2020 IEEE INTERNATIONAL RADAR CONFERENCE

RADAR 2020

RADAR VISION

Overcoming The Virus

♦ TABLE OF CONTENTS

Page

Contents

♦ INSTRUCTIONS FOR VIRTUAL CONFERENCE

IEEE RADAR 2020 | Virtual Event Information

Virtual Conference Details:

To access the Virtual Sessions, you will click on the Session you wish to attend in the list below

Opening Remarks
PL1: Spectrum Sharing Panel
A1L-A: Target Detection in Non-homogeneous Environments
A1L-B: Passive Radar I
A1L-C: Metacognition & Machine Learning for Radar Spectrum Sharing
A2L-A: Antennas
A2L-B: Advanced Software Defined Radar Implementations on COTS Hardware
A2L-C: Advanced Radar Waveform Design Algorithms
A2L-D: Signatures & RCS
A3L-A: Detection & Estimation I
A3L-B: Emerging Applications of Short-Range Radars
PL3: Machine Learning Panel
PL2: Industry Panel
B1P-D: Waveform & Waveform Diversity II
B1P-E: Classification & Machine Learning for Radar
B1P-F: Multistatic, Imaging & ATR
B2L-A: Continuing Influence of Karl Robert Gerlach, Tributes in Memoriam
B2L-B: Over the Horizon Radar
B2L-C: Spectrum Sharing I
B3L-A: Automotive & Transportation
B3L-B: Passive Radar II
B3L-C: Electronic Warfare
B4L-A: Array Processing
B4L-B: Emerging Techniques & Applications in Passive Radars
B4L-C: Machine Learning for Radar
B4L-D: Harmonic Radar & Its Applications
PL4: Future Ubiquity of FMCW radar chips across multiple application areas (radar-on-a-chip)
C1P-D: Detection & Estimation II
C1P-E: Low-cost, Emerging & mmW Technologies
C1P-F: Antennas & Array Processing
C2L-A: Adaptive Processing
C2L-B: SAR
C2L-C: Spectrum Sharing II
C3L-A: Tracking & Estimation
C3L-B: Multistatic, Networked & Distributed
C3L-C: Waveform & Waveform Diversity I
C3L-D: Quantum Radar: Current Status & Prospects
C4L-A: Medical & Biological Applications

In order to access the Virtual Sessions, you must have a paid registration to RADAR 2020.

- The virtual conference starts on April 27th, and runs for 4 weeks.
- The conference will be a collection of presentations, posters, and exhibitors posted online.

Help Desk Information:

Please direct any questions about access or the Virtual Conference platform to IEEE MCE's Brett Houseal at b.houseal@ieee.org

Please direct any questions about Registration Status to Tara Schrimer at RADARreg@ieee.org

Virtual Conference Sessions:

The above list contains the links to access each Virtual Session room. To enter a Session, simply click on the link and enter the Registration Email used for your Conference Registration. Please note that it must match the email address in your confirmation email or you will be unable to access the Session.

The event will run for 4 weeks, beginning on 27 April 2020, with all sessions being available on-demand. During the entire event, group chat is available in each session for Q&A and general discussion, and please note that the author of each presentation will be live in the session group chat during the time scheduled for their presentation.

During your virtual conference experience, be sure to utilize the engagement widgets within the online platform. The online platform features the ability to communicate with the speakers. The blue message button at the bottom of your screen allows you to submit questions to the presenters. Please ensure you include the paper title or number for which you are referring to in your question. If you are an author in a specified session, please check this group chat every so often to be able to answer any questions asked of you.

Dr. Michael Zatman
United States Government

Dr. Raviraj Advi
Edward S. Rogers Sr. Dept. of Elec. & Comp. Eng.
University of Toronto

General Co-Chairs, 2020 IEEE International Radar Conference

(Pre Covid-19) Welcome to the National Capital Region, Washington DC and its environs. Home to several world class universities, Government and private research laboratories and leading radar suppliers. The area is also rich in radar history. In 1922, Taylor and Young observed that ships in the Potomac River that runs through Washington DC interfered with their communications signals. They suggested that this might be used for detecting ships, and a few years later, aircraft. Almost 100 years later we thank you for coming to join us at the 2020 IEEE International Radar Conference. While maintaining the conference's traditional mixture of lectures, posters and tutorials, in the spirit of Taylor and Young we have tried to innovate by bringing you panel discussions on many subjects of interest, the Radar-A-Thon and sessions on new topics such as low-cost and home-brew radar...

(Current) It is a sign of the unusual times in which we live that we are getting more innovation at this year's conference than we bargained for. Thank you for joining us at the first ever virtual radar conference, and being willing to try a completely new format. In just a few weeks the conference has been transformed from an in-person conference with hundreds of people in a luxurious location with a superb slate of technical sessions, terrific tutorials, excellent exhibits and fantastic food to a virtual conference retaining as much of our original plan as possible. It is with great regret that we had to cancel the tutorials and the summer school. In making such a complete transformation in such a short period of time there are many people we need to thank.

Thank you to the IEEE Meetings, Conferences and Events (MCE) team who put together the infrastructure to host a virtual conference. Without the support of the IEEE MCE team we doubt the virtual conference would have been possible – especially in such a short time frame.

Thank you to the whole conference committee, who, just as we were getting close to the finish line had to adjust everything to the new circumstances. We treated it like a Space-Time Adaptive Processing (STAP) scenario which we had to solve in real-time. First, we broke up the problem into several reduced-dimension sub-spaces. For each (near-orthogonal) aspect we tried to collect enough data to compute an accurate solution, before bringing everything together and producing a result that we think is close to the optimum given the amount of data and resources available. As conference chairs we are proud of the way the committee came together and the amount of effort that went into making the virtual conference a reality.

In addition to the conference committee we especially have to thank Patty Woodard, the event coordinator. With many years of Radar Conference experience, she adapted to the new reality with aplomb. Her efforts are greatly appreciated.

Thank you to the authors, session chairs and exhibitors, who over the past few weeks have had to adapt to the new format for lectures, posters, panels and exhibits. Without their efforts over the past few weeks there would be no content to the conference.

Thank you to our corporate supporters, whose continued generosity has ensured our financial stability in these unstable times. Their continued support for the conference is a vital vote of confidence on our virtual format.

Lastly, thank you to you, all of the conference participants for joining us in this new on-line conference experience. We hope you get as much out of Radar 2020 as you would with a traditional offering – albeit in a new format. We encourage you to explore the functionality offered by the virtual format such as the ability to watch the talks of interest ahead of time, at your own pace, and the ability to interact with authors over an extended period.

What is clear to us is that the field is as vibrant and active as ever. 100 years after Taylor and Young, we see continue to see new theories and new applications for radar. The student paper competition gives us confidence that the next generation of radar engineers will be as determined and as innovative as the generations before them. So, while the format of the Radar Conference has changed, the field – and the conference series will live on – as vibrant as ever.

(5 Years in the Future) Welcome to the Washington DC area for the 2025 IEEE International Radar Conference ...

♦ WELCOME FROM THE TECHNICAL PROGRAM CHAIRS

Alessio Balleri
Cranfield University

Aaron Shackelford
U.S. Naval Research Laboratory

Technical Program Co-Chairs, 2020 IEEE International Radar Conference

Dear Colleagues,

It is a great pleasure for us to welcome you to the 2020 IEEE International Radar Conference, the first Virtual IEEE International Radar Conference!

We have created an exciting technical program which covers many areas related to different aspects of radar. You will find technical sessions on traditional radar topics such as signal processing, SAR, tracking, and waveform design, as well as many sessions focused on new and exciting areas. There are multiple sessions on machine learning applications for radar, passive and distributed concepts and a session on quantum radar. The program includes a number of special invited sessions, including a session in honor of the late Dr. Karl Gerlach.

We received 229 submissions from 27 different countries. Of these, 186 papers were accepted after a rigorous peer-review selection process that involved a Technical Program Committee (TCP) consisting of 245 reviewers. Over 80% of the submitted papers were reviewed by at least 4 reviewers with an overall average of over 4 reviews received per submitted paper. This rigorous review process would have not been possible without the help of the Special Session Chairs and nine selected Program Area Leaders (Shannon Blunt, Fabiola Colone, Antonio De Maio, Mark Govoni, Hugh Griffiths, Braham Himed, Justin Metcalf, Eric Mokole and Dan Sholnik) who helped us assign reviewers and oversee all the reviews amongst 29 technical tracks and 9 Special Sessions. We are profoundly grateful to the Program Area Leaders and the entire TPC for all their help and support!

We have organized daily plenary sessions which include 4 panel discussions with keynote, industry and invited speakers designed to maximize engagement between attendees. The technical program consists of 136 fifteen-minute long lectures, organized in 20 oral sessions and 9 Special Sessions, and 50 five-minute long presentations organized in 6 poster sessions.

The virtual conference format allows for on-going interaction between authors and attendees throughout the duration of the conference. All of the presentations in the technical sessions will be available for viewing from the beginning of the conference on April 27 through May 25. Each session is given its own virtual 'room' and has a chat feature where attendees can interact with the authors. Although the chat will be live for the duration of the conference, authors and session chairs will be logged into their session's chat at the scheduled session time, allowing for direct interaction between presenters and conference attendees.

We have been amazed by the level of encouragement and support we have received by our community during the transition to a virtual conference at a very difficult time for all, and we want to take this opportunity to thank you all: authors, presenters, invited speakers, exhibitors and sponsors!

We wish all of you a great experience at this truly innovative radar conference, and look forward to everyone making the most out of the Q&A sessions, on-demand technical content, and exhibitors' virtual rooms, all of which are designed to maximize engagement, networking and the exchange of research ideas.

With our Kindest Regards,
Aaron K. Shackelford and Alessio Balleri

♦ ORGANIZING COMMITTEE

Michael Zatman
United States Government

Raviraj Adve
Edward S. Rogers Sr. Dept. of Elec. & Comp. Eng.
University of Toronto

General Co-Chairs

Technical Program Co-Chair
Alessio Balleri
Cranfield University

Technical Program Co-Chair
Aaron Shackelford
U.S. Naval Research Laboratory

Finance Chair
Mark Davis, ME Davis Consulting

Student Program Chair
Philip Corbell, AFIT

Publications Co-Chair

Landon Garry, Johns Hopkins Univ. APL

Tutorials Co-Chair

Mike Picciolo, ENSCO

Publicity Chair

Rebecca Harrington, Leidos

Industry Participation Co-Chair

Paul Techau, Northrop Grumman

Publications Co-Chair

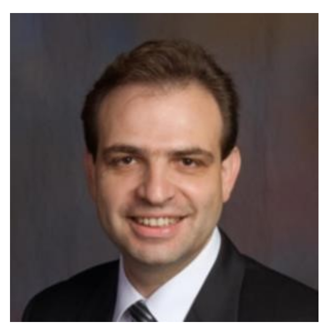
Matt Ritchie, University College London

Tutorials Co-Chair

Alexander Charlis, Fraunhofer Institute

Women In Engineering Chair

Abby Hedden, Army Research Lab



Industry Participation Co-Chair

Igal Bilik, General Motors

International Participation Chair (Europe)

Laura Anitori, Netherlands Organization for Applied Scientific Research

International Participation Chair (Australia)

Luke Rosenberg, Defence Science and Technology Group

Local Arrangements Chair

Ozlem Kilic, Catholic University of America

Event Planner and Exhibits Manager

Patty and Brian Woodard,
Simply the Best Event Planning

International Participation Chair (Asia)

Xiaopeng Yang, Beijing Institute of Technology

International Participation Chair (Africa)

Willie Nel, Council for Scientific and Industrial Research

Social Media Chair

Connor McNaney, U.S. Army Combat Capabilities Development Command


© 2020 Northrop Grumman
It's impossible to see
what others can't.
Until it's not.
NG
NORTHROP GRUMMAN
ngc.com/aesa

♦ AGENDA AT-A-GLANCE

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

Tuesday – April 28, 2020	
0830 – 0845	**Welcome and Opening Remarks**
0845 – 0900	**Tech. Program Overview**
0900 – 1000	**Spectrum Sharing Panel**
1020 – 1200	**Special Session: Target Detection in Non-homogeneous Environments** Session Chairs: Elias Aboutanios / Aboulnasr Hassanien
1020 – 1200	**Passive Radar 1** Session Chairs: Hugh Griffiths / Daniel Ohagan
1020 – 1200	**Special Session: Metacognition & Machine Learning for Radar Spectrum Sharing** Session Chairs: Anthony Martone/Mike Buehrer
1300 – 1440	**Antennas –** Session Chairs: Mark Davis / Krzysztof Kulpa
1300 – 1440	**Special Session: Advanced Software Defined Radar Implementations on COTS Hardware** Session Chairs: Justin Metcalf / Anthony Martone
1300 – 1440	**Special Session: Advanced Radar Waveform Design Algorithms** Session Chairs: Augusto Aubry/Antonio De Maio
1300 – 1440	**Signatures & RCS –** Session Chairs: Simon Watts / Jacques Cilliers
1510 – 1650	**Detection & Estimation I** Session Chairs: Fabiola Colone / Pierfrancesco Lombardo
1510 – 1650	**Special Session: Emerging Applications of Short-Range Radars** Session Chairs: Victor Chen/David Tahmoush
1510 – 1650	**Machine Learning Panel**
Wednesday – April 29, 2020	
0830 – 0920	**Industry Panel**
0920 – 1020	**Poster Session – Waveform & Waveform Diversity II** Session Chairs: Graeme Smith / Kristine Bell
0920 – 1020	**Poster Session – Classification & Machine Learning for Radar** Session Chairs: Vincenzo Carotenuto/ Shobha Sundar Ram
0920 – 1020	**Poster Session – Multistatic, Imaging & ATR –** Session Chairs: Debora Pastina/ Joe Deroba
1020 – 1200	**Special Session: Continuing Influence of Karl Robert Gerlach, Tributes in Memoriam** Session Chairs: Eric Mokole / Shannon Blunt
1020 – 1200	**Over The Horizon Radar** – Session Chairs: Marco Martorella / Aaron Shackelford
1020 – 1200	**Spectrum Sharing I –** Session Chairs: Justin Metcalf / Sahin Cenk

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

Wednesday – April 29, 2020 – Continued

1300 – 1440	**Automotive & Transportation** Session Chairs: Igal Bilik/Alessio Balleri
1300 – 1440	**Passive Radar** Session Chairs: Jonathan Bluestone / Hugh Griffiths
1300 – 1440	**Electronic Warfare** Session Chairs: Lorenzo Lo Monte / Piotr Samczyński
1510 – 1650	**Array Processing –** Session Chairs: Alfonso Farina / Laura Anitori
1510 – 1650	**Special Session: Emerging Techniques & Applications in Passive Radars** Session Chairs: Fabiola Colone / Philipp Wojaczek
1510 – 1650	**Machine Learning for Radar** Session Chairs: Fulvio Gini / Moeness Amin
1510 – 1650	**Special Session: Harmonic Radar & Its Applications** Session Chairs: Bruce Colpitts / Anastasia Lavrenko

Thursday – April 30, 2020

0830 – 0920	**Future Ubiquity of FMCW Radar Chips Across Multiple Application Areas (Radar-on-a-Chip) Panel**
0800 – 0940	**Poster Session – Detection & Estimation II** Session Chairs: Alessio Balleri / Luke Rosenberg
0800 – 0940	**Poster Session – Low-cost, Emerging & mmW Technologies** Session Chairs: Frank Robey / Phillip Corbell
0800 – 0940	**Poster Session – Antennas & Array Processing** Session Chairs: Alex Charlish / Mai Ngo
1020 – 1200	**Adaptive Processing –** Session Chairs: Michael Picciolo / Shannon Blunt
1020 – 1200	**SAR –** Session Chairs: Dan Scholnik / Raghu Raj
1020 – 1200	**Spectrum Sharing II -** Session Chairs: Chris Mountford / Patrick McCormick
1300 – 1440	**Tracking & Estimation –** Session Chairs: Maria Sabrina Greco / David Crouse
1300 – 1440	**Multistatic, Networked & Distributed –** Session Chair: Mark Govoni / Abigail Hedden
1300 – 1440	**Waveform & Waveform Diversity I –** Session Chairs: Aboulnasr Hassanien / Stephen Harman
1300 – 1440	**Special Session: Quantum Radar: Current Status & Prospects** Session Chairs: Ravi Advi / Jérôme Bourassa
1510 – 1650	**Medical & Biological Applications –** Session Chairs: Fauzia Ahmad / Willie Nel
1510 – 1650	**Radar Signature of UAVs –** Session Chairs: Matthew Ritchie / Mohammed Jahangir
1510 – 1650	**Cognitive Radar & Machine Learning** – Session Chairs: Yimin Zhang / Vincenzo Carotenuto
1650 – 1700	**Closing Remarks**

♦ TECHNICAL REVIEW COMMITTEE MEMBERS

The Technical Program Committee wish to thank all of the Review Committee Members for their support

Abdul-Ghani, Kamaruddin
Aboutanios, Elias
Abramovich, Yuri
Ahmad, Fauzia
Aittomaki, Tuomas
Akhtar, Jabran
Alharbi, Hazza
Alhujaili, Khaled
Ali, Murtaza
Al-Khaldi, Mohammad
Allen, Chris
Almutiry, Muhannad
Andre, Dan
Anitori, Laura
Antoniou, Michael
Arlow, Gregory
Aubry, Augusto
Baden, Mike
Baker, Chris
Baldygo, William
Ball, John
Balleri, Alessio
Barrett, John
Bar-Shalom, Yaakov
Baxter, William
Bekers, Dave
Bell, Kristine
Bidon, Stephanie
Bilik, Igal
Bing, Kristin
Blair, William
Blasone, Giampaolo
Blunt, Shannon
Bodine, David
Bok, Dominik
Bongioanni, Carlo
Bourassa, Jerome
Bouzerdoum, Salim
Brooker, Graham
Brueggenwirth, Stefan
Callahan, Michael
Cammerata, Jeff
Cao, Siyang
Cao, Tan
Capria, Amerigo
Carotenuto, Vincenzo
Celik, Turgay
Chapin, Elaine
Charlish, Alexander
Chen, Victor
Chen, Zezong
Cherniakov, Mike
Chetty, Kevin
Cifola, Lorenzo
Ciuonzo, Domenico
Clemente, Carmine
Colone, Fabiola
Colpitts, Bruce
Coraluppi, Stefano
Corbell, Phillip
Cordill, Brian
Correll Jr, Bill
Coutts, Scott
Cox, Pepijn
Cristallini, Diego
Davis, Mark
De Maio, Antonio
de Wit, Jacco
Deroba, Joseph
Doerry, Armin
Duly, Andrew
Ertin, Emre
Farina, Alfonso
Farr, Patrick
Feng, Xiang
Fenn, Alan
Fertig, Louis
Filippini, Francesca
Fioranelli, Francesco
Foglia, Goffredo
Foreman, Terry
Frasca, Marco
Frazer, Gordon
Fritz, Jason
Frölind, Per-Olov
Fuchs, Jonas
Furgala, Brian
Garmatyuk, Dmitriy
Garnham, John
Geng, Zhe
Gierull, Christoph
Gini, Fulvio
Goodman, Nathan
Govoni, Mark
Greco, Maria Sabrina
Gurbuz, Sevgi
Hack, Dan
Harman, Stephen
Hassanien, Aboulnasr
Hayward, Steve
Hedden, Abigail
Helmy, Amr
Hennessy, Brendan
Himed, Braham
Huang, Yulin
Ikram, Muhammad
Inggs, Michael
Isereau, Darrek
Ivanov, Tony
Jackson, Julie
Jacobs, Bas
Jahangir, Mohammed
Jarabo, Pilar
Johnson, Joel
Jones, Aaron
Jost, Randy
Kadlimatti, Ravi
Karbasi, Mohammad
Kastle, Todd
Kemkemian, Stephane
Khenchaf, Ali
Kirstetter, Pierre
Knödler, Benjamin

