Panchariya* 1959

Instrumentation for and Measurement in Communications

Binder Identification by Means of Phantom Measurements *C. Neus, W. Foubert, L. Van Biesen, Y. Rolain, P. Boets, and J. Maes* 1967

Instrumentation for and Measurement of Electric Power Systems, Energy Metering, and Electric Power Quality

A High Efficient Compression Method for Power Quality Applications *M. Zhang, K. Li, and Y. Hu* 1976

Denoising Techniques With a Spatial Noise-Suppression Method for Wavelet-Based Power Quality Monitoring *C.-C. Liao, H.-T. Yang, and H.-H. Chang* 1986

Online State-of-Health Assessment for Battery Management Systems *M. V. Micea, L. Ungurean, G. N. Cârstoiu, and V. Groza* 1997

Electronic Combined Transformer for Power-Quality Measurements in High-Voltage Systems. *M. Faifer, S. Toscani, and R. Ottoboni* 2007

Built-in Self-Test, Design-for-Testing, Fault Diagnosis, and Fault-Tolerance

Transformer-Coupled Loopback Test for Differential Mixed-Signal Dynamic Specifications *B. Kim and J. A. Abraham* 2014

Wavelet Analysis for the Detection of Parametric and Catastrophic Faults in Mixed-Signal Circuits. *A. D. Spyronasios, M. G. Dimopoulos, and A. A. Hatzopoulos* 2025

(Contents Continued on Page 1929)

IEEE INSTRUMENTATION AND MEASUREMENT SOCIETY

The Instrumentation and Measurement Society is an organization within the framework of the IEEE, of members with principal professional interest in instrumentation and measurement. All IEEE members are eligible for membership in the Society and will receive this TRANSACTIONS upon payment of the annual Society membership fee of \$28.00. For information on joining, write the IEEE at the address below. *Member copies of Transactions/Journals are for personal use only.*

KIM FOWLER
Society President

JORGE F. DAHER
Executive VP

SHREEKANTH MANDAYAM
VP Finance

RUTH A. DYER
VP Publications

ROBERT R. KRCHINAVEK
VP Conferences

MHAELA ALBU
VP Membership

JOHN L. SCHMALZEL
VP Technical & Standards Activities

FRANK REYES
Treasurer

AdCom Term Expires 2010
M. STEPHEN KARLOVIC
SHREEKANTH MANDAYAM
J. BARRY OAKES
MATTHEW PASTORINO

AdCom Term Expires 2011
RUTH A. DYER
PASQUALE DAPONTE
KIM FOWLER
JOHN L. SCHMALZEL

AdCom Term Expires 2012
MHAELA ALBU
VOICU Z. GROZA
ROBERT R. KRCHINAVEK
DANIEL ROSENTHAL

AdCom Term Expires 2013
SERGE DEMIDENKO
CHRY HARNETT
FERDINANDA PONCI
REZA ZOUUGH

Society Sr. Past President: STEPHEN A. DYER

Society Jr. Past President: ALESSANDRO FERRERO

Ex Officio AdCom Members:

Undergrad Student Rep: ALEXANDRU NECHIFOR
Graduate Student Rep: KRISTEN M. DONNELL
GOLD Representative: SANNA GASPARD

Transactions Editor-in-Chief: REZA ZOUUGH
Magazine Editor-in-Chief: SHLOMO ENGELBERG
Division II Director: ROBERT E. HEBNER

IEEE Staff Director, Technical Activities: MARY WARD-CALLAN
Society Executive Assistant: J. SCHARMANN
Conference Catalysts LLC: CHRIS DYER

Standing Committee Chairmen

Awards and Recognition Committee:

Chair: STEPHEN A. DYER
Society Awards: DANIEL ROSENTHAL
Fellows Evaluation: ROBERT GOLDBERG
Fellows Identification: REZA ZOUUGH
Conferences and Meetings: ROBERT R. KRCHINAVEK
Constitution and Bylaws: A. FERRERO
Finance: SHREEKANTH MANDAYAM

