PROCEEDINGS OF SPIE

Radar Sensor Technology XIX; and Active and Passive Signatures VI

Kenneth I. Ranney Armin Doerry G. Charmaine Gilbreath Chadwick Todd Hawley Editors

20–23 April 2015 Baltimore, Maryland, United States

Sponsored and Published by SPIE

Volume 9461

Proceedings of SPIE 0277-786X, V. 9461

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Radar Sensor Technology XIX; and Active and Passive Signatures VI, edited by K. Ranney, A. Doerry, G. C. Gilbreath, C. T. Hawley, Proc. of SPIE Vol. 9461, 946101 · © 2015 SPIE CCC code: 0277-786X/15/\$18 · doi: 10.1117/12.2202200 The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in Radar Sensor Technology XIX; and Active and Passive Signatures VI, edited by Kenneth I. Ranney, Armin Doerry, G. Charmaine Gilbreath, Chadwick Todd Hawley, Proceedings of SPIE Vol. 9461 (SPIE, Bellingham, WA, 2015) Article CID Number.

ISSN: 0277-786X ISBN: 9781628415773

Published by **SPIE** P.O. Box 10, Bellingham, Washington 98227-0010 USA Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445 SPIE.org

Copyright © 2015, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/15/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.



Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print. Papers are published as they are submitted and meet publication criteria. A unique citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering
- system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID Number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages.

Contents

- vii Authors
- ix Conference Committee

COMPONENTS AND TECHNOLOGIES

- 9461 02 Calculation of the phase-center offset from 2D antenna radiation patterns [9461-1]
- 9461 03 Characterization of radar cross section of carbon fiber composite materials [9461-2]
- 9461 04 Design considerations for eye-safe single-aperture laser radars [9461-3]
- 9461 06 System-on-chip architecture and validation for real-time transceiver optimization: APC implementation on FPGA [9461-5]
- 9461 07 Acceleration of generalized adaptive pulse compression with parallel GPUs [9461-6]

NON-LINEAR AND COGNITIVE RADAR

- 9461 08 Short-range harmonic radar: chirp waveform, electronic targets [9461-7]
- 9461 09 Nonlinear synthetic aperture radar imaging using a harmonic radar [9461-8]
- 9461 0A Filter selection for a harmonic radar [9461-9]
- 9461 OB Sparse SAR imaging for a stepped-frequency harmonic radar [9461-10]

ALGORITHMS AND PHENOMENOLOGY I

- 9461 OC Terrain clutter simulation using physics-based scattering model and digital terrain profile data [9461-11]
- 9461 OE Building detection in SAR imagery [9461-14]

INDOOR/URBAN TARGET DETECTION, LOCALIZATION, AND TRACKING

- 9461 0G Bistatic and multistatic target identification for through-wall radar imaging [9461-16]
- 9461 OH Personalized fall detection and classification through walls and in heavy indoor clutter [9461-17]
- 9461 0I SVM based target classification using RCS feature vectors [9461-18]

PROGRAMS AND APPLICATIONS

- 9461 0J Performance analysis of spectrally versatile forward-looking ground-penetrating radar for detection of concealed targets [9461-19]
- 9461 0K FlexSAR, a high-quality, flexible, cost-effective, prototype SAR system [9461-20]
- 9461 OL Recent experiments using the ARL Rail-SAR [9461-21]
- 9461 OM Technology integration and synergies: radar, optics, and AIS [9461-22]
- 9461 0N Radome effects on coherent change detection radar systems [9461-23]
- 9461 00 SAR-based vibrometry using the fractional Fourier transform [9461-24]

ALGORITHMS AND PHENOMENOLOGY

- 9461 OP An algorithm for segmenting polarimetric SAR imagery [9461-25]
- 9461 0Q Generalization of susceptibility of RF systems through far-field pattern superposition [9461-26]
- 9461 OR A practical look at target detection using MIMO radar [9461-27]
- 9461 0S **RF tomography of metallic objects in free space: preliminary results** [9461-28]
- 9461 0T Application of equalization notch to improve synthetic aperture radar coherent data products [9461-29]

NOISE AND LPI RADAR I

- 9461 0U Radar cross-sectional study using noise radar [9461-30]
- 9461 0V Principle and experimental results of ultra-wideband noise radar imaging of a cylindrical conducting object using diffraction tomography [9461-31]
- 9461 0W Design and implementation of a noise radar tomographic system [9461-32]
- 9461 0X Efficient pulse compression for LPI waveforms based on a nonparametric iterative adaptive approach [9461-33]
- 9461 0Y Qualitative analysis of interference on receiver performance using advanced pulse compression noise (APCN) [9461-34]