Kong, Gyuyeol
Kota, John
Kulpa, Krzysztof
Kurdzo, Jim
La Manna, Marco
La Manna, Mario
Lanzagorta, Marco
Laroussi, Toufik
Lavrenko, Anastasia
Le Kernec, Julien
Leifer, Mark
Leus, Geert
Li, Hongbin
Li, Zhe
Liu, Jun
Lombardo, Pierfrancesco
Lulu, Amro
Luong, David
Ma, Chao
Maffei, Marco
Malanowski, Mateusz
Maresca, Salvatore
Martelli, Tatiana
Martone, Anthony
Martorella, Marco
Mason, Eric
Mazzaro, Gregory
McCormick, Patrick
McDaniel, Jay
Melvin, William
Metcalf, Justin
Miceli, William
Mishra, Kumar Vijay
Mohr, Charles
Mokole, Eric
Money, David
Moss, Bryant
Mower, John
Moyer, Lee
Munoz-Ferreras, Jose-Maria
Narayanan, Ram
Nel, Willie
Ng, Brian
Ngo, Mai
Nickisch, L.J.
Nosrati, Hamed
O’donoughue, Nicholas
Osadciw, Lisa
Owen, Jonathan
Pallotta, Luca
Palmer, Robert
Pastina, Debora
Picciolo, Michael
Pidanic, Jan
Pillai, Unni
Piou, Jean E.
Potgieter, Monique
Poullin, Dominique
Rahman, Samiur
Ram, Shobha
Ravenscroft, Brandon
Ren, Jiaying
Riddolls, Ryan
Rigling, Brian
Ritchie, Matthew
Robey, Frank
Romero, Ric
Rosenberg, Luke
Ruggiano, Mayazzurra
Sahin, Cenk
Samczynski, Piotr
Sangston, James
Santi, Fabrizio
Santori, Agnes
Scholnik, Dan
Schupbach, Christof
Setlur, Pawan
Sherbondy, Kelly
Singh, Ajay
Smith, Charles
Stevens, Daniel
Stevens, Malcolm
Stiles, Jim
Stove, Andy
Stralka, John
Striano, Pasquale
Sun, Guohao
Sun, Hongbo
Tahmoush, David
Tan, Peng Seng
Thomas, Daniel
Timmoneri, Luca
Tivive, Fok Hing Chi
Tomei, Sonia
Uysal, Faruk
van Den Berg, Simon
van Rossum, Wim
Vehmas, Risto
Vela, Russell
Volkov, Vadym
Wagner, Simon
Wang, Xiangrong
Watts, Simon
Weiß, Matthias
Williams, John
Wojaczek, Philipp
Wong, Malcolm
Woodbridge, Karl
Yang, Qiang
Yeary, Mark
Yi, Jianxin
Yoon, Yeo-Sun
Young, Robert
Yu, Xianxiang
Yu, Xuelian
Zak, Jan
Zaugg, Evan
Zhang, Renyuan
Zhang, Xin
Zhang, Yimin
Zhang, Yuhong
Zhu, Zhenghan

♦ SESSION CHAIRS

The Technical Committee Chairs wish to thank all of the Session Chairs for their support

Elias Aboutanios
Ravi Advi
Fauzia Ahmad
Moeness Amin
Laura Anitori
Augusto Aubry
Alessio Balleri
Kristine Bell
Igal Bilik
Jonathan Bluestone
Shannon Blunt
Jérôme Bourassa
Mike Buehrer
Vincenzo Carotenuto
Sahin Cenk
Alex Charlish
Victor Chen
Jacques Cilliers
Fabiola Colone
Bruce Colpitts
Phillip Corbell
David Crouse
Mark Davis
Antonio De Maio
Joe Deroba
Alfonso Farina
Fulvio Gini
Mark Govoni
Maria Sabrina Greco
Hugh Griffiths
Stephen Harman
Aboulnasr Hassanien
Abigail Hedden
Mohammed Jahangir
Krzysztof Kulpa
Anastasia Lavrenko
Lorenzo Lo Monte
Pierfrancesco Lombardo
Anthony Martone
Marco Martorella
Patrick McCormick
Justin Metcalf
Eric Mokole
Chris Mountford
Willie Nel
Mai Ngo
Daniel Ohagan
Debora Pastina
Michael Picciolo
Raghu Raj
Matthew Ritchie
Frank Robey
Luke Rosenberg
Piotr Samczyński
Dan Scholnik
Aaron Shackelford
Graeme Smith
Shobha Sundar Ram
David Tahmoush
Simon Watts
Philipp Wojaczek
Yimin Zhang

♦ RADAR SYSTEMS PANEL

Fauzia Ahmad, *USA*
Laura Anitori, *USA*
Kristine Bell*, USA*
Stéphanie Bidon, *France*
Dan Bliss, *USA*
Shannon Blunt, *USA*
Alexander Charlish, *Germany*
Fabiola Colone, *Italy*
William Correll, *USA*
James Day, *USA*
Joe Fabrizio, *Australia*
Alfonso Farina, *Italy*
Fulvio Gini, *Italy*
Nathan Goodman, *USA*
Martie Goulding, *Canada*
Maria Sabrina Greco, *Italy*
Hugh Griffiths, *UK*
Joseph Guerci, *USA*
Braham Himed, *USA*
Julie Jackson, *USA*
Peter Knott, *Germany*
Visa Koivunen, *Finland*
Krzysztof Kulpa, *Poland*
Anthony Martone, *USA*
Marco Martorella, *Italy*
Bill Melvin, *USA*
Eric Mokole, *USA*
Willie Nel, *South Africa*
Karl Erik Olsen*, Norway*
Jennifer Palmer, *USA*
Michael Picciolo, *USA*
Dan Rabideau, *USA*
Frank Robey, *USA*
Luke Rosenberg, *Australia*
Stéphane Saillant, *France*
K. James Sangston, *USA*
Graeme Smith, USA
John Stralka, *USA*
Lars Ulander, *Sweden*
Jennifer Watson, *USA*
Xiaopeng Yang, *China*
Mark Yeary, *USA*

Emeritus Members:
William (Dale) Blair, *USA*
Eli Brookner, *USA*
Joseph Bruder, *USA*
Gerald Crain, *UK*
Mark Davis, *USA*
Charles Gager, *USA*
Marshall Greenspan, *USA*
John Milan, *USA*
Tom Miller, *USA*
Jim Scheer, *USA*
John Smith, *USA*

Moderator: Michael Zatman

The Radio Frequency Spectrum is coming under increasing pressure, with the biggest demand coming from the commercial telecommunications industry. Over the past few years several bands have be reallocated from radar to other purposes – either on a primary basis or a secondary basis. The commercial telecommunications industry has publicized the economic gains it believes would accrue from additional spectrum allocation. A key question for the future of radar in this environment is how well can radar and cellular communications systems share spectrum? The panelists will discuss both the policy and technical challenges that need to be overcome to make radar-communications spectrum sharing a reality that benefits both communities.

Panelists:

Fred Moorefield, The Deputy Chief Information Officer of the Department of Defense Mr. Moorefield is the Acting Deputy Chief Information Officer for Command, Control, Communications and Computers and Information Infrastructure Capabilities (C4IIC), Office of the Secretary of Defense, Chief Information Officer. As Acting DCIO, Mr. Moorefield provides technical expertise and broad guidance on policy, programmatic and technical issues relating to C4IIC to integrate and synchronize defense-wide communications and infrastructure programs. He also advises on efforts to achieve and maintain information dominance for the Department of Defense. He manages efforts defining DoD policies and strategies for design, architecture, interoperability standards, capability development and sustainment of critical command and control and communications for nuclear and non-nuclear strategic strike, integrated missile defense, Defense and National Leadership Command Capabilities, and spectrum.

Mr. Moorefield joined Federal service in 1989 in the Air Force as a civil servant, where he served for 19 years doing Research and Development and Acquisition at Wright Patterson Air Force Base Air Force Research Labs. He also served in the Defense Information Systems Agency at the Joint Spectrum Center for four years. He has been a member of the Senior Executive Corps since 2012. His education includes a Bachelor degree in mathematics from Wilberforce University, located in Wilberforce Ohio and a Bachelor and Master of Electrical Engineering degree from the University of Dayton in Dayton Ohio.

Joseph Evans, Technical Director for 5G, Office of the Secretary of Defense for Research & Engineering. Dr. Joseph B. Evans is the inaugural Technical Director for 5G. Dr. Evans is responsible for coordinating 5G efforts across the Department of Defense, oversees and directs the Department's "5G to Next G" research and development portfolio, and advises the Under Secretary of Defense for Research and Engineering on 5G-related topics.

Dr. Evans served as a Program Manager in the DARPA Strategic Technology Office from 2015 to 2019. While there, he started the SHARE (Secure Handhelds on Assured Resilient networks at the tactical Edge) and GCA (Geospatial Cloud Analytics) programs, and managed the Mobile Hotspots, RadioMap, SSPARC (Shared Spectrum Access for Radar and Communications), CommEx (Communications Under Extreme RF Spectrum Conditions), WND (Wireless Network Defense), and DyNAMO (Dynamic Network Adaptation for Mission Optimization) programs.

From 1989 to 2019, Dr. Evans was a professor at the University of Kansas (KU) in Lawrence, Kansas, where his ultimate position was the Deane E. Ackers Distinguished Professor of Electrical Engineering & Computer Science. At KU, he also served in various administrative posts and led funded research programs in the areas of adaptive networking and communications systems, high speed network testbeds, rapidly deployable broadband wireless systems, and spectrum sharing technologies. Dr. Evans served as a Program Director in the Division of Computer and Network Systems, Directorate of Computer & Information Science & Engineering (CISE) at the National Science Foundation (NSF) from 2003 to 2005. At NSF, he was responsible for multi-organizational networking research efforts in wireless networking, cybersecurity, optical networking, and scientific applications. Dr. Evans received the B.S.E.E. degree from Lafayette College in 1983, and the M.S.E., M.A., and Ph.D. degrees from Princeton University in 1984, 1986, and 1989, respectively. He is an IEEE Fellow.

Charles Cooper, Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administration (NTIA), United States Department of Commerce

Charles Cooper is Associate Administrator in NTIA's Office of Spectrum Management. He leads the agency's work on national and international spectrum policy issues, and oversees spectrum management efforts for federal agencies. He is responsible for frequency assignment and certification, and other strategic planning functions including development of innovation approaches to spectrum sharing.

Before joining NTIA in July, 2019, Cooper was the Enforcement Bureau Field Director at the Federal Communications Commission (FCC) where he managed the nationwide enforcement of spectrum interference affecting public safety communications, FCC licensees and Federal agencies. Prior to serving as Field Director, Cooper was District Director of the FCC's Los Angeles Field Office. Cooper also served as senior engineer and partner with du Treil, Lundin, and Rackley, Inc., an engineering firm specializing in radio frequency coordination and design. Cooper is a recognized subject matter expert on engineering principles applicable to a wide mix of communications technologies. He is a member and two-term past president of the Association of Federal Communications Consulting Engineers (AFCCE).

♦ PANEL SESSION – MACHINE LEARNING PANEL

Moderators: Sevgi Zubeyde Gurbuz and Eric Mason

Deep learning has garnered great interest in the radar community over the past decade; however, the unique phenomenology of radar data has presented challenges to its application in radar signal processing, and makes leveraging results from other fields, such as computer vision or natural language processing, challenging at best.

The application of deep learning to radar datasets is thus an interdisciplinary field, lying in the intersection of electromagnetics, signal processing, and computer science. As a result, experts contributing to this area approach the topic with different perspectives, conditioned by their expertise. This has led to a question of how to incorporate the conventional wisdom of radar engineering with the heuristic, data-driven perspective taken in computer vision.

During this panel, challenges and nuances relating to the art of deep learning of radar signals will be discussed.

Panelists:

Dr. Sevgi Z. Gurbuz [Co-Moderator] – Dr. Gurbuz is an Assistant Professor of Electrical and Computer Engineering at the University of Alabama. Her research is focused on radar understanding of human motion, including dismount detection, micro-Doppler analysis, and motion classification with machine learning and deep learning.

Dr. Eric Mason [Co-Moderator] – Dr. Mason is a researcher in the Tactical Electronic Warfare Division at the Naval Research Laboratory, Washington, DC. His research has focused on various problems in radar signal processing, spanning from detection/imaging methods for passive synthetic aperture radar to developing novel approaches based on incorporating modeling and machine learning methods for autonomous understanding of the electromagnetic spectrum.

Dr. Benjamin Migliori – Dr. Migliori is a scientist in the Applied Computer Sciences Division of Los Alamos National Laboratory, CA. His expertise lies in the application of machine learning and neuromorphic computing to RF and acoustic signal processing for applications to national security.

Dr. Simon Wagner – Dr. Wagner is a researcher in the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany. His expertise lies in the application of machine learning to synthetic aperture radar.

Dr. Theresa Scarnati – Dr. Scarnati is an Applied Mathematician in the Air Force Research Laboratory, Dayton, OH. Her expertise lies in the application of deep learning to automatic target recognition with SAR imagery, three-dimensional image reconstruction, multi-sensor information fusion, and exploitation of sparsity and prior knowledge in inverse problems.

Dr. George Stantchev – Dr. Stantchev is an Applied Mathematician in the Naval Research Laboratory, Washington DC. His expertise lies in the application of machine learning to RF emitter identification networking.

Moderator: Paul Techau, System Architect, Northrop Grumman Corp

A discussion of future technology trends in radar and what those trends will mean for the skill sets needed/desired by the radar industry in the future. This conversation is meant to be as inclusive as possible, spanning front-end hardware, to advanced signal processing (hardware and algorithms), through back end data processing including data fusion and exploitation.

Dr. Eric Reinke is the vice president, Strategy and Program Development, for the Airborne Sensors and Networks Division, part of Northrop Grumman's Mission Systems Sector. In this role, Dr. Reinke is responsible for the alignment and coordination of the division's strategy, investment and growth opportunities. Dr. Reinke has over 30 years of scientific and technical experience in sensors, signal processing and advanced systems architectures. He has extensive technical leadership experience in distributed systems, multi-domain family of systems integration, integrated air and missile defense, undersea systems and remote sensing. Dr. Reinke holds a Ph.D. in electrical engineering from Stanford University, a master's degree in electrical engineering from the Naval Postgraduate School and a bachelor's degree in electrical engineering from the U.S. Naval Academy. He is a member of Eta Kappa Nu, Sigma Xi, Tau Beta Pi and the Institute of Electrical and Electronics Engineers (IEEE)

Dave Fittz is the Raytheon Intelligence and Space Technical Director. He is a Senior Principal Engineering Fellow and has done research in advanced receiver/exciter development, advanced power supplies and power distribution as well as advance radar system development, integration and verification for over 40 years. Dave was awarded the IEEE Warren D White award in 2008 for his work in advancing Surveillance Radar Technologies. He is an independent reviewer for multiple programs across several business areas within Raytheon Technologies. Dave received his BSEE from Cal Poly and his MS in Systems Engineering from Texas Tech.

Steve Kogon is a Senior Vice President at Systems & Technology Research (STR) where he leads the Sensors Division performing research and development for next generation radar and electronic warfare systems. His research interests include digital arrays, signal processing, adaptive beamforming, detection and estimation, optimization and space-time adaptive processing (STAP). He has over 30 years' experience in the radar field having previously been with Raytheon, Georgia Tech Research Institute and MIT Lincoln Laboratory. Steve received his BS from Rensselaer Polytechnic Institute, MS from Worcester Polytechnic Institute and PhD from Georgia Tech.

Jonathon Bluestone is the Programme Manager for BAE Systems Maritime Services for the SAMPSON Radar, the primary sensor fitted to the UK Royal Navy's Type-45 Destroyers. In this role, Jonathon is responsible for overseeing the in-service support, and driving through-life capability development to ensure that SAMPSON remains at the forefront of world capabilities and will meet future requirements. Jonathon has over 25 years of management experience in research and development programmes including project managing the MESAR2 Technology Demonstrator Radar and the UK-U.S. collaborative 'ARTIST' programme, which culminated in joint trials in 2010/11 at SCSC Wallops Island, VA. Jonathon holds an Honours Degree in Electronic and Communications Engineering from the Polytechnic of North London, and is a member of the UK Institution of Engineering and Technology.

♦ PANEL SESSION – FUTURE UBIQUITY OF FMCW RADAR CHIPS ACROSS MULTIPLE APPLICATION AREAS (RADAR-ON-A-CHIP)

Moderator: Igal Bilik

The Panel will discuss the past, present, and future of low power frequency modulated continuous wave (FMCW) radar 'chips'. The discussion will center on current technical capabilities and future innovation trends, on applications in civil, commercial, and even military use, and on top level issues with mass proliferation such as industry coordination and Government spectrum planning and regulation.

Invited Panelists:

Ritesh Tyagi, Head of Infineon's Automotive Innovation Center, Milpitas, CA/US

Mark Steigemann, Chief Architect & Manager Product Architecture Radio Frequency Processing, NXP, Germany

Rentala Vijay, Texas Instrument, Engineering Manager mmWave products, US

Igal Bilik, General Motors, Advanced Technical Center, Israel

♦ IEEE INTERNATIONAL RADAR CONFERENCE 2020 SUPPORTERS

The Organizing Committee wishes to thank all of the generous supporters who helped make this virtual event possible.

PLATINUM CORPORATE SUPPORTERS

SILVER CORPORATE SUPPORTERS

BRONZE CORPORATE SUPPORTERS

♦ LIST OF EXHIBITORS

The Organizing Committee wishes to thank our Exhibitors for their support

Advanced Test Equipment

AESS

Ancortek

Artech House

HXI

IEEE Press & Wiley

Johns Hopkins University APL

Mathworks

Northrop Grumman

SamTech

♦ EXHIBITOR VIRTUAL ONLINE RAFFLE

We are pleased to announce that we will be doing a form of our yearly exhibitor bingo! To be eligible for prizes, you must sign-in with your name and email at each of the 10 exhibitor sessions (linked to the list above) and interact/view at least one file (or group chat). Everyone who signs in at all 10 of our exhibitors will be put into the drawing for prizes which will be mailed to you at the end of the event!

Prizes include: (*The organizers of the 2020 IEEE International Radar Conference wish to express their thanks to the generosity shown by our exhibitors in donating the prizes below!)*

- One Year Subscription to RFView Software, courtesy of ISL (over $10,000 value!) (http://www.islinc.com/products/#rfview_product)
- $100 Visa Gift Cards from 2020 IEEE International Radar Conference (5 winners of this prize)
- $250 Voucher for Wiley/IEEE Press Books (courtesy of Wiley/IEEE Press)
- $100 Visa Gift Card – courtesy of Samtec, Inc.
- Company Swag – courtesy of Johns Hopkins University Applied Physics Laboratory
- Swag package (T-shirt, MathWorks Membrane Stickers, a cinch backpack, and either Playing Cards or a Rubik's Cube) – donated by MathWorks (Winner of this prize will be contacted for T-shirt size.)
- Book of Choice – courtesy of Artech House.

♦ ROBERT T. HILL AWARD – DR. PHILIPP WOJACZEK

The Robert T. Hill Best Dissertation Award is an annual AESS award to recognize candidates that have recently received a Ph.D. degree and have written an outstanding Ph.D. dissertation in the field of interest of the Aerospace and Electronic Systems Society. Its purpose is to grant international recognition for the most outstanding Ph.D. dissertation by an AESS member.

The 2019 Robert T. Hill Award for most outstanding dissertation by an AESS member is presented to Dr. Philipp Wojaczek for his thesis "In recognition of the Ph.D. dissertation Passive Radar on Moving Platforms Exploiting DVB-T Transmitters of Opportunity."

♦ HARRY ROWE MIMNO AWARD

Established in 1979, this award is to recognize and foster excellence in clear communications of technical material of widespread interest to AESS members, and in doing so, to honor the contributions of AES Transactions Editor-in-Chief Emeritus Dr. Harry Rowe Mimno to the AESS and IEEE for over 50 years. The award is to the author of a paper which is primarily tutorial (including surveys), speculative, or which advocates new ideas or principles tending to promote debate. It is selected from among those published in the IEEE Aerospace & Electronic Systems Magazine. Prior to 1987, the Mimno Award was made for contributions to IEEE Transactions on Aerospace and Electronic Systems.

The 2018 Harry Rowe Mimno Award recipients are Hassan Shraim, Ali Awada, Rafic Younes

For the AES "Systems" Magazine Best Paper of 2018: "A survey on quadrotors: Configurations, modeling and identification, control, collision avoidance, fault diagnosis and tolerant control.

♦ WARREN D. WHITE AWARD – DR. SIMON WATTS

The Warren D. White Award for Excellence in Radar Engineering was established in 1999, by the family of Warren White, to recognize a radar engineer for the achievement of a major technical advance, or a series of advances over time, in the art of radar engineering.

The 2020 Warren D. White award is presented to Dr. Simon Watts, *"For contributions to airborne maritime surveillance radar design and the modelling of radar sea clutter."*

♦ NATHANSON MEMORIAL RADAR AWARD – MATEUSZ MALANOWSKI

The Nathanson Memorial Radar Award is an annual award, in honor of the late Fred Nathanson, sponsored by the IEEE/AES Radar Systems Panel of the Aerospace and Electronic Systems Society. The purpose of this award is to grant international recognition for outstanding contributions to the radar art by young IEEE/AESS members. The goals of the Radar Systems Panel in granting this award are to encourage individual effort and to foster increased participation by developing radar engineers.