Historian: OPEN

Long-Range Planning: A. FERRERO
Membership Development and Services: MHAELA ALBU
Ad Hoc Committee on Education: REZA ZOUUGH
Nominations: ALESSANDRO FERRERO
Organization: STEPHEN A. DYER AND ALESSANDRO FERRERO

Publications: RUTH A. DYER

Transactions Editor-in-Chief: REZA ZOUUGH
Magazine Editor-in-Chief: SHLOMO ENGELBERG
Website: JORGE F. DAHER
IEEE Press Books: ROBERT GOLDBERG
Webmaster: CHRISTOPHER DYER
Society Management: JORGE F. DAHER
Technical and Standards: JOHN SCHMALZEL

Technical Committee Chairmen

TC-1 *Measurement Precision, Sensitivity and Noise:* OPEN
TC-2 *DC-IF Measurement:* YICHENG WANG
TC-3 *Frequency and Time:* OPEN
TC-4 *HF Instrumentation and Measurement:* BRIAN LEE
TC-6 *Emerging Technologies:* VINCENZO PIURI
TC-7 *Signals and Systems in Measurements:* LASZLO SCHIBERT, RUQIANG YAN
TC-8 *Test and Instrument Systems:* MICHAEL STORA
Instrument/Computer Interface: ROBERT CRAM
TC-9 *Sensor Technology:* KANG LEE
Capacitive Sensors: GEORG BRASSEUR
TC-10 *Waveform Measurement and Analysis:* THOMAS LINSSENBRINK
Waveform Recorder: BILL BOYER
A/D Converters: STEVE TILDEN
D/A Converters: STEVE TILDEN
Pulse Techniques: NICOLAS PAULTRIER
Probe Standards: ROBERT GRAHAM
TC-11 *SCC-20 ATLAS Combinations:* JOSEPH J. STANCO AND MARK KAUFMAN
TC-13 *Wireless & Telecommunications:* REINER THOMAS
TC-15 *Virtual Systems:* EMIL PETRUJ
TC-16 *Laser & Optical Systems:* THIBERY BOSCH
TC-17 *Materials in Measurement:* JACOB SCHARCANSKI
TC-18 *Environmental Measurement:* MICHAEL GARD AND G. D'ANTORA

TC-19 *Imaging Systems Measurements:* GEORGE GIAROS AND GEORGE ZENTAI
TC-20 *Transportation:* FRANS C. A. GROEN AND GEORG BRASSEUR
TC-21 *Self Test & Built-in Test:* ROBERT GAO AND DENNIS HECHT
TC-22 *Intelligent Measurement Systems:* FABIO SCOTTI AND MEL SIEGEL
TC-23 *Education in Instrumentation and Measurements:* TREDDOR LAMPOULOS
TC-24 *Measurement Microsystems:* ANORDEZ BARWICK
TC-25 *Medical Measurements:* MARCO PARVIS
Blood Pressure Measurements: VOICU GROZA
TC-26 *Radar Cross-Section Measurements:* MARK YEARY
TC-27 *Human Computer Interface:* MEL SIEGEL AND PETER WIDE
TC-28 *Robotics & Automation:* MEL SIEGEL AND EMIL PETRUJ
TC-30 *Security & Contraband Detection:* MEL SIEGEL, V. PIURI, AND EMIL PETRUJ
TC-31 *I&M for Homeland Security:* BRIAN WADELL AND KANG LEE
TC-32 *Fault Tolerant Measurement:* SERGE DEMIDENKO AND NORPILL PARK
TC-33 *Electrical HF and Optical Nonlinear Components:* MARC VAN DEN BROECK AND YVES ROLAEN
TC-34 *Nanotechnology in I&M:* CINDY HARNETT
TC-35 *Nescentric Operations Interoperability:* (VACANT)
TC-36 *Industrial Inspection:* ZHENG LIU AND DAVID FORSYTH
TC-37 *Measurements for Networking:* C. NARDEZZI AND A. EL SADDIK
TC-38 *Spicy Measurements:* JOHN SCHMALZEL
TC-39 *Measurements in Power Systems:* LORENZO PERETTO

