

Novel Radar Techniques and Applications

Volume 1: Real Aperture Array Radar, Imaging
Radar, and Passive and Multistatic Radar

Edited by

Richard Klemm, Ulrich Nickel, Christoph Gierull,
Pierfrancesco Lombardo, Hugh Griffiths, Wolfgang Koch



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and Passive and Multistatic Radar

Novel Radar Techniques and Applications presents the state-of-the-art in advanced radar, with emphasis on ongoing novel research and development and contributions from an international team of leading radar experts.

This volume covers:

- **Real aperture array radar**, including target parameter estimation and array radar features; robust direct data domain processing; and array radar operation management
- **Imaging radar**, including VideoSAR imaging for real-time persistence; high-resolution wide-swath SAR; interferometric SAR imaging; space-based SAR-Ground moving target indication; 3D & tomographic SAR imaging; bi- and monostatic SAR-GMTI; multistatic and MIMO ISAR techniques; and focussing moving objects using the VSAR algorithm
- **Passive and multistatic radar**, including bistatic clutter modeling; airborne passive radar; forward scatter radar; through the wall imaging radar; short-range passive radar potentialities; GNSS-based passive radar; passive radar with airborne receivers; multi-illuminator and multistatic passive radar; and passive MIMO radar networks.

The companion volume 2 covers waveform diversity and cognitive radio, and target tracking and data fusion.

About the Editors

Richard Klemm has recently retired after a distinguished career at FGAN FHR (now Fraunhofer FHR), a research institute working in the areas defence and security, and decades of service to the radar community.

Ulrich Nickel has recently retired after a career as head of the research group Data Fusion for Array Sensors of the Sensor Data and Information Fusion (SDF) department of Fraunhofer FKIE in Wachtberg, Germany.

Christoph H. Gierull is a Senior Scientist with Defence R&D Canada, Ottawa Research Centre assuming the duties of Group Leader, Space-based Radar as well as Adjunct Professor at Laval University, Quebec and Simon Fraser University, British Columbia, Canada.

Pierfrancesco Lombardo is Full Professor at University of Rome "La Sapienza", where he leads the "Radar, Remote Sensing and Navigation" (RRSN) group.

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Richard Klemm

Volume 1 Editors

Part I: Real aperture array radar
Ulrich Nickel
Fraunhofer FKIE, Germany

Part II: Imaging radar
Christoph Gierull
DRDC, Canada

Part III: Passive and multistatic radar
Pierfrancesco Lombardo
University of Rome, Italy

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Preface to Volumes 1 and 2

The title ‘Novel Radar Techniques and Applications (NRTA)’ suggests that the content of these two volumes is twofold. On the one hand, the team of editors together with the authors aimed at presenting a variety of radar techniques that have not yet found their way into operational use. Techniques such as MIMO, compressive sensing, cognitive radar operation, radar management, radar networks and waveform diversity are presented in these volumes as well as tracking, data fusion, passive radar operation and new imaging techniques.

Moreover, a large number of applications demonstrate the usefulness, the potential and the limits of performance of the presented techniques. In order to reach this multifold goal, a large number of authors have been invited from universities, research laboratories and industry, so as to cover as many different aspects arising between theory, practice and operational use as possible.

These volumes are subdivided into five parts, each of them including a number of chapters. Each part is dedicated to a specific area: Vol. 1: Part I. Array Radar (interference and clutter cancellation, target parameter estimation, etc.); Part II. Imaging Radar; Part III. Passive and Multistatic Radar; Vol. 2: Part IV. Waveform Diversity; Part V. Data Fusion and Tracking. Each part has been taken care of by a co-editor, typically a renowned expert in the respective area. Each part starts with an introduction written by the associated co-editor. In their introductions, the co-editors give overviews of the current state of the art in the respective area and point out the relevance of the subsequent chapters.

These volumes would never have been completed without the enthusiastic effort of a large number of persons. First of all I have to thank the five co-editors Ulrich Nickel, Germany; Christoph Gierull, Canada; Pierfrancesco Lombardo, Italy; Hugh Griffiths, UK and Wolfgang Koch, Germany for their outstanding co-operation on this project. Based on the expertise in their respective fields, they assisted me in composing the contents of these volumes and identifying potential authors and reviewers who were selected according to their expertise in the specific fields. In this way an important feature of these volumes is its multiplicity of facets of modern radar technology and associated applications. It makes these volumes a deep source of information and inspiration for teachers, students, researchers and system designers, in summary all people involved in the development of the radar of tomorrow.