The 2020 Fred Nathanson Memorial Radar Award to the Young Engineer of the Year is presented to Mateusz Malanowski *"For pioneering research in long-range passive radar sensing, in particular the analysis and synthesis of novel detection and tracking methods."*

♦ AESS CHAPTER OF THE YEAR AWARD

The AESS Chapter of the Year award is given to the AESS Chapter whose performance is particularly noteworthy during the prior year. The Chapter receives a certificate from AESS.

2019 Best Chapter of the Year Award

Columbia Section Chapter, AES10
Chapter Chair: Giovanna Ramirez Ruiz

♦ OUTSTANDING ORGANIZATIONAL LEADERSHIP

The Outstanding organizational leadership award, established in 2007, is to recognize candidates that have the unique capability of conceiving and organizing innovative and successful events in the field of interest of the IEEE Aerospace and Electronic Systems Society (AESS).

The Outstanding Organizational Leadership award recipient is Pasquale Daponte *"For contributions to metrology for aerospace applications."*

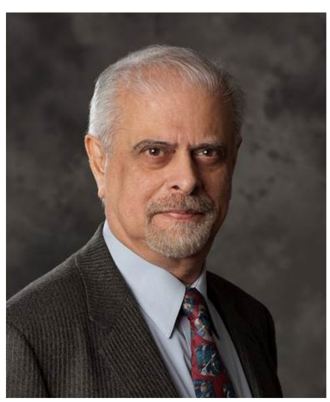
♦ 2020 EXCEPTIONAL SERVICE AWARD

The 2020 Exceptional Service Award is presented to Domenico Ciuonzo *"For outstanding service as an Associate and Technical Editor for IEEE Transactions on Aerospace and Electronic Systems."*

♦ 2019 PIONEER AWARD

The Pioneer Award has been given annually since 1949 to an individual or team for "contributions significant to bringing into being systems that are still in existence today." These systems fall within the specific areas of interest to the society, that is, electronic or aerospace systems. The contributions for which the award is bestowed are to have been made at least twenty (20) years prior to the year of the award, to ensure proper historical perspective. It is not a condition that any awardees should have been sole or original inventor or developer, "significant contribution" of a specific nature is the key criterion.

The 2019 Pioneer Award is presented to Azad M. Madni *"For contributions to advanced simulation-based training and intelligent decision aiding for aerospace systems."*



♦ M. BARRY CARLTON AWARD

The M. Barry Carlton Award acknowledges what is judged the best paper in the AES Transactions in each calendar year. In 1957, a year after his death in an air accident, M. Barry Carlton's friends established the award as a means to honor a man who had dedicated much of his life to promoting the reliability of communications equipment, especially that relating to air transportation. It is one of the IEEE's oldest awards and supports a wonderful tradition of excellence.

The 2020 M. Barry Carlton award goes to Jason Williams for his paper entitled, *"Marginal Multi-Bernoulli Filters: RFS Derivation of MHT, JIPDA, and Association-Based MeMBer."*

♦ AESS OUTSTANDING PANEL OF THE YEAR AWARD

Avionics Systems Panel

Chair: Aloke Roy

♦ AESS INDUSTRIAL INNOVATION AWARD

The 2020 IEEE AESS Industrial Innovation Award recipient is Asad M. Madni, *"For seminal contributions in advanced inertial guidance and their successful transition to defense and commercial applications."*

♦ AESS JUDITH A. RESNIK SPACE AWARD

The 2019 IEEE AESS Judith A. Resnik Space Award recipient is Margaret H. Hamilton *"For leading the successful development of the Apollo Guidance, Navigation & Control (GN&C) system software and helping to create the field of software engineering."*

♦ IEEE FELLOWS – AESS CLASS OF 2020

The IEEE Grade of Fellow is conferred by the Board of Directors upon a person with an extraordinary record of accomplishments in any of the IEEE fields of interest. The total number selected in any one year does not exceed one-tenth of one percent of the total voting Institution membership. Each new Fellow receives a beautifully matted and framed certificate with the name of the Fellow and a brief citation describing the accomplishment, a congratulatory letter from the incoming IEEE president and a gold sterling silver Fellow lapel pin with antique finish.

Congratulations to the 2020 AESS Class of IEEE Fellows:

Christ Richmond – *"For contributions to adaptive array processing algorithms."*

Daniel Rabideau – *"For contributions to radar architectures and technologies."*

Jeff Krolik – *"For contributions to statistical signal and sensor array processing for radar and sonar."*

Marco Martorella – *"For contributions to multi-static inverse synthetic aperture radars."*

The organizing expresses their thanks to Raytheon for supporting our conference at the Platinum level!

Raytheon

♦ STUDENT PAPER FINALISTS

Paper ID 4043 – Multi-Feature Encoder for Radar-Based Gesture Recognition
Student Author: Yuliang Sun (Ruhr-University Bochum, Germany)

Paper ID 4102 – Micro-Doppler Signatures of Dynamic Humans from Around the Corner Radar
Student Author: Shelly Vishwakarma (Indraprastha Institute of Information Technology, India)

Paper ID 4119 – Enhanced Hand Gesture Recognition Using Continuous Wave Interferometric Radar
Student Author: Huaiyuan Liang (Beihang University, China)

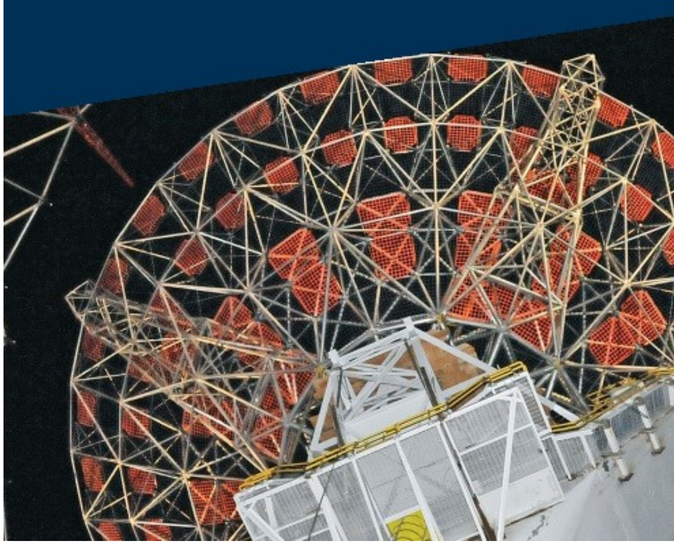
Paper ID 4141 – Structure-Based Adaptive Radar Processing for Joint Clutter Cancellation and Moving Target Estimation
Student Author: Christian C. Jones (University of Kansas, USA)

Paper ID 4181 – Facing Channel Calibration Issues Affecting Passive Radar DPCA and STAP for GMTI
Student Author: Giovanni Paolo Blasone (Sapienza University of Rome, Italy)

First Alternate:
Paper ID 4113 – An Initial Investigation Into Using Convolutional Neural Networks for Classification of Drones
Student Author: Holly Dale (University of Birmingham, UK)

Second Alternate:
Paper ID 4104 – Multichannel Coprime SAR/GMTI (CopGMTI)
Student Author: Abdulmalik Aldharrab (University of Edinburgh, UK)

The organizing committee wishes to thank Artech House for providing a book of choice to the top three winners of this year's student paper competition.



♦ AGENDA

TUESDAY – April 28, 2020		
All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th. *Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.*		
0830 – 0845	**Welcome and Opening Remarks**	
0845 – 0900	**Tech. Program Overview**	
0900 – 1000	**Spectrum Sharing Panel**	
1020 – 1200	**Special Session: Target Detection in Non-homogeneous Environments** Session Chairs: Elias Aboutanios / Aboulnasr Hassanien	
	ID	Title and *Authors*
	4219	HISAR-300: an Advanced Airborne Multi-Mission Surveillance Radar *Malcolm Hoe Kin Wong, Elias Aboutanios, Luke Rosenberg*
	4134	A Cognitive Architecture for Space Time Adaptive Processing *Samuele Gelli, Marco Martorella*
	4075	Detection Performance of Distributed MIMO Radar with Asynchronous Propagation and Timing/Phase Errors *Fangzhou Wang, Cengcang Zeng, Hongbin Li, Mark Govoni*
	4064	Practical Detection Using Sparse Signal Separation *Luke Rosenberg, Vichet Duk, Brian Ng*
1020 – 1200	**Passive Radar 1** Session Chairs: Hugh Griffiths / Daniel Ohagan	
	4042	Range Compression Strategies for Passive Radar on Airborne Platforms *Philipp Wojaczek, Diego Cristallini, Ingo Walterscheid, Daniel O'Hagan*
	4181	Facing Channel Calibration Issues Affecting Passive Radar DPCA and STAP for GMTI *Giovanni Paolo Blasone, Fabiola Colone, Pierfrancesco Lombardo*
	4161	Detecting Drones and Human Beings w/DVB-S Based COTS Passive Radar for Short-Range Surv. *Octavio Cabrera, Carlo Bongioanni, Francesca Filippini, Olena Sarabakha, Fabiola Colone, Pierfrancesco Lombardo*
	4096	Off-Grid Compressed Sensing for Radars with Unknown Transmit Waveform *Sudarshan Guruacharya, Batu Chalise, Braham Himed*
	4101	Beamforming and Tracking Assessment with Passive Radar Experimental Data *Tri-Tan Cao, Tuyet Vu, Marion Byrne, Nabaraj Dahal, Paul Berry, Ayobami Iji, Daniel Gustainis, Martin Ummenhofer, Michael Kohler*

Tuesday April 28, 2020 – Continued		
All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th. Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.		
1020 – 1200	**Special Session: Metacognition & Machine Learning for Radar Spectrum Sharing** Session Chairs: Anthony Martone/Mike Buehrer	
	4058	Metacognition for Radar Coexistence *Anthony Martone, Kelly Sherbondy, Jacob Kovarskiy, Benjamin Kirk, Charles Thornton, J. Owen, B. Ravenscroft, A. Egbert, A. Goad, A. Dockendorf, M. Buehrer, R. Narayanan, S. Blunt, C. Baylis*
	4061	Spectral Prediction and Notching of RF Emitters for Cognitive Radar Coexistence *Jacob Kovarskiy, Jonathan Owen, Ram Narayanan, Shannon Blunt, A. Martone, K. Sherbondy*
	4073	Experimental Analysis of Reinforcement Learning Techniques for Spectrum Sharing Radar *Charles Thornton, Michael Buehrer, Anthony Martone, Kelly Sherbondy*
	4175	Optimizing Transmitter Amplifier Load Impedance for Tuning Performance in a Metacognition-Guided, Spectrum Sharing Radar – *Adam Goad, Austin Egbert, Angelique Dockendorf, Charles Baylis, Anthony Martone, Robert Marks II*
	4192	Toward Metacognitive Radars: Concept and Applications *Kumar Vijay Mishra, Bhavani Shankar M. R., Björn Ottersten*
1300 – 1440	**Antennas –** Session Chairs: Mark Davis / Krzysztof Kulpa	
	ID	Title and *Authors*
	4115	Circularly Polarized Fabry Perot Cavity Antennas w/Peripheral Roughness in Superstrate Unit Cells – *Sagar Jain, Shobha Sundar Ram*
	4233	GaN Based Wide Band C-Band Active Phased Array Antenna Design with Wide Scan Volume *Ashutosh Kedar, Srinivas Rao D., Amit Bisht, Naveen Vishwakarma, Sreenivasulu K.*
	4186	Fast Switched-Stub Impedance Tuner Reconfiguration for Frequency and Beam Agile Radar and Electronic Warfare Applications *Caleb Calabrese, Angelique Dockendorf, Austin Egbert, Brandon Herrera, C. Baylis, R. Marks II*
	4039	Channel Cancellation Ratio in Highly Digital Direct RF Sampling Array Architectures *Gary Boardley, Paul Techau*
	4037	Hardware and Processing Architecture Impacts on Adaptive Beamforming in Digital Phased Arrays – *Paul Techau, Gary Boardley*
1300 – 1440	**Special Session: Advanced Software Defined Radar Implementations on COTS Hardware** Session Chairs: Justin Metcalf / Anthony Martone	
	4015	Zero-Order Reconstruction Optimization of Waveforms (ZOROW) for Modest DAC Rates *Charles Mohr, Jonathan Owen, Shannon Blunt, Christopher Allen*
	4045	Performance Analysis of Pulse-Agile SDRadar with Hardware Accelerated Processing *Benjamin Kirk, Anthony Martone, Kelly Sherbondy, Ram Narayanan*
	4172	Demonstration of Real-Time Cognitive Radar Using Spectrally-Notched Random FM Waveforms *Jonathan Owen, Charles Mohr, Benjamin Kirk, Shannon Blunt, Anthony Martone, K. Sherbondy*
	4185	Characterizing the Impact of IQ Imbalance and DC Bias on Pulse-Agile Radar Processing *Justin Metcalf, Shane Flandermeyer, Charles Mohr, Andrew Kordik, Patrick McCormick, C. Sahin*
	4189	Impedance Tuning with Notched Waveforms for Spectrum Sharing in Cognitive Radar *Angelique Dockendorf, Austin Egbert, Adam Goad, Caleb Calabrese, Benjamin Adkins, Brandon Ravenscroft, Jonathan Owen, Charles Baylis, Shannon Blunt, Anthony Martone, Robert Marks II*

Tuesday April 28, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

1300 – 1440		**Special Session: Advanced Radar Waveform Design Algorithms** Session Chairs: Augusto Aubry/Antonio De Maio
	4047	Joint Power Allocation for Multicarrier Radar and Communication Coexistence *Fangzhou Wang, Hongbin Li*
	4063	Characterisation of Sidelobes for Multibeam Radar Based on Quasi-Orthogonal LFM Waveforms *Alessio Balleri, Leon Kocjancic, Thomas Merlet*
	4078	Hidden Convexity in Robust Waveform and Receive Filter Bank Optimization for Range Unambiguous Clutter – *Augusto Aubry, Guolong Cui, Antonio De Maio, Xiaolin Du*
	4089	Unimodular MIMO Radar Waveform Design Under Spectral Interference Constraints *Khaled Alhujaili, Xianxiang Yu, Guolong Cui, Vishal Monga*
	4144	Time-Frequency Analysis of Spectrally-Notched Random FM Waveforms *Thomas Kramer, Shannon Blunt*
1300 – 1440		**Signatures & RCS** Session Chairs: Simon Watts / Jacques Cilliers
	4102	Micro-Doppler Signatures of Dynamic Humans from Around the Corner Radar *Shelly Vishwakarma, Aaquib Rafiq, Shobha Sundar Ram*
	4204	Synthesis of Micro-Doppler Signatures for Abnormal Gait Using Multi-Branch Discriminator with Embedded Kinematics – *Baris Erol, Sevgi Gurbuz, Moeness G. Amin*
	4132	A Closed Form Radar Cross Section Prediction Modeling for Overhead Wires at Millimeter Waves – *Vincent-De-Paul Onana, Ozlem Kilic*
	4182	The Use of SigmaHat for Modelling of Electrically Large Practical Radar Problems *Monique Potgieter, Jacques Cilliers, Ciara Blaauw*
	4242	Phenomenology Based Missile Classification Using Radar Micro-Doppler Processing *Tod Schuck, Mark Freisel, David Reese, Michael Villa*
1510 – 1650		**Detection & Estimation I** Session Chairs: Fabiola Colone / Pierfrancesco Lombardo
	ID	Title and *Authors*
	4038	Contrast of Contextual Fisher Vectors for Ship Detection in SAR Images *Xueqian Wang, Gang Li, Xiao-Ping Zhang*
	4044	Deep Temporal Detection – a Machine Learning Approach to Multiple-Dwell Target Detection *Daniel Gusland, Sigmund Rolfsjord, Børge Torvik*
	4085	Software Defined Doppler Radar for Landmine Detection Using GA-Optimized Machine Learning *Yan Zhang, Dan Orfeo, Dryver Huston, Tian Xia*
	4177	On Threshold Selection for Improved SAR Two-Stage Change Detection *Akshay Bondre, Christ Richmond*
	4179	Generative Adversial Network Based Extended Target Detection for Automotive MIMO Radar *Anand Dubey, Jonas Fuchs, Maximilian Lübke, Robert Weigel, Fabian Lurz*

Tuesday April 28, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

1510 – 1650		**Special Session: Emerging Applications of Short-Range Radars** Session Chairs: Victor Chen/David Tahmoush
	4119	Enhanced Hand Gesture Recognition Using Continuous Wave Interferometric Radar *Huaiyuan Liang, Xiangrong Wang, Maria Greco, Fulvio Gini*
	4147	A Linguistic Perspective on Radar Micro-Doppler Analysis of American Sign Language *Sevgi Gurbuz, Ali Gurbuz, Evie Malaia, Darrin Griffin, Chris Crawford, Mahbubur Rahman, Ridvan Aksu, Emre Kurtoglu, Robiulhossain Mdrafi*
	4154	Database of Simulated Inverse Synthetic Aperture Radar Images for Short Range Automotive Radar *Neeraj Pandey, Gaurav Duggal, Shobha Sundar Ram*
	4159	Fast-Time Clutter Suppression in mm-Wave Low-IF FMCW Radar for Fast-Moving Objects *Christopher Allen, Levi Goodman, Shannon Blunt, David Wikner*
	4088	Multi-Modal Cross Learning for Improved People Counting Using Short-Range FMCW Radar *Cem Yusuf Aydogdu, Souvik Hazra, Avik Santra, Robert Weigel*
1510 – 1650		**Machine Learning Panel**

Wednesday – April 29, 2020

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

0830 – 0920	**Industry Panel**	
0920 – 1020	**Poster Session – Waveform & Waveform Diversity II** Session Chairs: Graeme Smith / Kristine Bell	
	4012	Long Low-PSL Binary Codes by Multi-Thread Evolutionary Search *Greg Coxson, Jon Russo, Angeline Luther*
	4035	Good Code Sets via Coprime Powers – *Ravi Kadlimatti*
	4081	Interference Mitigation for a Joint Radar Communication System Based on the FrFT for Automotive Applications *Pasquale Striano, Christos Ilioudis, Jianlin Cao, Carmine Clemente, John Soraghan*
	4083	Design of Constant Modulus Sequences with Doppler Shift Tolerance and Good Complete Second Order Statistics – *Israel Alejandro Arriaga-Trejo*
	4213	Good Code Sets Based on Triangular Chirps with Signed Segments and Different Slopes *Ravi Kadlimatti*
	4028	Mismatch Filter Design Using Linear Programming *Peter Kajenski, Adria Kajenski*
0920 – 1020	**Poster Session – Classification & Machine Learning for Radar** Session Chairs: Vincenzo Carotenuto/ Shobha Sundar Ram	
	4009	Sparse Range-Doppler Image Construction with Neural Networks *Jabran Akhtar*
	4025	Moving Target Detection and Classification with Dual-Matched Filter Discriminator for Coherent Jammer Suppression in Cognitive Radar *Jeanette Tan, Ric Romero*
	4090	Arm Motion Classification Using Curve Matching of Maximum Instantaneous Doppler Frequency Signatures *Moeness G. Amin, Zhengxin Zeng, Tao Shan*
	4167	Augmenting Simulations for SAR ATR Neural Network Training *Spencer Sellers, Peter Collins, Julie Jackson*
	4178	Automotive Radar Interference Mitigation Using a Convolutional Autoencoder *Jonas Fuchs, Anand Dubey, Maximilian Lübke, Robert Weigel, Fabian Lurz*
	4188	Avoiding Jammers: a Reinforcement Learning Approach *Serkan Ak, Stefan Brüggenwirth*
	4024	Optimal Time-Frequency Distribution Selection for LPI Radar Pulse Classification *Ben Willetts, Matthew Ritchie, Hugh Griffiths*
	4238	Analysis and Mitigation of Receiver Induced Nonlinearities on Pulse-Doppler Radars *Nicholas Peccarelli, Zachary Peck, Joseph Garry*