Society Representatives and Directed Delegates

Chair: JORGE F. DAHER
ATLAS: JOSEPH J. STANCO AND MARK KAUFMAN
AUTOTESTCON Board of Directors: FRANK REYES, MILTON SLADE, M. STEPHEN KARLOVIC
Biometrics Council: VOICU GROZA
Committee on Earth Observation: JOHN SCHMALZEL
IEEE Conferences Committee: ROBERT C. RASSA
IEEE Fellows Evaluation: ROBERT GOLDBERG
IEEE Humanitarian Tech. Challenge: JOHN SCHMALZEL
IEEE Press: ROBERT GOLDBERG
IEEE Standards: RICHARD C. HOCHBERG
IEEE-USA Energy Policy Committee: MEL SIEGEL
IEEE-USA R & D Policy Committee: RICHARD HOCHBERG
IEEE-USA Critical Infrastructure Protection: ROBERT RASSA
IEEE-USA Technology Policy Committee: KANG LEE
International Society of Automation: HAROLD S. GOLDBERG AND KANG LEE
IMTC: KANG LEE, VINCENZO PIURI, PASQUALE DAPONTE, RUTH DYER, JOHN SCHMALZEL, SERGE DEMIDENKO AND VOICU GROZA

Journal of Lightwave Technology: BERNARD P. GOLLOMP AND ILAN GOLECKI
Measurement Science Conference: DAVID W. BRAIDAWAY
Nanotechnology Council: ROBERT R. KRCHINAVEK AND STEPHEN A. DYER
National Conference of Standards Laboratories: DAVID W. BRAIDAWAY
PACE Coordinator: LOUIS A. LUCERI
SAS Conference: S. MANDAYAM, H. S. GOLDBERG, R. M. GOLDBERG, KANG LEE, J. SCHMALZEL, M. SIEGEL, AND K. ARSHAK
Sensors Council: KANG LEE
Societies on Social Implications of Technology: S. MANDAYAM
Systems Council: SHREEKANTH MANDAYAM, PAOLO CARBONE
TAB Awards and Recognition Committee: ROBERT C. RASSA
TAB Finance Committee: SHREEKANTH MANDAYAM
TAB Magazines Committee: KIM FOWLER
TAB Periodicals Committee: KIM FOWLER
TAB Standards Association: RICHARD HOCHBERG
TAB Strategic Planning Committee: STEPHEN A. DYER
TAB Transactions Committee: REZA ZOUUGH
Women in Engineering Liaison: RUTH A. DYER

IEEE Officers

PEDRO A. RAY, *President and CEO*
MOSHE KAM, *President-Elect*
DAVID G. GREEN, *Secretary*
PETER W. STAECKER, *Treasurer*
JOHN R. VIG, *Past President*
TARIQ S. DURRANI, *Vice President, Educational Activities*

JON G. ROKNIK, *Vice President, Publication Services and Products*
BARRY L. SHOOK, *Vice President, Member and Geographic Activities*
W. CHARLTON (CHUCK) ADAMS, *President, IEEE Standards Association*
ROGER D. POLLARD, *Vice President, Technical Activities*
EVELYN H. HIRT, *President, IEEE-USA*

ROBERT E. HEBNER, JR., *Director, Division II*

IEEE Executive Staff

DR. E. JAMES PRENDERGAST, *Executive Director & Chief Operating Officer*

THOMAS SIEGERT, *Business Administration*
MATTHEW LIEB, *Corporate Activities*
DOUGLAS GORHAM, *Educational Activities*
BETSY DAVIS, *SPHR, Human Resources*
CHRIS BRANTLEY, *IEEE-USA*
ALEXANDER PASIK, *Information Technology*

PATRICK MAHONEY, *Marketing*
CECELIA JANKOWSKI, *Member and Geographic Activities*
ANTHONY DURINAK, *Publications Activities*
JUDITH GORMAN, *Standards Activities*
MARY WARD-CALLAN, *Technical Activities*