NOISE AND LPI RADAR II

9461 0Z Analysis of chaotic FM system synchronization for bistatic radar [946

9461 10 The implementation of compressive sensing on an FPGA for chaotic radars [9461-36]

QUANTUM RADAR

- 9461 11 Range detection using entangled optical photons [9461-37]
- 9461 12 Algorithmic analysis of quantum radar cross sections [9461-38]
- 9461 13 Low-brightness quantum radar [9461-39]
- 9461 14 **Quantum error reduction without coding** [9461-40]
- 9461 15 Space-based quantum sensing for low-power detection of small targets [9461-41]

MEDICAL APPLICATIONS OF RADAR

- 9461 16 Investigations on the effect of frequency and noise in a localization technique based on microwave imaging for an in-body RF source [9461-42]
- 9461 18 Diagnosis of edema and inflammation in human intestines using ultrawideband radar [9461-44]
- 9461 19 Radar sensitivity to human heartbeats and respiration [9461-45]

RADAR MICRO-DOPPLER: JOINT SESSION WITH CONFERENCES 9461A AND 9461B

- 9461 1A Micro-Doppler characteristics of elderly gait patterns with walking aids [9461-46]
- 9461 1B High-resolution time-frequency distributions for fall detection [9461-47]
- 9461 1C Born approximation, scattering, and algorithm [9461-13]
- 9461 1D Features associated with radar micro-Doppler signatures of various human activities [9461-56]
- 9461 1E Study of the microdoppler signature of a bicyclist for different directions of approach [9461-57]
- 9461 1F Extracting and analyzing micro-Doppler from ladar signatures [9461-58]
- 9461 1G High range resolution micro-Doppler analysis [9461-59]

ACTIVE AND PASSIVE SIGNATURES I

9461 1H	Application of a laser Doppler vibrometer for air-water to subsurface signature detection [9461-60]
9461 1J	Signature simulation of mixed materials [9461-62]
9461 1L	Electro-optical detection probability of optical devices determined by bidirectional laser retro-reflection cross section [9461-64]
9461 1M	Spectral reflectance variability of skin and attributing factors [9461-65]
9461 1N	Rugged target standards for HSI remote sensing [9461-66]
9461 10	Enhancing radar cross-section images of artificial targets using radar polarimetry [9461-67]
9461 1P	Anomalous reflection of THz pulse, containing a few cycles, from absorbing layer: influence of absolute phase of the pulse on the medium response [9461-68]
	ACTIVE AND PASSIVE SIGNATURES II
9461 1R	Real-time full-motion color Flash lidar for target detection and identification [9461-70]
9461 10	The Johns Hopkins University multimodal dataset for human action recognition [9461-79]
	POSTER SESSION
9461 1V	Spurious effects of analog-to-digital conversion nonlinearities on radar range-Doppler maps [9461-49]
9461 1W	Balancing radar receiver channels with commutation [9461-50]
9461 1X	Comments on radar interference sources and mitigation techniques [9461-51]
9461 1Y	Balancing I/Q data in radar range-Doppler images [9461-52]
9461 20	Experimental evaluation of single-aperture range finder [9461-54]
9461 21	Coherence model for building layover in interferometric SAR [9461-55]
9461 22	Instantaneous, stepped-frequency, nonlinear radar [9461-76]
9461 23	Adaptive OFDM waveform design for spatio-temporal-sparsity exploited STAP radar

Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Aardal, Øyvind, 19 Abellard, J. N., OM Ade-Bello, Jelili, 00 Ahmad, Fauzia, OH, 1A Allebach, Joshua M., 0G Allen, David W., 1M Amin, Moeness G., OH, 1A, 1B Andreou, Andreas G., 1U Antar, Y. M. M., OU Asmuth, Mark A., OV, OW Atwood, Thomas, 00 Baker, Christopher J., OS, 1G Balasingham, Ilangko, 16 Barhen, Jacob, 23 Berdanier, Charles, OS Berger, Tor, 19 Bhatta, Ishwor, 00 Bickel, Douglas L., 21 Blake, WIlliam, OX Boashash, Boualem, 1A, 1B Boehm, James, OZ Brandsema, Matthew J., 11 Broderick, Sean P., 0G Brovoll, Sverre, 19 Bufler, Travis D., Ol Burns, Bryan L., ON Cai, Jingxiao, 07 Cammenga, Zachary A., 1G Campbell, Justin B., 00 Carson, Tyler D., 1J Caudana, Humberto, 00 Chandra, Rohit, 16 Chen, Y., 0M Christnacher, Frank, 1L Cooksey, Catherine C., 1M Coppock, Eric, 1R Craig, Rex, 1R Craner, Jeremy, 1R Crowder, Tanner, 14 Dallmann, Thomas, 10 Debroux, Patrick, 02, 0Q, 0Z DiBenedetto, John, 1N Ding, Kung-Hau, OC Doerry, Armin W., 0O, 1V, 1W, 1X, 1Y Dogaru, Traian, OI, OL, OR Dubbert, Dale F., ON, 1V Dunkel, Ralf, 00 Elwell, Ryan A., OR, OY Ewing, Robert L., OS