Wednesday – April 29, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

0920 – 1020		**Poster Session – Multistatic, Imaging & ATR** Session Chairs: Debora Pastina/ Joe Deroba
	4014	Resolution Enhancement in High Resolution Wide Swath MIMO SAR *Mohammed Alshaya, Mehrdad Yaghoobi, Bernard Mulgrew*
	4036	Robustness of SAR Refraction Autofocus to Power-Law Errors *David Garren*
	4043	Multi-Feature Encoder for Radar-Based Gesture Recognition *Yuliang Sun, Tai Fei, Xibo Li, Alexander Warnecke, Ernst Warsitz, Nils Pohl*
	4155	Minimum Entropy Autofocus Correction of Range-Varying Phase Errors in ISAR Imagery *Joshua Kantor*
	4158	Bayes-SAR Net: Robust SAR Image Classification with Uncertainty Estimation Using Bayesian Convolutional Neural Network *Dimah Dera, Ghulam Rasool, Nidhal Bouaynaya, Adam Eichen, Stephen Shanko, Jeff Cammerata, Sanipa Arnold*
	4193	Embedded Micro Radar for Pedestrian Detection in Clutter *Zhe Zhang, Michael Jian, Zhenzhong Lu, Honglei Chen, Sara James, Chaofeng Wang, Rick Gentile*
	4230	Chaff Discrimination Using Convolutional Neural Networks and Range Profile Data *Utku Kaydok*
	4087	An Optimal Multistatic Synthetic Aperture Radar Reconstruction Filter *John Summerfield*
	4117	Measurement of Opaque Container Contents by an M-Sequence UWB Radar *Martin Pečovský, Pavol Galajda, Miroslav Sokol, Martin Kmec*
	4207	Comparison of the Mutual Information Content Between the Polarimetric Monostatic and Bistatic Measured RCS Data of a 1:25 Boeing 707 Model *Jacques Cilliers, Monique Potgieter, Ciara Blaauw, Wimpie Odendaal, Johan Joubert, Karl Woodbridge, Chris Baker*
	4126	Conventional SAR Change Detection Using Methods for Non-Conventional SAR *Viet Thuy Vu, Mats Pettersson, Thomas Sjören*

Wednesday – April 29, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

Time	ID	Title and Authors
1020 – 1200		**Special Session: Continuing Influence of Karl Robert Gerlach, Tributes in Memoriam** Session Chairs: Eric Mokole / Shannon Blunt
	ID	Title and *Authors*
	4070	A Dynamical Model for the Statistical Variation of Clutter *Kevin Sangston*
	4079	Design and Analysis of Adaptive Sidelobe Blanking Architectures *Augusto Aubry, Antonio De Maio, Giovanna Di Maria, Alfonso Farina, Salvatore Iommelli*
	4141	Structure-Based Adaptive Radar Processing for Joint Clutter Cancellation and Moving Target Estimation *Christian Jones, Lumumba Harnett, Charles Mohr, Shannon Blunt, Christopher Allen*
	4150	The L^{2P} Canceller *Karl Gerlach, Kevin Wagner*
	4195	M-Cancellers: Tunable, Robust, Rapid-Converging, Parallel/Pipeline, Linear Adaptive Processors *Michael Picciolo, Scott Goldstein, Wilbur Myrick*
1020 – 1200		**Over The Horizon Radar** Session Chairs: Marco Martorella / Aaron Shackelford
	4030	Doppler Signature Analysis of Mixed O/X-Mode Signals in Over-the-Horizon Radar *Ammar Ahmed, Yimin Zhang, Braham Himed*
	4098	Group Sparsity-Based Local Multipath Doppler Difference Estimation in Over-the-Horizon Radar *Vaishali Amin, Yimin Zhang, Braham Himed*
	4168	Receive Arrays for Polar Over-the-Horizon Radar *Ryan Riddolls, Simon Hénault*
1020 – 1200		**Spectrum Sharing I** Session Chairs: Justin Metcalf / Sahin Cenk
	4018	Experimental Assessment of Joint Range-Doppler Processing to Address Clutter Modulation from Dynamic Radar Spectrum Sharing *Brandon Ravenscroft, Jonathan Owen, Benjamin Kirk, Shannon Blunt, Anthony Martone, Kelly Sherbondy, Ram Narayanan*
	4120	Amplifier Performance Limits on Dual Function Radar and Communication *Alan O'Connor, Nicholas O'Donoughue*
	4174	Target Sidelobes Removal via Sparse Recovery in the Subband Domain of an OFDM RadCom System *Stephanie Bidon, Damien Roque, Steven Mercier*
	4169	Controlling Clutter Modulation in Frequency Hopping MIMO Dual-Function Radar Communication Systems *Indu Priya Eedara, Moeness G. Amin, Aboulnasr Hassanien*
	4183	Impact of Adjacent/Overlapping Communication Waveform Design Within a Radar Spectrum Sharing Context *Justin Metcalf, Cenk Sahin, Patrick McCormick, Shannon Blunt*

Wednesday – April 29, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

1300 – 1440	**Automotive & Transportation** Session Chairs: Igal Bilik/Alessio Balleri	
	4023	Phase-Coded FMCW Automotive Radar: Application and Challenges *Faruk Uysal, Simone Orru*
	4232	Radar Cross-Section of Potholes at Automotive Radar Frequencies *Abhilasha Srivastava, Abhishek Goyal, Shobha Sundar Ram*
	4149	Beam Squint Correction for Phased Array Antennas Using the Tansec Waveform *Oren Longman, Gaston Solodky, Igal Bilik*
	4005	On the Measurement of Range and its Time-Derivatives in LFMCW Radar *Peter Asuzu*
	4017	Accurate Time Synchronization for Automotive Cooperative Radar (CoRD) Applications *Ofer Bar-Shalom, Nir Dvorecki, Leor Banin, Yuval Amizur*
1300 – 1440	**Passive Radar** Session Chairs: Jonathan Bluestone / Hugh Griffiths	
	4130	Estimation of Transmitter Position Based on Known Target Trajectory in Passive Radar *Mateusz Malanowski, Krzysztof Kulpa, Marcin Żywek, Maciej Wielgo*
	4156	Tackling the Different Target Dynamics Issues in Counter Drone Operations Using Passive Radar *Tatiana Martelli, Francesca Filippini, Fabiola Colone*
	4071	Experimental Results of Polarimetric Passive ISAR Exploiting DVB-S2 Illumination *Iole Pisciottano, Diego Cristallini, Debora Pastina, Fabrizio Santi*
	4162	Ground Mapping Using Active and Passive UHF-Band SAR *Lars Ulander, Per-Olov Frölind, Anders Gustavsson, Anders Haglund, Rolf Ragnarsson, Thomas Sjögren*
1300 – 1440	**Electronic Warfare** Session Chairs: Lorenzo Lo Monte / Piotr Samczyński	
	4006	An Adaptive Spectrogram and Accelerogram Algorithm for Electronic Warfare Applications *Karol Abratkiewicz, Piotr Samczyński*
	4143	Adaptive Subspace Mappings for Super-Resolving Multiple Main-Beam Targets in Jamming *Manuel Fernández, Kai-Bor Yu*
	4200	Open-Set Radar Waveform Classification: Comparison of Different Features and Classifiers *Rohit Chakravarthy, Haoran Liu, Anne Pavy*
	4215	Sparsity-Based Time-Frequency Analysis for Automatic Radar Waveform Recognition *Shuimei Zhang, Ammar Ahmed, Yimin Zhang*
	4197	A Tensor-Based Localization Framework Exploiting Phase Interferometry Measurements *Farzam Hejazi, Mohsen Joneidi, Nazanin Rahnavard*

Wednesday – April 29, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

Time	ID	Title and *Authors*
1510 – 1650		**Array Processing –** Session Chairs: Alfonso Farina / Laura Anitori
	ID	Title and *Authors*
	4027	Sparse Array Design for Transmit Beamforming *Syed Ali Hamza, Moeness G. Amin*
	4065	Matrix Pencil Method for DoA Estimation with Interpolated Arrays *Christian Greiff, Fabio Giovanneschi, Maria Antonia Gonzalez-Huici*
	4157	Nonlinear Array Processing via a Nested Array: Theory and Experimental Evaluation *Hatim Alqadah, Dan Scholnik, Jean de Graaf*
	4196	Dynamic Range Considerations for Modern Digital Array Radars *Nicholas Peccarelli, Blake James, Caleb Fulton, Nathan Goodman*
1510 – 1650		**Special Session: Emerging Techniques & Applications in Passive Radars** Session Chairs: Fabiola Colone / Philipp Wojaczek
	4016	Transfer Learning from Audio Deep Learning Models for Micro-Doppler Activity Recognition *Kimberly Tran, Lewis Griffin, Kevin Chetty, Shelly Vishwakarma*
	4052	MIMO-FM: Some New Experimental Results Proving the Concept Feasibility *Dominique Poullin, Olivier Rabaste, Michel Menelle, Bruno Urbani, Maxime Goujon*
	4121	Passive Bistatic Radar Based on VHF DVB-T Signal *Marek Płotka, Mateusz Malanowski, Piotr Samczyński, Krzysztof Kulpa, Karol Abratkiewicz*
	4124	GNSS-Based Multistatic Passive Radar Imaging of Ship Targets *Fabrizio Santi, Debora Pastina, Michail Antoniou, Mikhail Cherniakov*
	4234	DVB-S2 Passive Bistatic Radar for Resident Space Object Detection: Preliminary Results *Luca Gentile, Amerigo Capria, Anna Lisa Saverino, Zenalda Hajdaraj, Marco Martorella*
1510 – 1650		**Machine Learning for Radar –** Session Chairs: Fulvio Gini / Moeness Amin
	4032	Waveform Recognition in Multipath Fading Using Autoencoder and CNN with Fourier Synchrosqueezing Transform – *Gyuyeol Kong, Minchae Jung, Visa Koivunen*
	4113	An Initial Investigation Into Using Convolutional Neural Networks for Classification of Drones *Holly Dale, Chris Baker, Michail Antoniou, Mohammed Jahangir*
	4160	Deep Interference Mitigation and Denoising of Real-World FMCW Radar Signals *Johanna Rock, Mate Toth, Paul Meissner, Franz Pernkopf*
	4129	Deep Convolutional Autoencoder Applied for Noise Reduction in Range-Doppler Maps of FMCW Radars - *Marcio Luiz Lima de Oliveira, Marco Bekooij*
	4109	Robust Drone Classification Using Two-Stage Decision Trees and Results from SESAR SAFIR Trials – *Mohammed Jahangir, Bashar Ahmad, Chris Baker*
1510 – 1650		**Special Session: Harmonic Radar & Its Applications –** Session Chairs: Bruce Colpitts / Anastasia Lavrenko
	4034	Compact Low-Cost FMCW Harmonic Radar for Short Range Insect Tracking *Greg Storz, Anastasia Lavrenko*
	4055	An Harmonic Radar Prototype for Insect Tracking in Harsh Environments – *Daniele Milanesio, Stefano Bottigliero, Maurice Saccani, Riccardo Maggiora, A. Viscardi, MM Gallesi*
	4060	Nonlinear Junction Detection vs. Electronics: System Design and Improved Linearity *Gregory Mazzaro*
	4092	Evaluation and Improvement of the Performance of Harmonic Radar Transponders *Ramin Ala, Bruce G. Colpitts, Nicholas Kozma*

Thursday – April 30, 2020

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

0830 – 0920	**Future Ubiquity of FMCW Radar Chips Across Multiple Application Areas (Radar-on-a-chip) Panel**	
0800 – 0940	**Poster Session – Detection & Estimation II** Session Chairs: Luke Rosenberg / Alessio Balleri	
	ID	Title and *Authors*
	4142	Estimating Radar Detection Coverage Probability of Targets in a Cluttered Environment Using Stochastic Geometry *Shobha Sundar Ram, Gaurav Singh, Gourab Ghatak*
	4145	Simulating Correlated K-Distributed Clutter *Ellis Humphreys, Michail Antoniou, Chris Baker, William Stafford*
	4218	Large-Scale Spectrum Occupancy Learning via Tensor Decomposition and LSTM Networks *Ismail Alkhouri, Mohsen Joneidi, Farzam Hejazi, Nazanin Rahnavard*
	4226	A Novel, Graphical Representation of the Classical Radar Range Equation *Paul Rose, Alexander Robinson, Tony Kinghorn*
	4237	Soft Iterative Method with Adaptive Thresholding for Reconstruction of Radar Scenes *Dmitrii Kozlov, Peter Ott, Otmar Loffeld, Marco Altmann*
	4139	Improved Covariance Matrix Estimation Using Riemannian Geometry for Beamforming Applications *Hossein Chahrour, Richard Dansereau, Sreeraman Rajan, Bhashyam Balaji*
	4074	A Quantitative Comparison of the Littoral Clutter Model (LCM) to Collected Data in the Ku-Band *Bryant Moss, Jennifer Sposato, Terry Foreman*
	4163	SINR Modeling for Evaluating the CRLB for ATSC Signal Based Passive Radar Systems *Moayad Alslaimy, Robert Burkholder, Graeme Smith*
	4225	Transversal Velocity Measurement of Multiple Targets Based on Spatial Interferometric Averaging *Pengcheng Wang, Huaiyuan Liang, Xiangrong Wang, Elias Aboutanios*
	4152	Radar Resource Allocation: Higher Rate or Better Measurements? *Yan Wang, William Dale Blair*
	4153	Spatiotemporal Density-Based Clustering for Dynamic Spectrum Sensing *Christopher Ebersole, Anthony Buchenroth, David Zilz, Vasu Chakravarthy*

Thursday – April 30, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

0800 – 0940		**Poster Session – Low-cost, Emerging & mmW Technologies** Session Chairs: Frank Robey / Phillip Corbell
	ID	Title and *Authors*
	4004	Interference Suppression and Signal Restoration Using Kalman Filter in Automotive Radar Systems *Jaehoon Jung, Sohee Lim, Jinwook Kim, Seong-Cheol Kim, Seongwook Lee*
	4180	MmWave Radar Point Cloud Segmentation Using GMM in Multimodal Traffic Monitoring *Feng Jin, Arindam Sengupta, Siyang Cao, Yao-Jan Wu*
	4054	FMCW Radar Prototype Development for Detection and Classification of Nano-Targets *Safiah Zulkifli, Alessio Balleri*
	4138	Exploring Gesture Recognition with Low-Cost CW Radar Modules in Comparison to FMCW Architectures *Alan Bannon, Richard Capraru, Matthew Ritchie*
	4026	Next-Generation Software Defined Radar: First Results *Evan Zaugg, Alexander Margulis, Maximillian Margulis, Joshua Bradley, Alexander Kozak, Jeffrey Budge*
	4053	Quantum Electromagnetic Scattering and the Sidelobe Advantage *Matthew Brandsema, Marco Lanzagorta, Ram Narayanan*
	4086	Quantum Two-Mode Squeezing Radar: SNR and Detection Performance *David Luong, Sreeraman Rajan, Bhashyam Balaji*
	4214	Development and Testing of a Low Cost Audio Based ISAR Imaging and Machine Learning System for Radar Education *Jacques Cilliers, Nicholas Blomerus, Pieter de Villiers*
	4245	Enabling In-Band Coexistence of Millimeter-Wave Communication and Radar *Hardik Jain, Ian Roberts, Sriram Vishwanath*
	4151	A High Power Compact X-Band RF Front-End for Weather Radar Applications *Vadym Volkov, Dmytro Vavriv, Volodymyr Vynogradov, Yevhenii Bulah, Andrii Kravtsov, Vladislav Ksenofontov*
0800 – 0940		**Poster Session – Antennas & Array Processing** Session Chairs: Alex Charlish / Mai Ngo
	4217	Performance Modelling of a Cost Effective COTS UHF Log-Periodic Antenna *Ciara Blaauw, Monique Potgieter, Jacques Cilliers*
	4128	KOSPAW Test Bed–A Phased Array Radar for Space Situational Awareness *Jiwoong Yu, Sungki Cho, Jung Hyun Jo*
	4184	Fixed Probe Based Digital Phased Array Calibration Using Virtual Probe Location *Shajid Islam, Caleb Fulton*
	4136	Studies of Front-End Distortion Characterization via Mutual Coupling Measurements in Phased Array Systems *Matthew Herndon, Mark Yeary, Robert Palmer*

Thursday – April 30, 2020

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

Time	ID	Title and *Authors*
1020 – 1200		**Adaptive Processing** Session Chairs: Michael Picciolo / Shannon Blunt
	ID	Title and *Authors*
	4033	A Modified Least-Squares Mismatched Filter for Use in Radar Applications with Additive Noise *Jerrod Kempf, Julie Jackson*
	4048	Language-Based Cost Functions for Fully Adaptive Radar Under Imprecise Performance Standards *Paul Singerman, Sean O'Rourke, Ram Narayanan, Muralidhar Rangaswamy*
	4235	Adaptive Digital Predistortion for Radar Applications Using Convex Optimization *Randall Summers, Mark Yeary, Hjalti Sigmarsson, Rafael Rincon*
1020 – 1200		**SAR** Session Chairs: Dan Scholnik / Raghu Raj
	4021	A Comparison of Autofocus Algorithms for Backprojection Synthetic Aperture Radar *Aaron Evers, Julie Jackson*
	4104	Multichannel Coprime SAR/GMTI (CopGMTI) *Abdulmalik Aldharrab, Mike Davies*
	4170	SAR Image Formation via Subapertures and 2D Backprojection *Callin Schone, Nathan Goodman*
	4212	Deep Learning for Joint Image Reconstruction and Segmentation for SAR *Samia Kazemi, Birsen Yazici*
	4013	Advanced Techniques for Robust SAR ATR: Mitigating Noise and Phase Errors *Nathan Inkawhich, Eric Davis, Uttam Majumder, Chris Capraro, Yiran Chen*
1020 – 1200		**Spectrum Sharing II** Session Chairs: Chris Mountford / Patrick McCormick
	4010	Computationally Efficient Narrowband RFI Mitigation for Pulse Compression Radar *Neal Smith, Mark Frankford, Richard Thompson*
	4067	Mitigation of Cross-Modulation Effects in Radar Receivers with Memory *Euan Ward, Bernard Mulgrew*
	4093	Multi-Pulse Processing of Dual Function Radar Waveforms Without Remodulation *Batu Chalise, Moeness G. Amin, Giuseppe Fabrizio*
	4069	Assessing Block-Sparsity-Based Spectrum Sensing Approaches for Cognitive Radar on Measured Data *Augusto Aubry, Vincenzo Carotenuto, Antonio De Maio, Mark Govoni, Alfonso Farina*
	4140	Algorithm for Fast Simultaneous Harmonic and Fundamental Impedance Tuning in Reconfigurable Radar Transmitter Power Amplifiers *Adam Goad, Charles Baylis, Paul Flaten, Brian Olson, Robert Marks II*

Thursday – April 30, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

Time	ID	Title and *Authors*
1300 – 1440		**Tracking & Estimation** Session Chairs: Maria Sabrina Greco / David Crouse
	ID	Title and *Authors*
	4103	Bernoulli Multi-Target Track-Before-Detect for Maritime Radar *Branko Ristic, Du Yong Kim, Luke Rosenberg, Robin Guan*
	4240	Steady-State Filter Design for Radar Tracking with Up-Chirp-Down-Chirp Waveforms *James Corwell, William Dale Blair, Yaakov Bar-Shalom*
	4008	Orbit Determination Before Detect: Orbital Parameter Matched Filtering for Uncued Detection *Brendan Hennessy, Mark Rutten, Steven Tingay, Robert Young*
	4029	Single Sensor Emitter Localization Based on TOA Sequence with Inter-Pulse Modulation *Xuefeng Feng, Zhen Huang, Jiazhi He, Lei Shi, Di Liu*
	4198	Covariance-Free TDOA/FDOA-Based Moving Target Localization for Multi-Static Radar *Xudong Zhang, Fangzhou Wang, Hongbin Li, Braham Himed*
1300 – 1440		**Multistatic, Networked & Distributed** Session Chair: Mark Govoni / Abigail Hedden
	4112	Investigating the Effects of Bistatic SAR Phenomenology on Feature Extraction *Michael Woollard, Matthew Ritchie, Hugh Griffiths*
	4123	Analysing Multibeam, Cooperative, Ground Based Radar in a Bistatic Configuration *Pepijn Cox, Wim van Rossum*
	4066	A Multifunctional Broadband Receiver for Bistatic X-Band Radar Measurements *Michael Kohler, Vichet Duk, Matthias Weiss, Wojciech Brodowski, Josef Worms, Daniel O'Hagan, Oliver Bringmann*
	4041	Doppler-Only Multistatic Radar via Sequential Convex Optimization *Jason Hodkin, V Chandrasekar*
	4209	Non-Orthogonality in MIMO Radar: a Fractional Fourier Approach – *Pawan Setlur, K. T. Arasu*
1300 – 1440		**Waveform & Waveform Diversity I –** Session Chairs: Aboulnasr Hassanien / Stephen Harman
	4072	Waveform Design Implemented on Neuromorphic Hardware *Patrick Farr, Aaron Jones, Trevor Bihl, Jayson Boubin, Ashley Demange*
	4091	Correlation-Gradient-Descent: Efficient Optimization Methods for Unimodular Waveform Design with Desirable Correlation Properties – *Khaled Alhujaili, Vishal Monga, Muralidhar Rangaswamy*
	4107	Generating Waveform Families Using Multi-Tone Sinusoidal Frequency Modulation *David Hague*
	4173	Matched Illumination Waveform Optimization for Radar Imaging *Zacharie Idriss, Raghu Raj, Ram Narayanan*
1300 – 1440		**Special Session: Quantum Radar: Current Status & Prospects** Session Chairs: Ravi Advi / Jérôme Bourassa
	4007	A System Engineering Perspective on Quantum Radar – *Fred Daum*
	4100	Inspiring Radar from Quantum-Enhanced Lidar – *Han Liu, Amr Helmy, Bhashyam Balaji*
	4118	Entangled Coherent States for Quantum Radar Applications – *Marco Frasca, Alfonso Farina*
	4135	Amplification Requirements for Quantum Radar Signals – *Jérôme Bourassa, Christopher Wilson*
	4222	Configuration-Dependent Characteristics of Virtual-Mode Quantum Sensing Systems *Marco Lanzagorta, Jeffrey Uhlmann*

Thursday – April 30, 2020 – Continued

All Sessions are available to view at your convenience, beginning 8 AM April 27th through 11:59 PM May 25th.
Times listed are UTC—4 – Authors will be available for live chat during the time listed for their presentation.