IEEE Periodicals

Transactions/Journals Department

Staff Director: FRAN ZAPPULLA

Editorial Director: DAWN MELLEY
Managing Editor: MARTIN J. MORAHAN
Production Director: PETER M. TUOHY
Journals Coordinator: SARA T. SCUDDER

IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT (ISSN 0018-9456) is published monthly by The Institute of Electrical and Electronics Engineers, Inc. Responsibility for the contents rests upon the authors and not upon the IEEE, the Society Council, or its members. **IEEE Corporate Office:** 3 Park Avenue, 17th Floor, New York, NY 10016-5997. **IEEE Operations Center:** 445 Hoes Lane, Piscataway, NJ 08854-4141. **NJ Telephone:** +1 732 981 0060. **Price/Publication Information:** Individual copies: IEEE Members \$20.00 (first copy only), nonmembers \$39.00 per copy. (Note: Postage and handling charge not included.) Member and nonmember subscription prices available upon request. **Copyright and Reprint Permissions:** Abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use of patrons, provided the per-copy fee indicated in the code at the bottom of the first page is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For all other copying, reprint, or republication permission, write to Copyrights and Permissions Department, IEEE Publications Administration, 445 Hoes Lane, Piscataway, NJ 08854-4141. Copyright © 2011 by The Institute of Electrical and Electronics Engineers, Inc. All rights reserved. Periodicals Postage Paid at New York, NY and at additional mailing offices. **Postmaster:** Send address changes to IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, IEEE, 445 Hoes Lane, Piscataway, NJ 08854-4141. GST Registration No. 125634188. **CPC Sales Agreement #40013087.** Return undeliverable Canada addresses to: Pitney Bowes IMEX, P.O. Box 4332, Stanton Rd., Toronto, ON M5W 3J4, Canada. IEEE prohibits discrimination, harassment and bullying. For more information visit <http://www.ieee.org/nondiscrimination>. Printed in U.S.A.



Medical and Biomedical Instrumentation and Applications

Signal Generator for Wireless Impedance Monitoring of Microbiological Systems *J. Wissenwasser, M. J. Vellekoop, and R. Heer* 2039

Measurement Techniques

Self-Calibrating Infrared Thermometer for Low-Temperature Measurement *T. Barry, G. Fuller, K. Hayatleh, and J. Lidgley* 2047

A Novel Calibration Method of Magnetic Compass Based on Ellipsoid Fitting *J. Fang, H. Sun, J. Cao, X. Zhang, and Y. Tao* 2053

Flow Rate Measurement in a High-Temperature, Radioactive, and Corrosive Environment *T. Moazzeni, J. Ma, Y. Jiang, and N. Li* 2062

A High-Resolution Time-to-Digital Converter on FPGA Using Dynamic Reconfiguration *M.-A. Daigneault and J. P. David* 2070

Wet-Gas Flow Modeling for the Straight Section of Throat-Extended Venturi Meter *L. Xu, W. Zhou, X. Li, and M. Wang* 2080

Networking, Networks, and Sensor Networks

Trust Evaluation Sensing for Wireless Sensor Networks *X. Wang, L. Ding, and S. Wang* 2088

Preventing the Collision of Requests From Slave Clocks in the Precision Time Protocol (PTP) *A. Ciuffoletti* 2096

CSP-Based Sensor Network Architecture for Reconfigurable Measurement Systems *S. Jaskó and G. Simon* 2104

Optical Instrumentation, Measurement, and Systems

Optical High-Voltage Sensor Based on Fiber Bragg Grating and PZT Piezoelectric Ceramics *R. C. S. B. Allil and M. M. Werneck* 2118

RF, Microwave, Millimeter Wave, and Tera-Hertz

Measurement of a Microwave Load Using One or Two Terminations of Known Reflection *U. Stumper* 2126

Sensors, Sensor Fusion, and Transducers

New Architecture for a Wireless Smart Sensor Based on a Software-Defined Radio *P. Ferrari, A. Flammini, and E. Sisinni* 2133

Particle-Filter-Based Multisensor Fusion for Solving Low-Frequency Electromagnetic NDE Inverse Problems *T. Khan, P. Ramuhalli, and S. C. Dass* 2142