I would like to thank the authors for their excellent work over a long period of time and the reviewers whose critical comments contributed to the quality of the book. Finally the excellent cooperation with Jennifer Grace, Nikki Tarplett and Paul Deards of IET Publishers as well as Vijay Ramalingam of MPS Ltd. is gratefully acknowledged.

Richard Klemm, Editor NRTA
08.09.2017, Bonn, Germany

Volume 1 Editor Biographies



Richard Klemm received his Dipl.-Ing. and Dr.-Ing. degrees in communications from the Technical University of Berlin in 1968 and 1974, respectively. Since 1968, he has been with FGAN FHR (now Fraunhofer FHR), a research institute working in the areas defence and security. From 1977 to 1980, he was with SACLANT ASW Centre, La Spezia, Italy. Richard Klemm's main fields of activity have been research into adaptive clutter and jammer suppression for radar, array processing for active and passive sonar, with emphasis on matched field processing for shallow water applications and detection of moving targets by moving sensor platforms. Richard Klemm has published numerous articles on various aspects of radar and sonar signal processing, and a book (3rd edition) on space-time adaptive processing. He is editor of a book on 'Applications of STAP', including contributions by 45 international authors. He is a permanent reviewer of renowned journals and has provided seminars and consultancy to various organizations in different countries (European Commission, several European countries, USA, Canada, Russia, China, Turkey). Richard Klemm has been a member of the NATO AGARD AVP and RTO-SET panels and chaired various AGARD and RTO symposia. He initialized and chaired the European Conference on Synthetic Aperture Radar EUSAR in 1996 which takes place every 2 years since then. He received several awards in recognition of his scientific achievements, among them the NATO RTO von Karman medal. Richard Klemm gave seminars to different Chinese institutions (Tsinghua University Beijing; Institute of Electronics CAS, Beijing; Xi'an University, Xi'an; UESTC Chengdu; Jiaotong University, Shanghai; NRIET Nanjing). He is honorary professor of UESTC (University of Electronics Science and Technology of China) in Chengdu. His book 'Principles of Space-Time Adaptive Processing 3rd edition' was translated into Chinese by members of NRIET, Nanjing, and has been published by Higher Education Press, Beijing. In his spare time, Richard Klemm is a passionate classical pianist. Under the motto Science and Music, he likes to give piano recitals at technical conferences. He is married, has three children and seven grandchildren.



Ulrich Nickel received the Diploma in Mathematics from the University of Cologne (Germany) in 1975 and the Dr. rer. nat. degree from the Technical University of Aachen (Germany) in 1983. Since 1975, he was at the Array-Based Radar Imaging Department of the Research Institute for High Frequency Physics and Radar Techniques (FHR) of FGAN (German Defence Research Establishment) in Wachtberg, Germany. Since 2007 he is with the Sensor Data and Information Fusion Department (SDF) of the Fraunhofer Institute for Communication,

Information Processing and Ergonomics (FKIE) in Wachtberg. His interests include all aspects of array signal processing, especially radar detection and parameter estimation with adaptive beamforming and superresolution methods. He was visiting scientist at the Defence R&D Canada, Ottawa, in 1987 and at the University of Connecticut, CT, USA, in 2009. He received the VDE-ITG paper prize 1989 and a conference paper prize at CIE RADAR 2006 (Shanghai). He is contributing author of the books ‘Radar Array Processing’ (eds. S. Haykin *et al.*, Springer-Verlag, 1993) and ‘Applications of Space-Time Adaptive Processing’ (ed. R. Klemm, IEE Publishers, 2004). From 1996 to 2010, he was member of the Editorial Board of the *International Journal of Electronics and Communications* (AEÜ) and from 2010 to 2013 Associate Editor of the *IEEE Transactions on Aerospace and Electronic Systems*.



Christoph H. Gierull received the Dr.-Ing. degree from the Ruhr-University Bochum, Germany, in 1995. Since 2011, he has been appointed as Adjunct Professor at Laval University, Quebec and since 2017 also at Simon Fraser University, British Columbia. From 1991 to 1994, he was a scientist with the research establishment FGAN, Germany. In 1994, he joined the German Aerospace Center DLR, where he headed the SAR Simulation Group. As part of a DLR team, he assured X-band interferometric SAR performance during the Space-Shuttle Radar Topography Mission (SRTM) at NASA’s Mission Control in Houston.