1510 – 1650		**Medical & Biological Applications** Session Chairs: Fauzia Ahmad / Willie Nel
	4190	UWB Radar Cardiac Activity Sensing : Novel Arctangent Demodulator for Direct-RF Receivers *Sharanya Srinivas, Yu Rong, Daniel W. Bliss*
	4202	Attention-Augmented Convolutional Autoencoder for Radar-Based Human Activity Recognition *Christopher Campbell, Fauzia Ahmad*
	4241	An Examination of Frequency-Modulated Continuous Wave Radar for Biomedical Imaging *Justin Metcalf, Jay McDaniel, Jessica Ruyle, Nathan Goodman, Jack Borders Jr.*
	4187	Cardiac Sensing Exploiting an Ultra-Wideband Terahertz Sensing System *Yu Rong, Panagiotis C. Theofanopoulos, Georgios C. Trichopoulos, Daniel W. Bliss*
1510 – 1650		**Radar Signature of UAVs** Session Chairs: Matthew Ritchie / Mohammed Jahangir
	4040	UAV Micro-Doppler Signature Analysis Using DVB-S Based Passive Radar *Martin Ummenhofer, Louis Cesbron Lavau, Diego Cristallini, Daniel O'Hagan*
	4077	Fundamental Frequency Estimation of HERM Lines of Drones *Andi Huang, Pascale Sévigny, Bhashyam Balaji, Sreeraman Rajan*
	4191	Measuring UAV Propeller Length Using Micro-Doppler Signatures *Zeus Gannon, David Tahmoush*
	4199	Data-Driven STFT for UAV Micro-Doppler Signature Analysis *Daniel Herr, David Tahmoush*
	4131	Propeller Modulation Analysis of 4-Blade, 4-Engine Aircraft in FM-Band Multistatic Passive Radar *Francois Maasdorp, Jacques Cilliers, Craig Tong*
1510 – 1650		**Cognitive Radar & Machine Learning** Session Chairs: Yimin Zhang / Vincenzo Carotenuto
	4076	Impulse Response Estimation for Wideband Multi-Channel Radar Systems *Sandeep Gogineni, Muralidhar Rangaswamy, Joseph Guerci, Jamie Bergin, David Kirk*
	4082	Reinforcement Learning Based Transmitter-Receiver Selection for Distributed MIMO Radars *Petteri Pulkkinen, Tuomas Aittomäki, Visa Koivunen*
	4095	Radar Human Motion Recognition Using Motion States and Two-Way Classifications *Moeness G. Amin, Ronny G. Guendel*
	4125	Clustering Radar Pulses with Bayesian Nonparametrics: a Case for Online Processing *Matthew Scherreik, Brian Rigling*
	4165	Uncertainty Function Design for Adaptive Beamsteering Cognitive Radar *Zachary Johnson, Ric Romero*
1650 – 1700		**Closing Remarks**

CALL FOR PAPERS
2021 IEEE RADAR CONFERENCE

ATLANTA, GEORGIA, USA

Radar on the Move

MAY 2021

Sheraton Atlanta | 165 Courtland St NE | Atlanta, GA 30303

Organizing Committee

Chair Kristin Bing

Vice Chair Theresa Brunasso

Technical Program Chairs
W. Dale Blair, Fabiola Colone
radar21-tech@ieee.org

Tutorials Chairs
Chris Barnes, Braham Himed
radar21tutorial@ieee.org

Special Session Chairs
Laura Anitori,
Luke Rosenberg, Graeme Smith
radar21-special@ieee.org

Plenary Chairs
Bill Melvin, Jacqueline Fairley

Student Program Chairs
Jim Skala, Kellie McConnell

Sponsors Chairs
Andy Register, Mark Mitchell

Exhibits Chairs
Audrey Paulus, Rikai Huang

Publications Chairs
Steve Conover, Sevgi Gurbuz

Finance Chairs
Jennifer Palmer, Jenny Reed

Publicity Chairs
Brian Conant, Joshua Kovitz

Local Arrangements Chair
Clayton Kerce

Guest Program Coordinator
Jeff Connor

WiE Luncheon Chairs
Dana Fitzgerald,
Anne Costolanski, Julie Jackson

European Liaisons
Maria S. Greco, Hugh Griffiths

Asia Pacific Liason
Joe Fabrizio

Patron Inquiries
Andy Register
radar21-sponsor@ieee.org

Exhibitor Inquiries
Audrey Paulus
radar21-exhibit@ieee.org

The IEEE Radar Conference 2021 will provide a rich technical program over a broad array of topics in radar systems, subsystems, techniques, technology, applications, phenomenology, and signal processing.

The vibrant city of Atlanta, Georgia, combines the entertainment, educational, and economic opportunities of an international city with the flavor and personality of close-knit, eclectic neighborhoods.

Originally a railroad terminus, Atlanta is now a rapidly growing 21st century global hub of transportation, education, and technology, and is the ideal venue to host ***Radar on the Move***.

Procedures for submitting papers and proposals for special sessions and tutorials are available at
radarconference21.org

8-9 May 2021
RADAR SUMMER SCHOOL

10-14 May 2021
CONFERENCE & WORKSHOPS

INCLUDING:
IEEE Young Professionals (YP)
& IEEE Women in Engineering (WIE) Events

Important Dates:

Special Session Proposals .... 30 Aug 2020
Paper Submissions.................... 18 Oct 2020
Tutorial Submissions................ 30 Nov 2020
Notification of Acceptance.........31 Jan 2021
Final Papers ....28 Feb 2021

2021 Conference Topic Areas

Techniques
- Waveforms & Waveform Diversity
- Tracking
- Resource Management
- Cognitive Radar & Machine Learning
- Fusion of Radar with Other Sensors
- Imaging
- Automatic Target Recognition
- Classification & Identification
- Detection & Estimation
- Adaptive Signal Processing
- Array Processing
- Spectrum Sharing

Applications & Phenomenology
- Space, Air, Sea & Ground-Based
- Automotive & Transportation
- Medical & Biological
- Over the Horizon Radar
- Weather & Environmental Sensing
- Multistatic, Networked, & Distributed
- Passive
- ECCM & Interference Cancellation
- Clutter & Interference Modeling
- Signatures & Characterization

Systems & Subsystems
- Low-cost & 'Home Brew' Radar
- Software Defined Radar
- RF Convergence
- Antennas
- Processors
- Transmitters & Receivers
- Components
- mm-wave & THz
- Emerging Systems & Technologies

IEEE
IEEE Atlanta Section
www.IEEE-Atlanta.org
AESS

radarconference21.org

Tuesday, April 24th, 2018

TARGET DETECTION IN NON-HOMOGENEOUS ENVIRONMENTS
10:20 – 12:00
ROOM 1
CHAIR: ELIAS ABOUTANIOS, *UNIVERSITY OF NEW SOUTH WALES*
ABOULNASR HASSANIEN, *WRIGHT STATE UNIVERSITY*

10:20 Multi-Channel Maritime Radar Target Detection using Morphological Component Analysis

Malcolm Hoe Kin Wong[1], Elias Aboutanios[1], Luke Rosenberg[2]
[1]University of New South Wales, Australia; [2]Defence Science and Technology Group, Australia

Radar detection of small maritime targets is challenging due to the dynamic motion of the sea. We present a new space-time signal separation technique that can extract stationary and moving targets from the background interference via a space-time implementation of morphological component analysis using a two-dimensional short-time Fourier transform as the dictionary. The choice of the penalty parameter is analysed to ensure good separation of the target and interference components. We demonstrate the performance against several practical detection schemes using Monte-Carlo simulation with synthetic multi-channel sea clutter data modelled on the Ingara X-band sea clutter dataset.

10:40 A Cognitive Architecture for Space Time Adaptive Processing

Samuele Gelli, Marco Martorella
University of Pisa, Italy

A cognitive radar can be conceived as a system that is able to autonomously and continuously change the parameters of both the transmitter and the receiver to optimise its performances in changing complex and changing environment with the available resources. In this paper, we implement a simple rule-based form of cognitive radar to optimise ground moving target imaging. The system architecture is presented that highlights the how cognition is implemented into STAP processing to optimise STAP filtering performances. Some preliminary results are shown based on recently acquired real airborne radar data.

11:00 Detection Performance of Distributed MIMO Radar with Asynchronous Propagation and Timing/Phase Errors

Fangzhou Wang[1], Cengcang Zeng[1], Hongbin Li[1], Mark A. Govoni[2]
[1]Stevens Institute of Technology, United States; [2]Army Research Laboratory, United States

In this paper, we examine target detection in distributed MIMO radar with synchronization errors. A general signal model is developed that takes into account asynchronous propagation and possible timing/phase synchronization errors in distributed MIMO radar. Two sets of linear frequency modulation (LFM) based waveforms with different characteristics, along with coherent and non-coherent detectors, are employed to examine the impact of asynchronous propagation and synchronization errors on target detection. Simulation results are provided to compare the target detection performance of these detectors under different scenarios.

Tuesday, April 28th, 2020

11:20 Practical Detection using Sparse Signal Separation

Luke Rosenberg[1,2], Vichet Duk[3], Brian Ng[2]
[1]Defence Science and Technology Group, Australia; [2]University of Adelaide, Australia; [3]Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany

Due to the dynamic motion of the sea, radar detection of small maritime targets can be difficult. Airborne maritime surveillance platforms are also increasingly required to operate at higher altitudes where backscatter from the sea becomes stronger. The focus of this paper is to investigate three sparse signal separation formulations using the short time Fourier transform as a dictionary. This approach has been demonstrated as effective in separating both stationary and moving targets from sea clutter, but relies on the tuning of different parameters. The first part of this work looks at the selection of the penalty parameter, which is essential to achieve good separation. Then a number of practical detection schemes are presented that allow control of the false alarm rate. The algorithm performance is demonstrated using Monte-Carlo simulation with synthetic targets injected into the Ingara medium grazing angle sea-clutter data set.

Notes:

Tuesday, April 24th, 2018

PASSIVE RADAR I

10:20 – 12:00
ROOM 2
CHAIR: HUGH GRIFFITHS, *UNIVERSITY COLLEGE LONDON*
DANIEL O'HAGAN, *FRAUNHOFER FHR*

10:20 Range Compression Strategies for Passive Radar on Airborne Platforms

Philipp Wojaczek, Diego Cristallini, Ingo Walterscheid, Daniel O'Hagan
Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany

This paper focuses on range compression aspects to be considered in the signal processing of passive radars. In particular it focuses on passive radar systems mounted on moving platforms for ground moving target indication (GMTI) on the one hand and on synthetic-aperture radar (SAR) on the other hand. As the signals of opportunity are not created for radar purposes, the underlying signal structure can lead to ambiguities and sidelobes and thus impede target detection or decrease the signal-to-noise ratio. Careful signal processing algorithms must be applied on the range compression stage in order to deal with these issues. Here we provide an overview of possible range compression techniques and give a suggestion which technique is the most appropriate depending on the type of application.

10:40 Facing Channel Calibration Issues affecting Passive Radar DPCA and STAP for GMTI

Giovanni Paolo Blasone, Fabiola Colone, Pierfrancesco Lombardo
Sapienza University of Rome, Italy

This paper addresses the problem of clutter cancellation for ground moving target indication (GMTI) in multi-channel passive radar on mobile platforms. Specifically, the advantages of a space-time adaptive processing (STAP) approach are presented, compared to a displaced phase centre antenna (DPCA) approach, in the case of an angle-dependent imbalance affecting the receiving channels. The schemes are tested against simulated clutter data. Finally, a space-time GLRT detection scheme is proposed, where steering vector is not specified in the spatial domain, resulting in a non-coherent integration of target echoes across the receiving channels. Such solution offers comparable clutter cancellation capability and is more robust against significant calibration errors compared to a conventional GLRT detector, which suffers from spatial steering vector mismatches.

11:00 Detecting Drones and Human Beings with DVB-S based COTS Passive Radar for Short-Range Surveillance

Octavio Cabrera, Carlo Bongioanni, Francesca Filippini, Olena Sarabakha, Fabiola Colone, Pierfrancesco Lombardo
Sapienza University of Rome, Italy

This work addresses the exploitation of Digital Video Broadcasting - Satellite (DVB-S) signals as sources of opportunity for the surveillance of small targets in the proximity of critical infrastructures. A performance analysis has been carried out and it is reported to demonstrate the feasibility of the proposed system. Then, a preliminary experimental validation is performed using data collected by means of a low cost COTS based multi-polarimetric receiver to detect small and close targets, as drones and human beings. We present promising experimental results that show the capability of the proposed system to perform the desired task. Moreover, they show the potential opportunity to gain more information on the target motion based on its Doppler signature.

Tuesday, April 28th, 2020

11:20 Off-Grid Compressed Sensing for Radars with Unknown Transmit Waveform

Sudarshan Guruacharya[1], Batu K. Chalise[1], Braham Himed[2]
[1]New York Institute of Technology, United States; [2]Air Force Research Laboratory, United States

We propose compressed sensing (CS)-based multiple target parameter estimation method for radar receivers where the transmit waveform is unknown a-priori. We use the noisy reference signal as a proxy to the unknown transmitted signal in order to construct the required dictionary matrix at the receiver. We demonstrate that the delays and Doppler frequencies associated with both the on-grid and off-grid target locations can be efficiently estimated with the proposed method. The upper bound for modeling error is obtained and two algorithms are proposed for solving the off-grid problem which is formulated as a structured perturbed basis de-noising problem. Numerical simulations are conducted to validate the proposed approach.

11:40 Beamforming and Tracking Assessment with Passive Radar Experimental Data

Tri-Tan Cao[1], Tuyet Vu[1], Marion Byrne[1], Nabaraj Dahal[1], Paul E. Berry[1], Ayobami B. Iji[1], Daniel Gustainis[1], Martin Ummenhofer[2], Michael Kohler[2]
[1]Defence Science and Technology Group, Australia; [2]Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany

Using experimental data captured with a passive radar linear array built by Defence Science and Technology (DST) Group, the performance of various beamforming algorithms (beamformers) for direction-of-arrival (DoA) estimation is comparatively assessed. Beamformers' DoA estimates are passed to a tracker which performs angle tracking, and the resulting track quality is examined based on the Optimal Sub-Pattern Assignment Metric for Multiple Tracks (OSPAMT). By matching the ground-truth tracks with the confirmed tracks, the OSPAMT takes into account both the locality error (how close the confirmed tracks are to the ground-truth tracks) and the cardinality error (the numbers of false tracks, track breaks and missed tracks). The best OSPAMT score is achieved by a newly-designed sparse solution beamformer derived from a compressive sensing principle and based on off-grid approaches.

Notes:

Tuesday, April 24th, 2018

METACOGNITION & MACHINE LEARNING FOR RADAR SPECTRUM SHARING

10:20 – 12:00
ROOM 3
CHAIR: ANTHONY MARTONE, *U.S. ARMY RESEARCH LABORATORY*
MIKE BUEHRER, *VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY*

10:20 Metacognition for Radar Coexistence

Anthony F. Martone[1], Kelly D. Sherbondy[1], Jacob A. Kovarskiy[2], Benjamin H. Kirk[2], Charles E. Thornton[3], Jonathan W. Owen[4], Brandon Ravenscroft[4], Austin Egbert[5], Adam Goad[5], Angelique Dockendorf[5], R. Michael Buehrer[3], Ram M. Narayanan[2], Shannon D. Blunt[4], Charlie Baylis[5]
[1]U.S. Army Research Laboratory, United States; [2]Pennsylvania State University, United States; [3]Virginia Polytechnic Institute and State University, United States; [4]University of Kansas, United States; [5]Baylor University, United States

We investigate a metacognitive radar (MCR) model that comprehensively combines disparate cognitive radar (CR) strategies for advanced performance in congested electromagnetic environments (EME). This model changes CR strategies as the spectral environment and target conditions evolve for efficient radar dynamic spectrum access (DSA). The model first implements spectrum sensing followed by spectrum classification to identify known EME scenarios. These spectral scenarios assess the congestion and complexity of time-frequency data collected by the passive sensing process. This evaluation prioritizes possible CR strategies that are effective for the given spectral conditions. The MCR model then evaluates different CR strategies via learning and selects the technique that provides the best radar performance.

10:40 Spectral Prediction and Notching of RF Emitters for Cognitive Radar Coexistence

Jacob A. Kovarskiy[1], Jonathan W. Owen[2], Ram M. Narayanan[1], Shannon D. Blunt[2], Anthony F. Martone[3], Kelly D. Sherbondy[3]
[1]Pennsylvania State University, United States; [2]University of Kansas, United States;
[3]Army Research Laboratory, United States

The increasing demand for radio frequency (RF) spectrum requires radars to coexist with interfering RF emitters. Innovations in waveform design paired with dynamic spectrum access techniques allow for efficient spectrum sharing for radar. This work evaluates a recently developed real-time implementation of spectrum sharing cognitive radar using commercial-of-the-shelf (COTS) hardware. Prediction of coexisting RF emitter frequencies informs the design of spectrally notched FM noise waveforms on transmit. Waveform notches are optimized on a pulse-to-pulse basis while accounting for the zero-order hold model inherent to lower fidelity digital-to-analog converters to ensure desired reconstruction. The radar system employs cognition to learn and predict RF emitter activity via a stochastic model-based approach. Initially, passive spectrum observations are used to estimate a stochastic model which is then exploited to predict the likelihood of future RF activity. The benefits and limitations of this sense-predict-and-notch (SPAN) approach are evaluated using a set of synthetic interference scenarios in real time.

Tuesday, April 28th, 2020

11:00 Experimental Analysis of Reinforcement Learning Techniques for Spectrum Sharing Radar

Charles E. Thornton[1], R. Michael Buehrer[1], Anthony F. Martone[2], Kelly D. Sherbondy[2]
[1]Virginia Polytechnic Institute and State University, United States; [2]Army Research Laboratory, United States

This paper experimentally compares reinforcement learning techniques for radar waveform selection. Both dynamic programming and Deep RL techniques are considered. The cognitive radar system discussed learns to effectively share 100MHz of spectrum with a non-cooperative communications system. The radar's performance is analyzed using a COTS hardware prototype. We examine performance in terms of convergence, detection characteristics, and spectrum sharing performance.

11:20 Optimizing Transmitter Amplifier Load Impedance for Tuning Performance in a Metacognition-Guided, Spectrum Sharing Radar

Adam Goad[1], Austin Egbert[1], Angelique Dockendorf[1], Charles Baylis[1], Anthony Martone[2], Robert J. Marks II[1]
[1]Baylor University, United States; [2]Army Research Laboratory, United States

Transmitter power amplifier load impedance impacts the transmitted power of the radar, which affects the maximum detection range. In spectrum sharing radars, the operating frequency is expected to change on the order of a coherent processing interval (CPI), which can be in the low milliseconds. While a high-power impedance tuner has been developed for radar applications, its reconfiguration time is in the hundreds of milliseconds to multiple seconds, significantly exceeding the CPI time scale; preventing per-CPI circuit configuration adjustments. We demonstrate an algorithm that improves the amplifier impedance tuning during a spectrum sharing metacognition process in a cognitive radar.

11:40 Toward Metacognitive Radars: Concept and Applications

Kumar Vijay Mishra[1,2], Bhavani Shankar M.R.[2], Björn Ottersten[2]
[1]Army Research Laboratory, United States; [2]University of Luxembourg, Luxembourg

We introduce a metacognitive approach to optimize the radar performance for a dynamic wireless channel. Similar to the origin of the cognitive radar in the neurobiological concept of cognition, metacognition also originates from neurobiological research on problem-solving and learning. Broadly defined as the process of learning to learn, metacognition improves the application of knowledge in domains beyond the immediate context in which it was learned. We describe basic features of a metacognitive radar and then illustrate its application with some examples such as antenna selection and resource sharing between radar and communications. Unlike previous works in communications that only focus on combining several existing algorithms to form a metacognitive radio, we also show the transfer of knowledge in a metacognitive radar. A metacognitive radar improves performance over individual cognitive radar algorithms, especially when both the channel and transmit/receive hardware are changed.