Fedotov, Mikhail V., 1P Feng, Johnny, 14 Flores, Benjamin C., OZ, 1E Freundorfer, A. P., 0U Gallagher, Kyle A., 08, 09, 0A, 0B, 22 Geaga, Jorge V., OP Gerstle, Walter H., 00 Gonzalez Chevere, D., 0M Goold, Jeremy, 0E Govoni, Mark A., OR, OY Gu, Haicheng, 1C Hahn, Mark, 1N Hamran, Svein-Erik, 19 Haslem, Brent, OK Hayat, Majeed M., 00 Heberling, Dirk, 10 Hengy, Sebastien, 1L Hensley, William H. Jr., ON Hoe, Benjamin, OG Hoe, David H., 10 Hu, Mengqi, 1C Jensen, Mark, OK Johnson, Joel T., OC Jokanovic, Branka, OH Kim, Kristopher, OC Kirose, Getachew A., 0J, 0L Knight, Chad, OK Koch, Mark W., 0E Komarova, Elena S., 1P Land, Phillip, 1H Lande, Tor Sverre, 19 Lanzagorta, Marco, 11, 12, 13, 15 Laurenzis, Martin, 1L Lenzing, Erik H., 03 Li, Jia, OS Li, Zhengzheng, OX Liao, DaHan, OR Maile, Michael, 1E Majumdar, Arun, 1H Martin, Keye, 14 Martinez, Alex, 1C Martone, Anthony F., 08, 09, 0A, 22 Matwyschuk, Alexis, 1L Mazzaro, Gregory J., 08, 09, 0A, 22 McCormick, K., 04, 20 Mendat, Daniel R., 1U Messaris, Evangelos, 18 Morey, Mark, 1N Moya, Mary M., 0E

Murray, Thomas S., 1U Musgrove, Cameron, 0T Narayanan, Ram M., 03, 08, 09, 0A, 0G, 0I, 0J, 0L, 0V, 0W, 11, 18, 1D, 22 Nelson, Roy, 1R Nepal, Ramesh, OX Nguyen, Lam H., 09, 0B Nicks, Dennis, 1R Ochoa, Hector A., 10 O'Neill, Mary, 1N Paichard, Yoann, 19 Pappu, Chandra S., OZ Park, James, 0C Phelan, Brian R., OJ, OL Pichardo, S., 02 Pouliquen, Philippe O., 1U Qiao, Zhijun, 1C Rangaswamy, Muralidhar, OV, OW Ranney, Kenneth I., 09, 0B, 0J, 0L, 22 Raynal, Ann Marie, ON Ressler, Marc A., OJ Riley, Elliot J., 03 Robinson, Dennis, 1H Rodriguez-Hervas, Berta, 1E Roeder, James, 1H Salvaggio, Carl, 1J Santhanam, Balu, 00 Schertzer, Stephane, 1L Sen, Satyabrata, 23 Shahid, H., OM Sherbondy, Kelly D., 08, 09, 0A, 0J, 0L, 22 Shin, Hee Jung, OV, OW Siddiqui, J.Y., OU Smith, Graeme E., 1G Smith, Gregory D., 0J Smith, Sonny, 18 Starodubov, D., 04, 20 Steinbach, Ryan M., OE Suarez, Hernan, 06 Tahmoush, Dave, 1F Tenbarge, Joseph, 0C Tise, B. L., 1V Trofimov, Vyacheslav A., 1P Trujillo, Nicole B., 00 Tsai, Benjamin K., 1M Uhlmann, Jeffrey, 15 Veeramachaneni, Dinesh, 10 Venegas-Andraca, Salvador, 12 Verdin, Berenice, 02, 0Q, 0Z Volfson, L., 04, 20 von Niederhausern, Kurt, 1R Wang, Qi, 00 West, James C., OT Zenaldin, Matthew, 1D Zhang, Yan Rockee, 06, 07, 0X Zhang, Yimin D., 1A, 1B

Conference Committee

Symposium Chair

Nils R. Sandell Jr., Strategic Technology Office, DARPA (United States)

Symposium Co-chair

David A. Logan, BAE Systems (United States)