Virtual Measurements and Systems and Synthetic Instrumentation

A Synthetic Vector Network Analyzing Measurement System *M. Isaksson and E. Zenteno* 2154

IEEE Instrumentation and Measurement Society Transactions

I & M Society President
KIM FOWLER
9513 Old Court Road
Windsor Mill, MD 21244, USA
Fax: 410 521 3432
e-mail: kimf@ieee.org

I & M Society Publications Chair
SHREEKANTH MANDAYAM
Rowan University
Electrical & Computer Engineering
201 Mullica Hill Road
Glassboro, NJ 08028, USA
Fax: 856-256-5241
e-mail: shreek@rowan.edu

Transactions Editor-in-Chief
REZA ZOUGHBI
Missouri University of Science and Technology (MST)
224 Emerson Electric Co. Hall
301 W. 16th Street
Rolla, MO 65409, USA
Fax: 573-341-6671
e-mail: zoughi@mst.edu

Ex-Officio Editor-in-Chief
MILTON G. SLADE
86 Holden Wood Road
Concord, MA 01742, USA
Fax: 978-287-0227
e-mail: m.slade@ieee.org

Scope of the Transactions

Please send all manuscript correspondence directly to the Transactions Assistant: Cam Ingelin, 717 Lakefield Dr., Independence, KY 41051, Tel: 859 363 8260, Fax: 859 495 0463, email: c.ingelin@ieee.org.

Associate Editors

SALVATORE BAGLIO
University of Catania
DIEES
Catania I-95125, Italy
e-mail: salvatore.baglio@diees.unict.it

KURT BARBE
Vrije Universiteit Brussel
Dept. Electrical Engineering
Faculty of Engineering-Building K Pleinlaan 2
B-1050 Brussels BELGIUM
e-mail: kbarbe@irexchange.vub.ac.be

DARYL BERTNER
Missouri Univ. of Sci. Technol. Elect. Compt. Eng.
126 Emerson Electric Co. Hall
Rolla, MO 65401 USA
e-mail: daryl@mst.edu

MARK BLODGETT
AFRL NDE Branch
2230 Tenth St., Ste. J
Dayton, OH 45433, USA
e-mail: mark.blodgett@wpafb.af.mil

SERGE DEMIDENKO
IIS&T, Riddet Building
Massey University
Palmerston North, New Zealand
e-mail: S.Demidenko@massey.ac.nz

ALESSANDRO FERRERO
Dipartimento di Elettrotecnica
Politecnico di Milano
Piazza Leonardo da Vinci 32
20133 Milano, Italy
e-mail: alessandro.ferrero@ieee.org

ROBERT GAO
Dept. of Mechanical Engineering
University of Connecticut
191 Auditorium Road, Unit 3139
Storrs, CT 06269 USA
e-mail: rgao@engr.uconn.edu

DOMENICO GRIMALDI
Università Della Calabria
D.E.I.S.
Rende
CS I-87036, Italy
e-mail: grimaldi@deis.unical.it

DENIZ GURKAN
University of Houston
Dept. of Engineering Technology
4800 Calhoun Road
Houston, TX 77204-4020
e-mail: dgurkan@central.uh.edu

SHANT KENDERIAN
The Aerospace Corporation
Materials Science Department
2310 E. El Segundo Blvd.
El Segundo, CA 90145
e-mail: shant.kenderian@aero.org

SERGEY KHARKOVSKY
Missouri Univ. of Science and Technology
Department of Electrical and Computer Eng.
301 W. 16th St.
Rolla, MO 65409, USA
e-mail: sergiy@mst.edu

THEODORE LAPOULOS
Aristotle University of Thessaloniki
Department of Physics
Electronics Laboratory
Thessaloniki 54124, Greece
e-mail: lapoulos@physics.auth.gr

THOMAS LIPE
Quantum Electrical Metrology Division
NIST
Gaithersburg, MD 20899, USA
e-mail: thomas.lipe@nist.gov