Notes:

Tuesday, April 24th, 2018

ANTENNAS

13:00 – 14:40
ROOM 1
CHAIR: MARK DAVIS, *MEDAVIS CONSULTING*
KRZYSZTOF KULPA, *WARSAW UNIVERSITY OF TECHNOLOGY*

13:00 Circularly Polarized Fabry Perot Cavity Antennas with Peripheral Roughness in Superstrate Unit Cells

Sagar Jain, Shobha Sundar Ram
Indraprastha Institute of Information Technology Delhi, India

Fabry Perot cavity antennas have been extensively researched and developed for their reduced fabrication complexity and cost as compared to other high gain planar antennas. Recently, the partially reflecting surfaces of the FPC antennas have been engineered with metasurfaces with desirable electromagnetic properties in order to reduce their profile dimensions. These surfaces usually consist of an array of unit cells that are skillfully designed in order to obtain high bandwidth or desired polarization. In this paper, we have considered a unit cell design of a rectangular loop with a diagonal - with an objective of achieving circular polarization. Then we introduced a new design parameter in the form of peripheral roughness in the edge of each of the unit cells. We demonstrate that the incorporation of the new design feature in the unit cell results in an enhancement of the return loss bandwidth to 202.8 MHz (8.9%) and gain to 9.5 dBi along with a reduced axial ratio of 4.8 dB.

13:20 GaN based Wide Band C-Band Active Phased Array Antenna Design with Wide Scan Volume

Ashutosh Kedar, Amit S. Bisht, K. Sreenivasulu, Srinivas Rao D., Naveen K. Vishwakarma
Defence Research and Development Organization, India

This article presents design and development of a high power, wide band and wide scanning active phased array antenna in C-band using GaN based semiconductor technology. It highlights the usage of commercial tools such as Keysight's ADS, Ansys HFSS and MATLAB in a combined manner in reducing the design cycle and achieve accurate design for manufacturing. First time usage of GaN technology within country has made it possible to achieve high peak power output from a smaller aperture with least heat dissipation. Some of the salient features achieved include high directive gain, high PT, high efficiency, narrow beamwidth, low sidelobe level (SLL), modularity and scalability over the specified frequency band and scan volume. It is used for the realization of a four-walled active phased array radar.

13:40 Fast Switched-Stub Impedance Tuner Reconfiguration for Frequency and Beam Agile Radar and Electronic Warfare Applications

Caleb Calabrese, Angelique Dockendorf, Austin Egbert, Brandon Herrera, Charles Baylis, Robert J. Marks II
Baylor University, United States

Tunable matching networks using switched stubs show promise for real-time impedance matching in high-power radar and jamming applications based on the emerging developments of high-power switches. These self-tuning transmitter amplifiers will quickly maximize range upon changing operating frequency in a dynamically changing spectrum environment. In this paper, we present a fast tuning algorithm capable of maximizing the output power from tuner with six switched stubs. The control of the tuner from a software-defined radio platform is demonstrated, and complete optimization for output power can be performed in under 35 μs following a change in operating frequency or antenna impedance.

Tuesday, April 28th, 2020

14:00 Channel Cancellation Ratio in Highly Digital Direct RF Sampling Array Architectures

Gary Boardley, Paul M. Techau
Northrop Grumman Corporation, United States

Conventional receive digital beamforming (DBF) systems generally employ array architectures that use fixed radio frequency (RF) manifolds to combine the elements of several subapertures into a small number of digital channels. These channels are then used in adaptive beamforming to cancel interference. A significant limiting factor in the performance of an adaptive array is how well the transfer functions match among the various receiver chains. Emerging technologies have the potential to allow for much greater achievable channel match. This paper describes the potential benefits for cancellation ratio that can be realized as a result of these emerging technologies.

14:20 Hardware and Processing Architecture Impacts on Adaptive Beamforming in Digital Phased Arrays

Paul M. Techau, Gary Boardley
Northrop Grumman Corporation, United States

Typical approaches to receive digital beamforming (DBF) have used antenna array architectures wherein large numbers of elements are combined via fixed radio frequency (RF) manifolds into a small number of digital channels. These channels can then be used to adaptively cancel interference within limits pertaining to the number of digital channels relative to the number of interference sources and hardware considerations such as channel-pair cancellation ratio (CPCR). This paper describes how emerging digital array technology provides greater flexibility and performance when adapting to varying RF interference environments.

Notes:

Tuesday, April 24th, 2018

ADVANCED SOFTWARE DEFINED RADAR IMPLEMENTATIONS ON COTS HARDWARE

13:00 – 14:40
ROOM 2
CHAIR: JUSTIN METCALF, *UNIVERSITY OF OKLAHOMA*
ANTHONY MARTONE, *U.S. ARMY RESEARCH LABORATORY*

13:00 Zero-Order Reconstruction Optimization of Waveforms (ZOROW) for Modest DAC Rates

Charles A. Mohr[1,2], Jonathan W. Owen[1], Shannon D. Blunt[1], Christopher T. Allen[1]
[1]University of Kansas, United States; [2]Air Force Research Laboratory, United States

The use of waveforms possessing constant envelope and good spectral containment, combined with high-fidelity arbitrary waveform generation (AWG) capability, has been shown to minimize transmitter distortion effects when waveform diversity is needed. Software-defined radios (SDRs) represent a lower cost, attritable alternative to AWGs at the price of lower fidelity. Specifically, the lower digital-to-analog conversion (DAC) rates supported by SDRs introduce new design challenges for the generation of waveforms requiring high fidelity, most notably those containing in-band spectral notches. Here these challenges are addressed via the ZOROW waveform design scheme that accounts for physical attributes of the SDR. Distortion effects arising from the modest DAC rate are characterized and their mitigation is demonstrated using experimental measurements.

13:20 Performance Analysis of Pulse-Agile SDRadar with Hardware Accelerated Processing

Benjamin H. Kirk[1], Anthony F. Martone[2], Kelly D. Sherbondy[2], Ram M. Narayanan[1]
[1]Pennsylvania State University, United States; [2]Army Research Laboratory, United States

With the increasing demand for access to the radio frequency spectrum, there has been an emergence of spectrum sharing radar systems. Along with this comes the need for rapid pulse-agility for the best avoidance of other time varying signals in the spectrum. A software defined radar (SDRadar) system that has been previously explored was further developed in this work to improve its spectrum sharing performance. To take advantage of the rapid reaction time of the improved system, pulse adaption occurs within a radar coherent processing interval. It was observed that this caused significant distortion in the Doppler dimension. A simulation was formulated which shows that the distortion becomes more significant as the magnitude of the adaptation increases. The distortion was also shown to have a significant impact on the number of false alarms detected reducing the ability to verify true targets.

13:40 Demonstration of Real-Time Cognitive Radar using Spectrally-Notched Random FM Waveforms

Jonathan W. Owen[1], Charles A. Mohr[1,2], Benjamin H. Kirk[3,4], Shannon D. Blunt[1], Anthony F. Martone[4], Kelly D. Sherbondy[4]
[1]University of Kansas, United States; [2]Air Force Research Laboratory, United States; [3]Pennsylvania State University, United States; [4]Army Research Laboratory, United States

With the reality of increasing radio frequency (RF) spectral congestion, radar systems capable of dynamic spectrum sharing are needed. Recent work has demonstrated a real-time cognitive capability on a software defined radio (SDR) by generating pulse-agile LFM chirps that vary their center frequency and bandwidth to avoid dynamic interference on a perpulse basis. Separately, spectral notching of random FM waveforms was developed and experimentally evaluated as another means with which to mitigate emulated interference, though real-time operation had not yet been demonstrated.

Tuesday, April 28th, 2020

14:00 Characterizing the Impact of IQ Imbalance and DC Bias on Pulse-Agile Radar Processing

Justin G. Metcalf[1], Shane Flandermeyer[1], Charles A. Mohr[2,3], Andrew Kordik[2,4], Patrick McCormick[2,3], Cenk Sahin[2]

[1]University of Oklahoma, United States; [2]Air Force Research Laboratory, United States; [3]University of Kansas, United States; [4]Defense Engineering Corporation, United States

The advent of commercial-off-the-shelf (COTS) software-defined radars (SDRs) has enabled low-cost, flexible experimentation with emerging pulse-agile waveform designs to mitigate spectral congestion, improve radar performance, embed communications, and other applications. We examine the impact of direct digital downconversion sampling imperfections in the form of IQ imbalance and DC bias on pulse-agile waveforms. A general framework is developed and examples given for a particular radar-embedded communication waveform. It is shown that the clutter response due to IQ imbalance is significantly increased in a pulse agile framework.

14:20 Impedance Tuning with Notched Waveforms for Spectrum Sharing in Cognitive Radar

Angelique Dockendorf[1], Austin Egbert[1], Adam Goad[1], Caleb Calabrese[1], Benjamin Adkins[1], Brandon Ravenscroft[2], Jonathan Owen[2], Charles Baylis[1], Shannon Blunt[2], Anthony Martone[3], Kyle Gallagher[3], Robert J. Marks II[1]

[1]Baylor University, United States; [2]University of Kansas, United States; [3]Army Research Laboratory, United States

Real-time impedance tuning allows the radar transmitter power amplifier to maximize its output power while adjusting its linearity to meet notch and/or out-of-band spectral requirements. In real-time spectrum sharing, the system decides whether to provide a notched waveform around the interference or to avoid the interference. Considerations in this decision include the maximum detection range obtainable from a tuned amplifier in both cases versus the maximum range resolution, based on the transmitted bandwidth. This paper describes a comparison of a real-time impedance tuning based on spectral constraints for a notched pseudo-random optimized frequency modulated waveform versus a contiguous-band chirp.

Notes:

Tuesday, April 24th, 2018

ADVANCED RADAR WAVEFORM DESIGN ALGORITHMS
13:00 – 14:40
ROOM 3
CHAIR: AUGUSTO AUBRY, *UNIVERSITY OF NAPLES - FEDERICO II*
ANTONIO DE MAIO, *UNIVERSITY OF NAPLES - FEDERICO II*

13:00 Joint Power Allocation for Multicarrier Radar and Communication Coexistence

Fangzhou Wang, Hongbin Li
Stevens Institute of Technology, United States

This paper examines the coexistence of radar and communication systems on a common frequency band using multicarrier waveforms. We propose a sharing based approach, which allows the radar and communication systems to occupy the same subcarrier, but controls the mutual interference through joint power allocation. This leads to a non-convex problem that maximizes the communication throughput under a radar SINR constraint, as well as total and per-subcarrier power constraints for both the radar and communication systems. The problem is solved by an alternating optimization and sequential convex programming algorithm.

13:20 Characterisation of Sidelobes for Multibeam Radar based on Quasi-Orthogonal LFM Waveforms

Alessio Balleri[1], Leon Kocjancic[1], Thomas Merlet[2]
[1]Cranfield University, United Kingdom; [2]Thales Group, France

Multibeam radars (MBRs) enable multiple independent channels by simultaneously exploiting spatial and waveform diversity. The use of orthogonal waveforms is employed to form multiple independent antenna beams, each one providing a different function using diverse radar resources. This paper investigates sidelobe levels in MBRs and present a comparison with those of an Electronic Steerable Array (ESA) that employs a single waveform in transmission. Simulations are carried out for a 3-channel MBR transmitting quasi-orthogonal Linear Frequency Modulated (LFM) waveforms at Ku band. Simulation results corroborate the analytical findings and show that sidelobe levels in MBRs are attenuated by the orthogonal waveform properties of the array.

13:40 Hidden Convexity in Robust Waveform and Receive Filter Bank Optimization for Range Unambiguous Clutter

Augusto Aubry[1], Guolong Cui[2], Antonio De Maio[1], Xiaolin Du[1,2,3]
[1]Università degli studi di Napoli Federico II, Italy; [2]University of Electronic Science and Technology of China, China; [3]Yantai University, China

This paper deals with robust joint design of the transmit waveform and the receive filter bank in a background of range unambiguous signal-dependent clutter. Assuming an unknown Doppler shift for the target, the worst-case signal-tointerference-plus-noise-ratio (SINR) (at the output of the receive filter bank) is considered as figure of merit. The design problem is formulated as a max-min optimization with some constraints on the transmit energy, similarity, and signal dynamic range. Hidden convexity is shown and a procedure to get optimal waveform and filters is given. Simulation results highlight the effectiveness of the devised method.

Tuesday, April 28th, 2020

14:00 Unimodular MIMO Radar Waveform Design under Spectral Interference Constraints

Khaled Alhujaili[1], Xianxiang Yu[2], Guolong Cui[2], Vishal Monga[1]
[1]Pennsylvania State University, United States; [2]University of Electronic Science and Technology of China, China

We propose a new algorithm that designs a transmit beampattern for MIMO radar considering coexistence with other wireless systems. This design process is conducted by minimizing the deviation of the generated beampattern against an idealized one while enforcing the waveform elements to be constant modulus and in the presence of spectral restrictions. This leads to a hard non-convex optimization problem due to simultaneous presence of the constant modulus constraint (CMC) and spectral constraint (SC). In this work, we employ the geometrical structure of CMC, that is we redefine this constraint as an intersection of two sets. The proposed Iterative Beampattern with Spectral design (IBS) algorithm solves a sequence of convex problems. Furthermore, we show that at convergence the obtained solution satisfies the KKT conditions of the problem.

14:20 Time-Frequency Analysis of Spectrally-Notched Random FM Waveforms

Thomas J. Kramer, Shannon D. Blunt
University of Kansas, United States

Various classes of random FM waveforms have recently emerged that are amenable for high-power radar transmitters while providing high dimensionality that facilitates a variety of new applications. One prominent example is the generation of transmit spectral notching to contend with dynamic radio frequency interference (RFI) for the purpose of spectrum sharing. While previous design-focused work has used the aggregate power spectrum and autocorrelation properties of these waveforms to facilitate spectrum-shaping optimization, here we examine their time-frequency characteristics to better understand the efficacy of spectral notching at different time scales.

Notes:

Tuesday, April 24th, 2018

SIGNATURES & RCS

13:00 – 14:40
ROOM 4
CHAIR: SIMON WATTS, *THALES UK (RTD)*
JACQUES CILLIERS, *CSIR*

13:00 Micro-Doppler Signatures of Dynamic Humans from Around the Corner Radar

Shelly Vishwakarma, Aaquib Rafiq, Shobha Sundar Ram
Indraprastha Institute of Information Technology Delhi, India

Recent studies have demonstrated the possibility of sensing dynamic targets around the corners with no direct signal in line-of-sight with respect to the radar. These works have mostly focused on the detection of targets around the corner on the basis of multipath scattering from lateral walls. However, strong specular multipath returns are only obtained for highly conductive walls or at high carrier frequencies. There is minimal research effort into using the existing indoor radar hardware at much lower carrier frequencies for around the corner sensing of targets. In this paper, we have performed a detailed experimental analysis, including both simulations and measurements, of the effect of wall parameters and carrier frequency on the around the corner micro-Doppler signatures of dynamic humans.

13:20 Synthesis of Micro-Doppler Signatures for Abnormal Gait using Multi-Branch Discriminator with Embedded Kinematics

Baris Erol[1], Sevgi Z. Gurbuz[2], Moeness G. Amin[3]
[1]Siemens Corporation, United States; [2]University of Alabama, United States; [3]Villanova University, United States

A key limiting factor in the depth, hence accuracy of deep neural networks (DNNs) designed for radar applications, is the meager amount of data typically available for training. Generative adversarial networks (GANs) have been proposed in many fields for the generation of synthetic data. It was shown, however, that when applied to micro-Doppler signature simulation, GANs suffer from performance degradation due to the generation of kinematically impossible samples. In this work, kinematic analysis of the micro-Doppler signature envelope is integrated as an additional branch in the discriminator network of a GAN to improve the kinematic fidelity of synthetic data when simulating abnormal gait signatures. Results show that the proposed multi-branch GAN network results in greater overlap in the feature space of synthetic abnormal gait samples with that of measured signatures for abnormal gait.

13:40 A Closed Form Radar Cross Section Prediction Modeling for Overhead Wires at Millimeter Waves

Vincent-De-Paul Onana[1], Ozlem Kilic[2]
[1]Catholic University of America, United States; [2]University of Tennessee, United States

A closed form modeling of a RCS prediction of OHWs at mmWaves is presented. Using exact equations of a BTSs, accurately modeling the outermost layer of an OHW, first, cylindrical expansions of the Z-component of the incident plane wave are derived both for TM and TE modes. Using Maxwell equations in cylindrical coordinates, scattered fields are inferred and then closed forms of RCS are deduced in both modes. The proposed RCS modeling is simulated on OHWs ACSR type at 3-mm, 2-mm, and 1-mm waves. The resulting RCSs vs incident angles well highlight Bragg peaks that characterize OHW signatures at mm-waves and are contrasted with previous published ones.

Tuesday, April 28th, 2020

14:00 The use of SigmaHat for Modelling of Electrically Large Practical Radar Problems

M. Potgieter, J.E. Cilliers, C. Blaauw
Council of Scientific and Industrial Research, South Africa

SigmaHat is a computational electromagnetic (CEM) tool developed to solve the electromagnetic (EM) scattering from electrically large targets. The main goal with the development of SigmaHat was to solve practical radar problems. The software is an ideal tool for radar and electronic warfare (EW) engineers to design and investigate various systems as well as gain insight into the underlying scattering mechanisms from complex geometries. This paper demonstrates the capability of SigmaHat as a tool to solve practical radar problems.

14:20 Phenomenology based Missile Classification using Radar Micro-Doppler Processing

Tod M. Schuck, Mark A. Freisel, David B. Reese, Michael A. Villa
Lockheed Martin RMS, United States

Using a pure CW waveform, it is possible to dimension structures that are rotating in the Doppler dimension by exploiting cyclostationary signal processing methods that allow for the replacement of absolute time with the relative periodicity of a rigid body rotating structure across a fixed axis. The formulaic breakdown is given to determine a rotating object’s rotation rate, main body diameter, fin/stabilizer lengths, and the number of fins/scatterers on a rigid body with high precision that is not dependent on the range resolution of the radar.

Notes:

Tuesday, April 24th, 2018

DETECTION & ESTIMATION I

15:10 – 16:50
ROOM 1
CHAIR: FABIOLA COLONE, *SAPIENZA UNIVERSITY OF ROME*
PIERFRANCESCO LOMBARDO, *SAPIENZA UNIVERSITY OF ROME*

15:10 Contrast of Contextual Fisher Vectors for Ship Detection in SAR Images

Xueqian Wang[1], Gang Li[1], Xiao-Ping Zhang[2]
[1]Tsinghua University, China; [2]Ryerson University, Canada

The problem of ship detection based on superpixels in synthetic aperture radar (SAR) images is considered. Existing detectors are often developed according to the simple contrast between the gray-levels of ship targets and their surrounding sea clutter. These detectors are only based on first-order statistics of gray-levels and may suffer from deteriorative performance in low signal-to-clutter ratio (SCR) scenarios because of the blurry SAR images. In this paper, we propose a new detector for ship target detection in SAR images based on the contrast of contextual fisher vectors (CCFVs). CCFV provides more abundant contrast between ship targets and their surrounding background clutter on multi-order information and multi-Gaussian components. Experimental results on the measured SAR images show that, compared with commonly used detectors, the proposed CCFV-based detector achieves better performance especially for weak target detection in low SCR scenarios.

15:30 Deep Temporal Detection – A Machine Learning Approach to Multiple-Dwell Target Detection

Daniel Gusland, Sigmund Rolfsjord, Børge Torvik
Norwegian Defence Research Establishment, Norway

In this paper, we attempt a new approach to radar detection, based on machine learning, to increase the PD while retaining a low PFA. We propose two approaches, using a Convolutional Neural Network (CNN) on the range-Doppler images and stacking multiple range-Doppler images as layers, called the Temporal CNN detector. The models are trained and tested solely on measured radar data by using the estimated position and velocity from a collaborative target UAV. It is shown that training a model based solely on measured data is achievable and performance metrics calculated from the testing data shows that both models outperform the Cell-Averaging Constant False Alarm Rate (CA-CFAR) by having higher PD with the same PFA.

15:50 Software Defined Doppler Radar for Landmine Detection using GA-Optimized Machine Learning

Yan Zhang, Dan Orfeo, Dryver Huston, Tian Xia
University of Vermont, United States

Using software defined radar (SDR) technology and modern machine learning algorithms, this paper demonstrates a software defined Doppler Radar(SDDRadar) system that can distinguish buried non-metallic landmine from other buried objects (rock, wood, etc.) with a high rate accuracy. In the sensing, the spectrum responses of different buried objects are collected using the SDDRadar. The motion spectrum data are fed into a Random Forest where a Genetic Algorithm(GA) is designed to optimize the Random Forest and to improve its performance. To leverage SDDRadar sensitivity, a clutter cancellation circuit is designed and integrated into the system. Two outdoor tests are performed under dry and wet soil conditions. For performance evaluation, the GA-optimized Random Forest is compared with other two machine learning algorithms, including Support Vector Machine and Logistic Regression. As it turns out, the GA optimized Random Forest has the best classification performance in terms of both precision and recall parameters.