Part A Radar Sensor Technology XIX

Conference Chairs

Kenneth I. Ranney, U.S. Army Research Laboratory (United States) Armin Doerry, Sandia National Laboratories (United States)

Conference Program Committee

Fauzia Ahmad, Villanova University (United States) Moeness G. Amin, Villanova University (United States) Joseph C. Deroba, U.S. Army CERDEC Intelligence and Information Warfare Directorate (United States) Mark Govoni, U.S. Army CERDEC Intelligence and Information Warfare Directorate (United States) **Maieed Havat**, The University of New Mexico (United States) Chandra Kambhamettu, University of Delaware (United States) Seong-Hwoon Kim, Raytheon Space & Airborne Systems (United States) James L. Kurtz, University of Florida (United States) Changzhi Li, Texas Tech University (United States) Jenshan Lin, University of Florida (United States) Hao Ling, The University of Texas at Austin (United States) **David G. Long**, Brigham Young University (United States) Jia-Jih Lu, General Atomics Aeronautical Systems, Inc. (United States) **Neeraj Magotra**, Western New England University (United States) Anthony F. Martone, U.S. Army Research Laboratory (United States) Gregory J. Mazzaro, The Citadel (United States) George J. Moussally, Mirage Systems (United States) Ram M. Narayanan, The Pennsylvania State University (United States) Lam H. Nguyen, U.S. Army Research Laboratory (United States) Hector A. Ochoa, The University of Texas at Tyler (United States) Zhijun G. Qiao, The University of Texas-Pan American (United States) Ann M. Raynal, Sandia National Laboratories (United States)

Jerry Silvious, U.S. Army Research Laboratory (United States) Brian Smith, U.S. Army Armament Research, Development and Engineering Center (United States)

Helmut Suess, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany)

David Tahmoush, U.S. Army Research Laboratory (United States) Russell Vela, Air Force Research Laboratory (United States) Berenice Verdin, The University of Texas at El Paso (United States) Frank Yakos, SELEX Galileo, Inc. (United States) Yan Zhang, The University of Oklahoma (United States)

Session Chairs

Components and Technologies Ann M. Raynal, Sandia National Laboratories (United States)

Non-Linear and Cognitive Radar Gregory J. Mazzaro, The Citadel (United States) Anthony F. Martone, U.S. Army Research Laboratory (United States)

Algorithms and Phenomenology I Mark A. Govoni, U.S. Army CERDEC Intelligence and Information Warfare Directorate (United States)

Indoor/Urban Target Detection, Localization, and Tracking Fauzia Ahmad, Villanova University (United States)

Programs and Applications

Jerry L. Silvious, U.S. Army Research Laboratory (United States) Seong-Hwoon Kim, Raytheon Space & Airborne Systems (United States)

Algorithms and Phenomenology Lam H. Nguyen, U.S. Army Research Laboratory (United States)

Noise and LPI Radar I Yan Rockee Zhang, The University of Oklahoma (United States)

Noise and LPI Radar II

Mark A. Govoni, U.S. Army CERDEC Intelligence and Information Warfare Directorate (United States)

Quantum Radar Marco O. Lanzagorta, U.S. Naval Research Laboratory (United States) Medical Applications of Radar **Ram M. Narayanan**, The Pennsylvania State University (United States)

Part B Active and Passive Signatures VI

Conference Chairs

 G. Charmaine Gilbreath, U.S. Naval Research Laboratory (United States)
 Chadwick Todd Hawley, Senior Expert for Signatures (United States)

Conference Program Committee

David W. Allen, National Institute of Standards and Technology (United States)

Kelly W. Bennett, U.S. Army Research Laboratory (United States)
Carlos Omar Font, U.S. Naval Research Laboratory (United States)
Marco O. Lanzagorta, U.S. Naval Research Laboratory (United States)
Ram M. Narayanan, The Pennsylvania State University (United States)
Frank Pipitone, U.S. Naval Research Laboratory (United States)
Frank Pipitone, U.S. Naval Research Laboratory (United States)
Robert Richardson, U.S. Dept. of Defense Intelligence Information Systems (United States)
Carl Salvaggio, Rochester Institute of Technology (United States)

Fred Schnarre, National Geospatial-Intelligence Agency (United States)

David N. Strafford, Soter Technology (United States)

Session Chairs

Radar Micro-Doppler: Joint Session with Conferences 9461A and 9461B

G. Charmaine Gilbreath, U.S. Naval Research Laboratory (United States)

Active and Passive Signatures I

G. Charmaine Gilbreath, U.S. Naval Research Laboratory (United States)

Active and Passive Signatures II Kelly W. Bennett, U.S. Army Research Laboratory (United States)