ZHENG LIU
Institute for Research in Construction
National Research Council Canada
1200 Montreal Road, Building M-20
Ottawa, Ontario, K1A0R6 Canada
e-mail: zheng.liu@nrc-cnrc.gc.ca

JENNIFER E. MICHAELS
School of Electrical & Computer Eng.
Georgia Institute of Technology
777 Atlantic Dr., NW
Atlanta, GA 30332, USA
e-mail: jennifer.michaels@ece.gatech.edu

SUBHAS C. MUKHOPADHYAY
School of Eng. & Advanced Technol.
AG-HORT Building AH 3.77
Massey University - Turitea
Palmerston North, New Zealand
e-mail: S.C.Mukhopadhyay@massey.ac.nz

CARLO MUSCAS
Università di Cagliari
Dipartimento di Ingegneria Elettrica ed
Elettronica (DIEE)
Piazza d'Armi s.r.l.
09123 Cagliari, Italy
e-mail: carlo@diee.unica.it

MATTEO PASTORINO
University of Genoa
Dept. of Biophysical and Electronic Eng.
Via Opera Pia 11A
I-16145 Genova, Italy
e-mail: matteo.pastorino@unige.it

J. M. DIAS PEREIRA
Departamento de Sistemas e Informatica
Escola Superior de Tecnologia de Setubal
Polytechnic Institute of Setubal
Rua do Vale de Chaves
Estefanilha, 2910-761 Setubal Portugal
e-mail: joseper@est.ipv.pt

DARIO PETRI
Dipartimento di Ingegneria e Scienza
dell'Informazione
Università degli Studi di Trento
Via Sommarive 14
Povo Trento 38050, Italy
e-mail: petri@disi.unitt.it

RIK PINTELON
Vrije Universiteit Brussel
Department ELEC
Pleinlaan 2
Brussels 1050, Belgium
e-mail: rik.pintelon@vub.ac.be

JOHN SHEPPARD
Montana State University
Dept. of Computer Science
Bozeman, MT 59717, USA
e-mail: john.sheppard@cs.montana.edu

SHERVIN SHIRMOHAMMADI
University of Ottawa
School of Information Technology
and Engineering
800 King Edward Ave.
Ottawa, ONT K1N 6N5, CANADA
e-mail: shervin@discover.uottawa.ca

V. R. SINGH
National Physical Laboratory
Instrumentation & Sensors Group
Dr. K. S. Krishnan Road
New Delhi 110012, India
e-mail: vrsingh@ieee.org

JIONG TANG
Dept. of Mechanical Engineering
The University of Connecticut
Storrs, CT 06269, USA
e-mail: jtang@engr.uconn.edu

SAMIR TRABELSI
U. S. Dept. of Agriculture
Russell Research Center
Athens, GA 30604, USA
e-mail: samir.trabelsi@ars.usda.gov

ANTONIOS TSOURDOS
Defence Academy of United Kingdom
Cranfield University
Shrivenham, Swindon SN6 8LA, U.K.
e-mail: a.tsourdos@cranfield.ac.uk

JESUS URENA
Dept. of Electronics, Univ. of Alcala
Polytechnical School
Campus Universitario s/n
28805 Alcala de Henares
Madrid, Spain
e-mail: urena@depeca.uah.es

WENDY VAN MOER
Vrije Universiteit Brussel
Dept. ELEC/M²ESA
Pleinlaan 2
Brussels B-1050, Belgium
e-mail: wendy.vanmoer@vub.ac.be

GERD VANDERSTERN
Vrije Universiteit Brussel
Pleinlaan 2
Brussels B-1050, Belgium
e-mail: vdsteeng@irmec.be

GAOZHI GEORGE XIAO
Institute for Microstructural Science
National Research Council of Canada
1200 Montreal Road, M-50
Ottawa, Ontario K1A 0R6, Canada
e-mail: george.xiao@nrc-cnrc.gc.ca

MARK YEARY
University of Oklahoma
School of Elec. & Comp. Eng.
Atmospheric Radar Research Ctr.
Norman, OK 73019-1102, USA
e-mail: yeary@ieee.org