Tuesday, April 28th, 2020

16:10 On Threshold Selection for Improved SAR Two-Stage Change Detection

Akshay S. Bondre, Christ D. Richmond
Arizona State University, United States

Cha and others have proposed a two-stage change detection method for detecting areas of change between two synthetic aperture radar images of the same scene, taken at different times, and with the help of experimental results, they have shown that the two-stage change detector performs better than the sample intensity ratio as well as the sample coherence detector. However, they have used a heuristic approach to determine the thresholds for the two-stage change detection test. In this paper, using the joint distribution of the sample intensity ratio and the Berger's coherence estimate, an approach for determining the thresholds for this two-stage change detection method is proposed. Theoretical ROC curve analysis suggests that for a given probability of false alarm, the proposed threshold selection method yields a significantly higher probability of detection as compared to the heuristic approach. Also, it is shown that when some practical considerations are taken into account, a modified detector must be used in order to achieve this improved change detection.

16:30 Generative Adversial Network based Extended Target Detection for Automotive MIMO Radar

Anand Dubey, Jonas Fuchs, Maximilian Lübke, Robert Weigel, Fabian Lurz
Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

In recent years, the automotive radar systems has gained substantial interest for different applications of autonomous driving. The performance of most applications like classification and tracking directly relies on accurate target detection. The state-of-the-art detection pipeline (i.e. algorithm) is vulnerable to multi-path reflections, clutter noise, interference from another radar and leads to false or ghost detections. To address this issue, an end-to-end target detection pipeline using a residual based U-Net architecture is proposed. In contrast to the conventional approach, the network directly generates the detection map from range-Doppler map. The network uses a generative adversarial training over multiple real world measurements. We demonstrate that the proposed network can learn effectively to detect extended targets and shows significant improvement under increased noise floor in comparison to the state-of-the-art detection techniques.

Notes:

Tuesday, April 24th, 2018

EMERGING APPLICATIONS OF SHORT-RANGE RADARS

15:10 – 16:50
ROOM 2
CHAIR: VICTOR C. CHEN, *ANCORTEK INC.*
DAVID TAHMOUSH, *UNIVERSITY OF KANSAS*

15:10 Enhanced Hand Gesture Recognition using Continuous Wave Interferometric Radar

Huaiyuan Liang[1], Xiangrong Wang[1], Maria S. Greco[2], Fulvio Gini[2]
[1]Beihang University, China; [2]University of Pisa, Italy

Recently, radar micro-Doppler signatures have been extensively utilized for hand gesture recognition. As reported by existing works, recognition accuracy of different hand gestures is heavily affected by the aspect angle. In general, the accuracy deteriorates significantly with the increasing aspect angle. To solve this problem, we propose to utilize interferometric radar for hand gesture recognition in this paper, which is capable of providing two-dimensional micro-motions information, referred to as radial and transversal micro-moitions. We record data of 9 different hand gestures in 4 aspect angles, where three empirical features are extracted from both Doppler and interferometric spectrograms and fed into support vector machine classifier for recognition. The experimental results demonstrate that hand gesture recognition using interferometric radar, 1) enhances recognition accuracy, 2) exhibits robustness against aspect angle, 3) recognizes horizontally symmetric gestures, by providing transversal micro-motion information and increasing spatial resolution.

15:30 A Linguistic Perspective on Radar Micro-Doppler Analysis of American Sign Language

Sevgi Z. Gurbuz[1], Ali C. Gurbuz[2], Evie A. Malaia[1], Darrin J. Griffin[1], Chris Crawford[1], M. Mahbubur Rahman[1], Ridvan Aksu[1], Emre Kurtoglu[1], Robiulhossain Mdrafi[2]
[1]University of Alabama, United States; [2]Mississippi State University, United States

Although users of American Sign Language (ASL) comprise a significant minority in the U.S. and Canada, people in the Deaf community have been unable to benefit from many new technologies, which depend upon vocalized speech,and are designed for hearing individuals. While video has led to tremendous advances in ASL recognition, concerns over invasion of privacy have limited its use for in-home smart environments. This work presents initial work on the use of RF sensors, which can protect user privacy, for the purpose of ASL recognition. The new offerings of 2D/3D RF data representations and optical flow are presented. Fractal complexity is shown to differ, on average, between daily activities and ASL usage, and may hence be a means to extract periods of ASL signing from long duration observations of the flow of life.

15:50 Database of Simulated Inverse Synthetic Aperture Radar Images for Short Range Automotive Radar

Neeraj Pandey, Gaurav Duggal, Shobha Sundar Ram
Indraprastha Institute of Information Technology Delhi, India

Inverse synthetic aperture radar (ISAR) images of dynamic targets have been used for automatic target recognition purposes. Limited experimental data of ISAR images of automotive targets are currently available to the radar community. In this paper, we propose an electromagnetic simulation model for generating ISAR images of dynamic automotive targets for a short-range automotive radar. Further, we provide an open-source database of approximately 750 ISAR images for each of five common automotive targets - two cars, truck, bicycle, and auto-rickshaw. Our results show that ISAR images provide useful insights regarding the dimensions of the vehicles, the number of wheels and the orientation of the vehicle along its trajectory with respect to the radar.

Tuesday, April 28th, 2020

16:10 Fast-Time Clutter Suppression in mm-Wave Low-IF FMCW Radar for Fast-Moving Objects

Christopher Allen[1], Levi Goodman[1], Shannon D. Blunt[1], David Wikner[2]
[1]University of Kansas, United States; [2]Army Research Laboratory, United States

A dual-DDS-based, mm-wave, heterodyne, FMCW radar with a 108-GHz center frequency and a 600-MHz bandwidth was used to characterize backscatter from static clutter and a small, fast-moving target. Employing a symmetric triangular frequency-vs-time FMCW waveform with 500-us up-chirp and down-chirp durations, signals from a reusable paintball (reball) with a radial velocity of about 90 m/s were measured in an indoor, clutter-rich environment over intervals of ~100-ms. Unambiguous estimation of the reball's range and radial velocity were derived from observations made during both the up-chirp and down-chirp observations. Specifically, when the reball's echo signal was obscured or degraded by coincident clutter (e.g. during down-chirp), estimates of its amplitude characteristics were obtained from measurements when the reball and clutter were spectrally separable (during up-chirp). Consequently, it is demonstrated that the clutter in this context can be suppressed by more than 25 dB.

16:30 Multi-Modal Cross Learning for Improved People Counting using Short-Range FMCW Radar

Cem Yusuf Aydogdu[1], Souvik Hazra[1], Avik Santra[1], Robert Weigel[2]
[1]Infineon Technologies AG, Germany; [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Radar systems enable remote-less sensing of multiple persons in its field of view. In this paper, we propose a novel people counting system using 60-GHz frequency modulated continuous wave radar sensor. The proposed deep convolutional neural network learns from supervised radar data and also through knowledge distillation via multi-modal cross-learning of representation from a synchronized camera-based deep convolutional neural network. To overcome several shortcomings of the radar data, novel multi-modal cross learning algorithms are proposed, in this paper, that utilizes the high-level abstractions learnt from camera modality. We also propose novel focalregularized loss function to facilitate improved feature learning. We demonstrate the performance of our proposed solution in counting upto 9 people in indoor environment and compare its' performance to state-of-art radar-based uni-modal learning.

Notes:

Wednesday, April 29th, 2020

WAVEFORM & WAVEFORM DIVERSITY II

9:20 – 10:20
POSTER AREA 1
CHAIR: GRAEME SMITH, *JO APPLIED PHYSICS LAB*
KRISTINE BELL, *METSCI*

Long Low-PSL Binary Codes by Multi-Thread Evolutionary Search

Greg E. Coxson[1], Jon C. Russo[2], Angeline Luther[1]
[1]United States Naval Academy, United States; [2]Lockheed Martin Advanced Technology Laboratories, United States

A new evolutionary search algorithm is applied to find binary codes with peak sidelobe levels below those found by other search algorithms. Improved peak sidelobe levels are achieved for selected lengths between 106 and 3000. Likely optimal-PSL binary codes are found for lengths 106 to 112.

Good Code Sets via Coprime Powers

Ravi Kadlimatti
State University of New York at Oswego, United States

It is shown that a good code set with minimum peak cross-correlations (i.e. 1/N in unity magnitude codes of length N) can be generated by replacing z, in any good code (C_N (z))), by a set of coprime powers, each of which generates a member of the set. This is achieved by allowing only two elements of any two codes, one from each, in the set to meet at any relative delay within the correlation window. By beginning with a good code set, each of its members can be transformed into a good code set using the same coprime powers, resulting in a correspondingly larger good code set. The resulting codes are sparse. However, by spreading the generating code elements by any good code or members of a good code set, the average code efficiency can be significantly increased, while still keeping the average cross-correlation small. Such sets could be used in MIMO radar and orthogonal netted radar systems.

Interference Mitigation for a Joint Radar Communication System based on the FrFT for Automotive Applications

Pasquale Striano, Christos V. Ilioudis, Jianlin Cao, Carmine Clemente, John J. Soraghan
University of Strathclyde, United Kingdom

In multi user scenarios to prevent interference between users that share the same bandwidth at the same time, each user has to transmit waveforms that are uncorrelated with those of other users. However, due to spectrum limitations, the uncorrelated property cannot always be satisfied meaning that interference is unavoidable. In order to alleviate the interference, a framework for interference mitigation is presented. The performance of the proposed framework is tested on simulated and real signals. The real signal is acquired in a controlled laboratory environment using a Software Defined Radio (SDR). The simulated and experimental results show that the proposed framework is capable of mitigating the interference from other users.

Wednesday, April 29th, 2020

Design of Constant Modulus Sequences with Doppler Shift Tolerance and Good Complete Second Order Statistics

I.A. Arriaga-Trejo
Universidad Autónoma de Zacatecas, Mexico

The design of phase coded waveforms with a complete second order characterization, resilient to Doppler shifts in a specified interval, is here addressed. A cost function that imposes good second order statistics over a window of interest for different Doppler shifts, is used to determine the phases that minimize it. Due to the design criteria imposed, the resultant sequences minimize the sidelobe levels of the Ambiguity Function (AF) as well as those of an associated function hereby referred to as the Complementary Ambiguity Function (CAF). It is shown by numerical examples, that quasi-Newton optimization methods can be used to determine sets of phases for the discrete time sequences that minimize the cost function, for the given design criteria.

Good Code Sets based on Triangular Chirps with Signed Segments and Different Slopes

Ravi Kadlimatti
State University of New York at Oswego, United States

A good code set based on triangular chirps is introduced. It is shown that changing the sign of one of the segments of the triangular chirp results in a quazi-orthogonal waveform. A good code set is generated by varying the slope and the sign of one of the segments of the triangular chirp. Thus, doubling the number of codes in the set obtained by varying the slope alone while preserving the cross-correlation properties of the set. The different members of the good code set satisfy other important conditions like constant time bandwidth product, tolerance to and the ability to detect Doppler shifts. It also shown that extended matched filters could be used to enhance the Doppler tolerance and detection capability of the codes. The proposed good codes sets could be used for MIMO radar and netted radar applications.

Mismatch Filter Design using Linear Programming

Peter J. Kajenski[1], Adria L. Kajenski[2]
[1]BAE Systems, United States; [2]University of Massachusetts Lowell, United States

Mismatch filters are generally used to reduce the range sidelobes when phase coded waveforms are used. It is shown that such mismatch filters can be designed with linear programming techniques. This particular formulation allows a trade between the degree of sidelobe suppression and the loss to the main peak sensitivity.

Notes:

CLASSIFICATION & MACHINE LEARNING FOR RADAR

9:20 – 10:20
POSTER AREA 2
CHAIR: VINCENZO CAROTENUTO, *UNIVERSITY OF NAPLES FEDERICO II*
SHOBHA SUNDAR RAM, *IIITD-DELHI*

Sparse Range-Doppler Image Construction with Neural Networks

Jabran Akhtar
Norwegian Defence Research Establishment, Norway

The principles outlined by compressed sensing can permit a sensor to collect reduced amount of data and still reconstruct an exact outcome. This can for example be used to generate super-resolution sparse range-Doppler radar images while emitting a reduced number of pulses within a coherent processing interval. In this paper, we investigate the use of neural networks as a mean to solve the sparse reconstruction problem with specific emphasis towards range-Doppler images. The neural networks are trained to generate a sparse Doppler profile from incomplete time domain data in line with traditional sparse L1-norm minimization. We show that this approach is viable through fully connected feed forwarding networks and the results closely mimic sparse recovered range-Doppler maps.

Moving Target Detection and Classification with Dual-Matched Filter Discriminator for Coherent Jammer Suppression in Cognitive Radar

Q. Jeanette O. Tan, Ric A. Romero
Naval Postgraduate School, United States

We introduce an integrated moving target detection and classification closed-loop framework that utilizes a nested dual-matched-filter-discriminator (DMFD) for coherent jammer (CJ) suppression. This is accomplished by incorporating the DMFD into a cognitive radar (CRr) framework utilizing the range-Doppler map (RDM) for extended target detection and classification. The DMFD is a technique that uses mutual information-based matched illumination transmit waveform to mitigate false target detection in the presence of CJ interference. The results from simulation show that this framework identifies and suppresses the CJ emission thereby improving the probability of correct classification in the presence of CJ interference.

Arm Motion Classification using Curve Matching of Maximum Instantaneous Doppler Frequency Signatures

Moeness G. Amin[1], Zhengxin Zeng[2], Tao Shan[2]
[1]Villanova University, United States; [2]Beijing Institute of Technology, China

Hand and arm gesture recognition using the radio frequency (RF) sensing modality proves valuable in man-machine interface and smart environment. In this paper, we use curve matching techniques for measuring the similarity of the maximum instantaneous Doppler frequencies corresponding to different arm gestures. In particular, we apply both Frechet and dynamic time warping (DTW) distances that, unlike the Euclidean (L2) and Manhattan (L1) distances, take into account both the location and the order of the points for rendering two curves similar or dissimilar. It is shown that improved arm gesture classification can be achieved by using the DTW method, in lieu of L2 and L1 distances, under the nearest neighbor (NN) classifier.

Wednesday, April 29th, 2020

Augmenting Simulations for SAR ATR Neural Network Training

Spencer R. Sellers, Peter J. Collins, Julie Ann Jackson
Air Force Institute of Technology, United States

A training data augmentation technique is presented that approximates the differences between measured and simulated SAR imagery. This method is applied to simulated images and a CNN is trained with them. We achieve over 95% cross-class classification using the SAMPLE dataset from AFRL, with 1% measured data in the training set. We compare this to 89.6% accuracy when the augmentation technique is not used. Our hypothesis is that, while simulations can be made to approximate the measurements very closely, further augmentation can increase accuracy over non-augmented simulations.

Automotive Radar Interference Mitigation using a Convolutional Autoencoder

Jonas Fuchs, Anand Dubey, Maximilian Lübke, Robert Weigel, Fabian Lurz
Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Automotive radar interference imposes big challenges on signal processing algorithms as it raises the noise floor and consequently lowers the detection probability. With limited frequency bands and increasing number of sensors per car, avoidance techniques such as frequency hopping or beamforming quickly become insufficient. Detect-and-repair strategies have been studied intensively for the automotive field, to reconstruct the affected signal samples. However depending on the type of interference, reconstruction of the time domain signals is a highly non-trivial task, which can affect following signal processing modules. In this work a autoencoder based convolutional neural network is proposed to perform image based denoising. Interference mitigation is phrased as a denoising task directly on the range-Doppler spectrum. The neural networks shows significant improvement with respect to signal-to-noiseplus- interference ratio in comparison to other state-of-the-art mitigation techniques, while better preserving phase information of the spectrum compared to other techniques.

Avoiding Jammers: A Reinforcement Learning Approach

Serkan Ak, Stefan Brüggenwirth
Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany

This paper investigates the anti-jamming performance of a cognitive radar under a partially observable Markov decision process (POMDP) model. First, we obtain an explicit expression for the uncertainty of jammer dynamics, which enables us to discover new insights into the performance metric of probability of being jammed for the radar beyond a conventional signal-to-noise ratio (SNR) based analysis. Considering two frequency hopping strategies developed in the framework of reinforcement learning (RL), this performance metric is analyzed with deep Q-network (DQN) and long short term memory (LSTM) networks under various uncertainty values.

Optimal Time-Frequency Distribution Selection for LPI Radar Pulse Classification

Ben Willetts, Matthew Ritchie, Hugh Griffiths
University College London, United Kingdom

The work presented in this paper shows the performance of various time-frequency distributions when gathering ELectronic INTelligence (ELINT) from an electromagnetic environment that contains transmissions from radars operating in a Low Probability of Interception (LPI) mode. A radar device varying waveform parameters on a pulse-by-pulse basis to enhance sensing capabilities and/or to avoid interception warrants a method that can assign a unique Pulse Descriptor Word (PDW) to each pulse detected. The simulations presented here makes use of a Deep Learning classifier that is fed by time-frequency images of noisy LFM pulses that each have unique signal parameters. The performance of the radar pulse classifier is conveyed for multiple time-frequency methods. The results show that the time-frequency representation requirements for accurate PDW generation varies for each signal parameter being estimated whilst also having a dependence on the SNR of the intercepted signal.

Wednesday, April 29th, 2020

Analysis and Mitigation of Receiver Induced Nonlinearities on Pulse-Doppler Radars

Nicholas Peccarelli, Zachary Peck, J. Landon Garry
Johns Hopkins University Applied Physics Laboratory, United States

Receiver nonlinearities can degrade pulse-Doppler radar performance when strong interferers are present. Nonlinear equalization (NLEQ), typically used to digitally mitigate receiver distortions, has the potential to reduce intermodulation distortion (IMD) and cross-modulation distortion (CMD) that may be incurred when strong adjacent channel signals are present. This article reports on an investigation of NLEQ's viability to counter these deleterious effects and improve radar system performance. A simulation was developed analyzing the received signal for a weak target return in the presence of a strong adjacent band interferer, which was present for a fraction of the coherent processing interval (CPI). The receive signal's spectral regrowth increased the radar's in-band noise floor and corrupted the magnitude and phase of the target response, degrading the receive pulse-Doppler processing. It is shown that NLEQ can be used to compensate for these receiver-induced nonlinearities thus improving radar system performance.

Notes:

MULTISTATIC, IMAGING & ATR

9:20 – 10:20
POSTER AREA 3
CHAIR: DEBORA PASTINA, *SAPIENZA UNIVERSITY OF ROME*
JOE DEROBA, *NA*

Resolution Enhancement in High Resolution Wide Swath MIMO SAR

Mohammed Alshaya, Mehrdad Yaghoobi, Bernard Mulgrew
University of Edinburgh, United Kingdom

A new MIMO SAR configuration is proposed to map wider image swaths with higher cross-range. It allows the use of all the phase centres including the overlapping ones to reduce the minimum PRF. The waveforms used for transmission share the same bandwidth and centre frequency. Echoes corresponding to different phase centres are separated at the receiver using digital beamforming (DBF) on receive in elevation. The estimated range profile is IRCI-free as an FDSI-based estimation algorithm is used to identify the impulse response in the range dimension. Finally, simulated data is used to validate the effectiveness of the proposed configuration.

Robustness of SAR Refraction Autofocus to Power-Law Errors

David A. Garren
Naval Postgraduate School, United States

A recent analysis has yielded a non-parametric methodology which automatically estimates and compensates for atmospheric refraction defocus in synthetic aperture radar (SAR) imagery. Such deleterious defocus effects result from the delay and bending of the individual SAR radar pulses as they refraction through the atmosphere. A primary benefit of the recent data-driven refraction autofocus is that it is robust to non-parametric delay and bending errors which can vary from one pulse to the next, as arises due to changing atmospheric conditions along the synthetic aperture of the radar's trajectory. The current investigation examines the robustness of these techniques for realistic scenarios in which the refraction-induced delay and bending vary in time according to a power-law spectrum. Specifically, this refraction autofocus methodology yields sharp scene focus when applied to measured Ku-band SAR imagery in which power-law errors have been injected into the delay and bending of the radar pulses.