Since 2000, he has been a Senior Defence Scientist with DRDC Ottawa assuming the duties of Group Leader, Space-Based Radar. From 2006 to 2009, he was on assignment to Fraunhofer FHR, Germany. He has been a Technical Advisor to the Canadian and the European Space Agency on several SAR missions including RADARSAT-2, RCM and Sentinel-1. Dr. Gierull is author and coauthor of numerous journal publications, scientific reports and a chapter in *Application of Space-Time Adaptive Processing* (IEE, 2004). He served as Associate Editor for EURASIP’s Signal Processing in 2004 and for IEEE Trans. Geoscience and Remote Sensing 2010–2013. He initiated and co-organized the first Special Issue on Multi-channel Spaced-Based SAR in IEEE J-STARS, Nov. 2015. He has been

granted a CAN/US patent on vessel detection in SAR imagery. Dr. Gierull received the Best Annual Paper Award of the Association of German Electrical Engineers in 1998 and jointly the Best Paper Awards at the Int. Radar Conf. 2004, the EUSAR 2006 as well as EUSAR 2016. He is recipient of DRDC's S&T Performance Excellence Award 2013 and winner of the IEEE Geoscience and Remote Sensing Society 2016 J-STARS Paper Award. He is a Fellow of the IET.



Pierfrancesco Lombardo graduated in 1991 at the University of Rome 'La Sapienza', Italy. After serving at the Official Test Center of the Italian Air Force, he was Associate at Birmingham University (UK) and at Defense Research Agency in Malvern. In 1995, he received his Ph.D. and was research associate at Syracuse University (NY, USA). In 1996 he joined the University of Rome 'La Sapienza', where he is presently Full Professor. Dr. Lombardo is involved in, and coordinates, research projects funded by European and National Research Agencies and national industries. He

leads the 'Radar, Remote Sensing and Navigation' (RRSN) group at the University of Rome 'La Sapienza'. He chairs the Cosmo SkyMed consulting group for the Italian Space Agency. His main interests are radar adaptive signal processing, radar clutter modelling, radar coherent detection, passive radar and multistatic radar, SAR processing and radio-localization systems. Dr. Lombardo's research has been reported in over 250 publications in international technical journals and conferences. He is co-recipient of the Barry Carlton award (best paper) of IEEE Trans. on AES for year 2001 and of the best paper award for the IEEE Trans. on Geoscience and Remote Sensing for year 2003. He served in the technical committee of many international conferences on radar systems and signal processing. He was Technical Committee Chairman of the IEEE/ISPRS Workshop on Remote Sensing and Data Fusion over Urban Areas URBAN'2001, Rome, URBAN'2003, Berlin, and URBAN'2005, Tempe (US). He was also Technical Chairman of the IEEE Radar Conference 2008. Dr. Lombardo is associate Editor for Radar Systems for the IEEE Transactions on Aerospace and Electronic Systems (AES) since June 2001 and Technical Editor for radar System since January 2016. He is member of the IEEE AES Radar System Panel and the Editorial board of *IET Proceedings on Radar Sonar and Navigation*.

List of Authors

Ahmad, Fauzia	Temple University	USA
Allen, Christopher	University of Kansas	USA
Amin, Moeness	Villanova University	USA
Antoniou, Michail	University of Birmingham	UK
Aubry, Augusto	Università degli studi di Napoli Fed. II	Italy
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Charlish, Alexander	Fraunhofer FKIE	Germany
Cherniakov, Mikhail	University of Birmingham	UK
Colone, Fabiola	DIET University of Rome 'La Sapienza'	Italy
Cristallini, Diego	Fraunhofer FHR	Germany
Damini, Anthony	DRDC Ottawa	Canada
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Fargetton, Hervé	DGA Defense	France
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Fornaro, Gianfranco	IREA-CNR	Italy
Fränken, Dietrich	Hensoldt Sensors GmbH	Germany
Gashinova, Marina	University of Birmingham	UK
Georgiev, Krasin	Cranfield University	UK
Gierull, Christoph	DRDC Ottawa	Canada
Govaers, Felix	Fraunhofer FKIE	Germany
Griffiths, Hugh	University College London	UK
Gromek, Damian	Warsaw University of Technology	Poland
Hack, Daniel E.	Matrix Research Inc.	USA
Hernandez, Marcel	Hernandez Technical Solutions Ltd.	UK
Himed, Braham	AFRL	USA
Hoffmann, Fabienne	Airbus Defence & Space	Germany
Hoffmann, Folker	Fraunhofer FKIE	Germany
Holderied, Marc	University of Bristol	UK
Jakabosky, John	University of Kansas	USA
Jovanoska, Snezhana	Fraunhofer FKIE	Germany
Katsilieris, Fotios	Fraunhofer FKIE	Germany
Klemm, Richard	Fraunhofer FHR ret.	Germany

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Koch, Wolfgang	Fraunhofer FKIE	Germany
Kohlleppel, Robert	Fraunhofer FHR	Germany
Kulpa, Krzysztof	Warsaw University of Technology	Poland
Kuschel, Heiner	Fraunhofer FHR	Germany
Linderman, Richard	Office of the Secretary of Defense	USA
Lombardo, Pierfrancesco	DIET University of Rome 'La Sapienza'	Italy
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Maslikowski, Lukas	Warsaw University of Technology	Poland
Myakinkov, Alexander	Nishny Novgorod Technical State University	Russia
Monti-Guarnieri, Andrea	DEI POLIMI	Italy
Nadjiasngar, Roaldje	Fraunhofer FKIE	Germany
Nickel, Ulrich	Fraunhofer FHR/FKIE	Germany
Opitz, Felix	Airbus Space & Defence	Germany
Palamà, Riccardo	University College London	UK
Pastina, Debora	DIET University of Rome 'La Sapienza'	Italy
Patton, Lee K.	Matrix Research Inc.	USA
Pauciullo, Antonio	IREA – CNR	Italy
Piezzo, Marco	Università degli studi di Napoli Fed. II	Italy
Ristic, Branko	RMIT University	Australia
Rocca, Fabio	DEI POLIMI	Italy
Rosenberg, Luke	Defence Science and Technology Group	Australia
Schroeder, Alexander	Airbus Defence & Space	Germany
Sen, Satyabrata	Oak Ridge National Laboratory	USA
Sikaneta, Ishuwa	DRDC Ottawa	Canada
Sletten, Mark	NRL	USA
Stove, Andy	Stove Specialities, Sussex	UK
Tebaldini, Stefano	DEI POLIMI	Italy
Thomä, Reiner	Technical University Ilmenau	Germany
Toporkov, Jakov	NRL	USA
Walterscheid, Ingo	Fraunhofer FHR	Germany

List of reviewers

Reviewer	Affiliation	Country
Baumgartner, Stefan	German Aerospace Center DLR	Germany
Bucciarelli, Marta	Sympas S.r.l.	Italy
Charlish, Alexander	Fraunhofer FKIE	Germany
Cristallini, Diego	Fraunhofer FHR	Germany
Damini, Anthony	DRDC Ottawa	Canada
Demissie, Bruno	Fraunhofer FKIE	Germany
Erricolo, Danilo	University of Illinois at Chicago	USA
Fabrizio, Joe	Defence Science and Technology Group	Australia
Farina, Alfonso	Selex-ES ret. and ELETTRONICA S.p.A	Italy
Fornaro, Gianfranco	IREA – CNR	Italy
Geudtner, Dirk	European Space Agency ESA	Netherlands
Gierull, Christoph	DRDC Ottawa	Canada
Gini, Fulvio	University of Pisa	Italy
Govaers, Felix	Fraunhofer FKIE	Germany
Griffiths, Hugh	University College London	UK
Klemm, Richard	Fraunhofer FHR ret.	Germany
Koch, Wolfgang	Fraunhofer FKIE	Germany
Kohlleppel, Robert	Fraunhofer FHR	Germany
Lesturgie, Marc	ONERA	France
Livingstone, Chuck	DRDC Ottawa	Canada
Lombardo, Pierfrancesco	University of Rome La Sapienza	Italy
Mertens, Michael	Elettronica, Meckenheim	Germany
Monti-Guarnieri, Andrea	DEI POLIMI	Italy
Mihaylova, Mila	University of Sheffield	UK
Nickel, Ulrich	Fraunhofer FHR/FKIE	Germany
Pastina, Debora	DIET University of Rome 'La Sapienza'	Italy
Pauciullo, Antonio	IREA – CNR	Italy
Prati, Claudio Maria	Politecnico di Milano	Italy
Rosenberg, Luke	Defence Science and Technology Group	Australia
Savy, Laurent	ONERA DEMR	France
Schlangen, Isabel	Heriot-Watt University	UK
Sikaneta, Ishuwa	DRDC Ottawa	Canada
Sletten, Mark	NRL	USA
Smith, Graeme	The Ohio State University	USA
Soldovieri, Francesco	IREA	Italy

(Continues)

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Reviewer	Affiliation	Country
Ulmke, Martin	Fraunhofer FKIE	Germany
Wiedmann, Michael	Airbus Defence & Space	Germany
Walterscheid, Ingo	Fraunhofer FHR	Germany
Wirth, Wulf-Dieter	Fraunhofer FKIE	Germany
Woodbridge, Karl	University College London	UK