Multi-Feature Encoder for Radar-Based Gesture Recognition

Yuliang Sun[1,2], Tai Fei[1], Xibo Li[1], Alexander Warnecke[1], Ernst Warsitz[1], Nils Pohl[2]
[1]HELLA GmbH & Co. KGaA, Germany; [2]Ruhr-Universität Bochum, Germany

In this paper, a multi-feature encoder for gesture recognition based on a 60 GHz frequency-modulated continuous wave (FMCW) radar system is proposed to extract the gesture characteristics, i.e., range, Doppler, azimuth and elevation, from the low-level raw data. The radar system updates the hand information for each measurement-cycle on all the scattering centers in its field of view, and our proposed encoder is devised to only focus on those essential scattering centers. After observing the hand over several measurement-cycles, we encode the gesture characteristics sequentially into a 2-D feature matrix, which is successively fed into a shallow convolutional neural network (CNN) for classification. For the purpose of distinguishing relevant gestures, the proposed multi-feature encoder is able to efficiently extract adequate information from a multi-dimensional feature space. Thus, the proposed approach is practical for industrial applications where the available dataset is mostly small-scale. The experimental results show that the proposed multi-feature encoder could guarantee a promising performance for a gesture dataset with 12 gestures.

Wednesday, April 29th, 2020

Minimum Entropy Autofocus Correction of Range-Varying Phase Errors in ISAR Imagery

Joshua M. Kantor
MIT Lincoln Laboratory, United States

In this article, we present an ISAR autofocus algorithm that compensates for range-varying phase errors which can degrade ISAR imagery formed with an unknown rotation rate. Our algorithm is non-parametric and is capable of dealing with a non-constant rotation rate. The algorithm described is based on optimizing image focus by minimizing the image entropy.

Bayes-SAR Net: Robust SAR Image Classification with Uncertainty Estimation using Bayesian Convolutional Neural Network

Dimah Dera[1], Ghulam Rasool[1], Nidhal C. Bouaynaya[1], Adam Eichen[2], Stephen Shanko[2], Jeff Cammerata[1], Sanipa Arnold[2]
[1]Rowan University, United States; [2]Lockheed Martin Rotary and Mission Systems, United States

Synthetic aperture radar (SAR) image classification is a challenging problem due to the complex imaging mechanism as well as the random speckle noise, which affects radar image interpretation. Recently, convolutional neural networks (CNNs) have been shown to outperform previous state-of-the art techniques in computer vision tasks owing to their ability to learn relevant features from the data. However, CNNs in particular and neural networks, in general, lack uncertainty quantification and can be easily deceived by adversarial attacks. This paper proposes Bayes-SAR Net, a Bayesian CNN that can perform robust SAR image classification while quantifying the uncertainty or confidence of the network in its decision. Bayes-SAR Net propagates the first two moments (mean and covariance) of the approximate posterior distribution of the network parameters given the data and obtains a predictive mean and covariance of the classification output. Experiments, using the benchmark data-sets Flevoland and Oberpfaffenhofen, show superior performance and robustness to Gaussian noise and adversarial attacks, as compared to the SAR-Net homologue.

Embedded Micro Radar for Pedestrian Detection in Clutter

Zhe Zhang[1], Michael Jian[2], Zhenzhong Lu[2], Honglei Chen[3], Sara James[3], Chaofeng Wang[3], Rick Gentile[3]
[1]George Mason University, United States; [2]Ancortek Inc., United States; [3]Mathworks Inc., United States

Embedded micro radars that include integrated hardware, application software, and a real-time operating system as part of an enclosed system provide convenient platforms for outdoor and indoor environment monitoring. This paper discusses methods to suppress clutter and to extract features of weak radar targets, such as pedestrians. With the help of MATLAB® simulation tools, algorithms to detect pedestrians in a high clutter environment can be investigated. A hybrid neural network is developed on micro-Doppler signatures generated synthetically. It outperforms the traditional convolutional neural network in terms of accuracy and the amount of training data required. We then use an embedded micro radar for field trials to test the performance of the hybrid neural network on real data sets.

Chaff Discrimination using Convolutional Neural Networks and Range Profile Data

Utku Kaydok
Roketsan A.S., Turkey

In this paper a method for chaff and ship discrimination is discussed. The method uses one dimensional range profile data for the input of the convolutional neural network (CNN). The classification results for the CNN running on MATLAB and using Levenberg-Marquardt algorithm is presented for a database composed of 3 types of ship and one type of chaff. This input database is corrupted with different levels of sea clutter in order to conclude on the performance of the CNN in different SCR conditions. The same CNN also built using Python with Tensorflow backend. The CNN tested for the database corrupted with sea clutter having a Gaussian spectral function on Python. Classification rates starting from % 87 for low SCR (5 dB) up to %99 for high SCR (20 dB) are obtained for the ship and chaff database corrupted with sea clutter on MATLAB.

Wednesday, April 29th, 2020

An Optimal Multistatic Synthetic Aperture Radar Reconstruction Filter

John Summerfield
University of Massachusetts Lowell, United States

Approximations are used to overcome spatial and time variations in the multistatic synthetic aperture radar (MSAR) image formation process in order to define an optimal reconstruction filter that maximizes signal to noise ratio (SNR), clutter to noise ratio (CNR), and target to clutter ratio (TCR). The objective is to geolocate a known target with unknown position. The target is surrounded by homogeneous clutter while return signals are corrupted by thermal noise in each receiver.

Measurement of Opaque Container Contents by an M-Sequence UWB Radar

Martin Pečovský[1], Pavol Galajda[1], Miroslav Sokol[1], Martin Kmec[2]
[1]Technical University of Kosice, Slovakia; [2]Ilmsens GmbH, Germany

This paper deals with the method for liquid or powder level measurement inside closed non-metallic opaque containers. The proposed method uses the progressive M-sequence short-range radar technology which achieves high measurement precision and according to previous publications, allows not only the localization of the desired material interface, but is capable to estimate material properties as well. In the first part of the article, the M-sequence radar system is described. Later, the measurement technique is proposed using a low-cost microstrip transmission line as a probe. In the final parts, simulations and measurement results are presented to confirm the viability of the proposed method. The measurements show that the proposed method is able to distinguish the liquid level changes of less than 1 mm in a simple measurement setup.

Comparison of the Mutual Information Content between the Polarimetric Monostatic and Bistatic Measured RCS Data of a 1:25 Boeing 707 Model

J.E. Cilliers[1], M. Potgieter[1], C. Blaauw[1], J.W. Odendaal[2], J. Joubert[2], K. Woodbridge[3], C.J. Baker[4]
[1]Council of Scientific and Industrial Research, South Africa; [2]University of Pretoria, South Africa; [3]University College London, United Kingdom; [4]University of Birmingham, United Kingdom

Many studies have suggested that a fully polarimetric radar or a bistatic radar can improve the classification and recognition of airborne targets due to enhanced target information. This paper makes use of the information theoretic concept of mutual information (MI) and investigates the comparison of the MI content between polarimetric monostatic and bistatic radar cross section (RCS) measurements of a 1:25 Boeing 707 scale model. It aims to quantify the increases in the MI content, and hence recognition performance, due to the additional reflected signals available in a fully polarimetric radar or in a bistatic scenario.

Conventional SAR Change Detection using Methods for Non-Conventional SAR

Viet T. Vu[1], Mats I. Pettersson[1], Thomas K. Sjören[2]
[1]Blekinge Institute of Technology, Sweden; [2]Swedish Defence Research Agency, Sweden

Conventional SAR refers to conventional systems with small fractional bandwidth and short relative aperture whereas non-conventional SAR refers to non-conventional systems with large fractional bandwidth and long relative aperture. There are a large number of change detection methods developed for non-conventional SAR. A research question is that whether these change detection methods are available for conventional SAR or not. In this study, we will try to answer this research question by applying a change detection method developed for non-conventional SAR system to conventional SAR system

Wednesday, April 29th, 2020

Notes:

Wednesday, April 29th, 2020

CONTINUING INFLUENCE OF KARL ROBERT GERLACH, TRIBUTES IN MEMORIAM

10:20 – 12:00
ROOM 1
CHAIR: ERIC L. MOKOLE, *THE MITRE CORPORATION*
SHANNON D. BLUNT, *UNIVERSITY OF KANSAS*

10:20 A Dynamical Model for the Statistical Variation of Clutter

K. James Sangston
Georgia Institute of Technology, United States

We examine the effect that fluctuations in the number of elementary scatterers contributing to a scattered signal have on the amplitude statistics of the scattered field. In particular, we posit that the number of scatterers fluctuates due to the interaction of a limited swath with an environment in which the number of scatterers is Poisson distributed on a local basis but with an underlying Poisson intensity that varies in space and/or time. As an example we derive K distributed statistics as a function of the radar range resolution size, with the expected result that as the range resolution increases the tails of the distribution increase (i.e. the distribution gets spikier).

10:40 Design and Analysis of Adaptive Sidelobe Blanking Architectures

A. Aubry[1], A. De Maio[2], G. Di Maria[1], A. Farina[2], S. Iommelli[1]
[1]Università degli studi di Napoli Federico II, Italy; [2]Technical Consultant, Italy

The paper starts with a brief retrace of some seminal publications of Dr. K. R. Gerlach on adaptive antennas. This legacy motivates the core of the present paper which addresses the design of SideLobe Blanking (SLB) architectures capable of providing Electronic Protection (EP) against a coherent repeater interference in the presence of continuous jamming signals. In this respect, a generalized adaptive beamforming technique which synthesizes the SLB auxiliary channel output, is introduced. Then, an optimization algorithm is developed to design the adaptive weights so that the resulting outputs fulfill SLB specific requirements. The effectiveness of the resulting architecture is assessed in terms of sidelobe pattern and continuous jamming rejection.

11:00 Structure-Based Adaptive Radar Processing for Joint Clutter Cancellation and Moving Target Estimation

Christian C. Jones[1], Lumumba A. Harnett[1,2], Charles A. Mohr[1,3], Shannon D. Blunt[1], Christopher T. Allen[1]
[1]University of Kansas, United States; [2]U.S. Naval Research Laboratory, United States;
[3]U.S. Air Force Research Laboratory, United States

During his many years with the Radar Division of the US Naval Research Laboratory (NRL) Dr. Karl Gerlach made significant contributions to adaptive interference cancellation for radar. For this memorial tribute special session, this paper leverages the reiterative minimum mean square error (RMMSE) estimator, which he also helped to develop, to formulate two techniques whereby interference cancellation is performed jointly with signal estimation as a way to enhance the subsequent range-Doppler response. Experimental results are demonstrated using free-space measurements from pulsed, nonrepeating waveforms at S-band and standard FMCW at W-band.

Wednesday, April 29th, 2020

11:20 The L^{2P} Canceller

Karl Gerlach, Kevin Wagner
United States Naval Research Laboratory, United States

In this manuscript a treatment of the L^{2P} canceller is presented for real and complex inputs. The L^{2P} canceller seeks to minimize the 2P -norm for integer values of P . Minimizing the 2P -norm approximates the mini-max function as P increases.

11:40 M-Cancellers: Tunable, Robust, Rapid-Converging, Parallel/Pipeline, Linear Adaptive Processors

Michael L. Picciolo[1], J. Scott Goldstein[2], Wilbur L. Myrick[1]
[1]ENSCO, United States; [2]SAIC, United States

We present M-cancellers, a novel class of robust and fast-converging linear adaptive processors with a single tuning parameter that trades sensitivity (output noise power) for robustness. The analysis assumes a general epsilon-contaminated noise model, with Gaussian as a special case. Both the conventional Sample Matrix Inversion (SMI) processor and its numerically equivalent form, the Gram Schmidt Cascaded Canceller (GSCC), are well known to be non-robust to outliers and non-Gaussian noise. We show M-Cancelers (after Huber's robust M-estimators) offer an elegant solution based on a new location filter theory developed herein to replace Wiener filter theory. Using location theory, canceller performance can be optimized jointly to the expected level of contamination and to the assumed dominant noise distribution. This work is inspired by, and builds on, the remarkable contributions of Dr. Karl Gerlach, a pioneer in the fields of radar and adaptive processing algorithms.

Notes:

OVER THE HORIZON RADAR

10:20 – 12:00
ROOM 2
CHAIR: JOE FABRIZIO, *DEFENCE SCIENCE AND TECHNOLOGY GROUP*
MARCO MARTORELLA, *UNIVERSITY OF PISA*

10:20 Doppler Signature Analysis of Mixed O/X-Mode Signals in Over-the-Horizon Radar

Ammar Ahmed[1], Yimin D. Zhang[1], Braham Himed[2]
[1]Temple University, United States; [2]Air Force Research Laboratory, United States

We analyze the Doppler signatures of local multipath signals in an over-the-horizon radar in the presence of both ordinary (O) and extraordinary (X) polarization modes. As the ionospheric signal reflection for the two polarization modes varies from each other, the existing local multipath model developed for a single polarization mode must be extended to account for such a propagation environment. In this paper, we focus on the case with small delays between the signals corresponding to the two propagation modes. We exploit the multipath signal model considering the mixed O/X mode signals and analyze the variation in the resulting Doppler signatures. The analytical as well as numerical results show that the existence of both O/X polarization modes renders more signal components with close Doppler signatures. In the underlying situation with small delays between the two modes, the mixed O/X-mode signals corresponding to each local multipath signal component are unresolvable and yield time-varying fading magnitude. Accurate parameter estimation is still achieved using fractional Fourier transform over a longer coherent processing time.

10:40 Group Sparsity-Based Local Multipath Doppler Difference Estimation in Over-the-Horizon Radar

Vaishali S. Amin[1], Yimin D. Zhang[1], Braham Himed[2]
[1]Temple University, United States; [2]Air Force Research Laboratory, United States

In sky-wave over-the-horizon radar systems, the received signal contains local multipath signal components as a result of reflection and refraction from ionosphere and the earth surface. For a maneuvering target, these multipath signals generally yield three distinct, yet closely separated, and highly time-varying Doppler components. Due to the proximity of these Doppler frequencies, it is a challenging task to accurately estimate the difference between these signatures, which reveal the important elevation velocity of the target. In this paper, we propose a group sparsity-based approach that exploits the correlation between these Doppler signatures and utilizes the a priori information about their characteristics. Simulation results verify the effectiveness of the proposed approach.

11:00 Receive Arrays for Polar Over-the-Horizon Radar

Ryan J. Riddolls, Simon Hénault
Defence Research and Development Canada, Canada

Receive array design for Polar Over-the-Horizon Radar is driven primarily by the need to mitigate auroral radar clutter that appears at all azimuth angles. Arrays must be adequate to enable the detection and location of targets in the presence of this clutter. While it is feasible to deploy a maximum-performance large two-dimensional antenna grid at half-wavelength element spacing, thinning of the array can reduce cost. Based on an analytic clutter model, it is shown that the element density could potentially be halved without significant decrease in performance. Thinning to one-quarter density starts to incur noticeable perfomance impacts.

Notes:

Wednesday, April 29th, 2020

SPECTRUM SHARING I
10:20 – 12:00
ROOM 3
CHAIR: JUSTIN METCALF, *UNIVERSITY OF OKLAHOMA*
CENK SAHIN, *USAF*

10:20 Experimental Assessment of Joint Range-Doppler Processing to Address Clutter Modulation from Dynamic Radar Spectrum Sharing

Brandon Ravenscroft[1], Jonathan W. Owen[1], Benjamin H. Kirk[2], Shannon D. Blunt[1], Anthony F. Martone[3], Kelly D. Sherbondy[3], Ram M. Narayanan[2]
[1]University of Kansas, United States; [2]Pennsylvania State University, United States;
[3]Army Research Laboratory, United States

Cognitive sense-and-avoid (SAA) and sense-and-notch (SAN) emission strategies have recently been experimentally demonstrated as effective ways in which to reduce the interference a spectrum-sharing radar causes to other in-band users. In both cases, however, it has been observed that when the spectral content occupied by the radar changes during the coherent processing interval (CPI) in response to dynamic radio frequency interference (RFI), a nonstationarity in the form of clutter modulation is induced that degrades clutter cancellation. Here the joint range/Doppler processing formulation known as non-identical multiple pulse compression (NIMPC) is briefly reviewed and then experimentally evaluated for this problem. The additional degrees of freedom provided by NIMPC are shown to compensate for this clutter modulation effect to a significant degree.

10:40 Amplifier Performance Limits on Dual Function Radar and Communication

Alan O'Connor[1], Nicholas A. O'Donoughue[2]
[1]Analog Devices, Inc., United States; [2]RAND Corporation, United States

Congestion in the electromagnetic spectrum has spurred a significant body of work on the topic of spectrum sharing. One avenue of research is Dual-Function Radar Communications (DFRC), in which a single system performs both radar and communications tasks. Numerous approaches to DFRC have been proposed, but there has been no direct comparison of the efficiency with which different approaches utilize the shared array's capabilities. This paper considers the impact of amplifier nonlinearity on the performance of simultaneous dual-beam (SDB) DFRC, and how nonlinearity affects the competitiveness of SDB against alternative concepts, including timesharing and aperture partitioning. We show that SDB operation is most efficient if the additional beams and out-of-band signals produced by the amplifier nonlinearity can be tolerated.

11:00 Target Sidelobes Removal via Sparse Recovery in the Subband Domain of an OFDM RadCom System

Stéphanie Bidon, Damien Roque, Steven Mercier
University of Toulouse, France

In this paper, the problem of target masking induced by sidelobes arising in an OFDM RadCom System is considered. To fully exploit the waveform structure and address practical scenarios, we propose to deal with the sidelobes in the subband domain via sparse recovery. Accordingly, we design a sparsifying dictionary modeling at the same time the target's peak and pedestal. Results on synthetic data show that our approach allows one to remove not only the target random sidelobes but also range ambiguities arising when all subbands are not active.

Wednesday, April 29th, 2020

11:20 Controlling Clutter Modulation in Frequency Hopping MIMO Dual-Function Radar Communication Systems

***Indu Priya Eedara*[1], *Moeness G. Amin*[1], *Aboulnasr Hassanien*[2]**
[1]Villanova University, United States; [2]Wright State University, United States

We present a dual-function radar communication system applying signal embedding through code shift keying strategy. The information symbol is phase encoded into a sequence and then modulated by the continuous phase modulation before embedding into frequency-hopping radar sub-pulses. The CPM modulated communication symbol phase coded sequence is multiplied with the FH radar waveforms in fast-time and transmitted through multiple-input multiple-output (MIMO) radar platforms. In this paper, we address the problem of range sidelobe modulation (RSM) and propose the design of the optimum CSK sequences to reduce the degree of change in the range sidelobe levels of the ambiguity function. It is shown that the optimum CSK sequences yield a significant reduction in the RSLs of the DFRC system. They also maintain the same degree of correlation between FH sub-pulses regardless of the communication symbol sequences embedded. Additionally, the proposed DFRC system with the optimized waveform design provides good spectrum containment and achieves high communication data rates.

11:40 Impact of Adjacent/Overlapping Communication Waveform Design within a Radar Spectrum Sharing Context

***Justin G. Metcalf*[1], *Cenk Sahin*[2], *Patrick McCormick*[2], *Shannon D. Blunt*[3]**
[1]University of Oklahoma, United States; [2]Air Force Research Laboratory, United States; [3]University of Kansas, United States

We consider the design of spectrum sharing communication waveforms that may partially overlap spectrally with a pulse-Doppler radar yet maintain a low, predictable level of interference with radar operation. This is in contrast to traditional communication symbol designs, which interfere with radar operation despite having a negative interference-to-noise ratio. Several legacy designs are presented, as well as a new waterfilling design that results in significant reduction in interference to the radar while maintaining comparable symbol error rate performance.

Notes:

Wednesday, April 29th, 2020

AUTOMOTIVE & TRANSPORTATION

13:00 – 14:40
ROOM 1
CHAIR: IGAL BILIK, *GM*
STEPHANIE BIDON, *ISAE SUPAERO*

13:00 Phase-Coded FMCW Automotive Radar: Application and Challenges

Faruk Uysal, Simone Orru
Delft University of Technology, Netherlands

Phase-Coded frequency-modulated continuous-wave (PC-FMCW) radar is an emerging radar system with its unique features such as enabling joint sensing and communication or advanced interference mitigation. Even though radars with phase coding capabilities are available in the automotive radar market today, there are some challenges in phase coded radar applications. With this paper we demonstrate multiple bit coding per single transmit chirp waveform in a FMCW automotive radar system for the first time. We concentrate on the sensing aspect of PC-FMCW radar and point out the challenges due to instantaneous phase change. To overcome these issues and improve sensing performance, this paper proposes a smart filtering method which consists of rejection filtering and signal recovery steps.

13:20 Radar Cross-Section of Potholes at Automotive Radar Frequencies

Abhilasha Srivastava, Abhishek Goyal, Shobha Sundar Ram
Indraprastha Institute of Information Technology Delhi, India

Automated detection of potholes in roads canincrease driving safety for both passengers and vehicles. Potholes-especially those covered with water - are hard to detect usingcameras, while vibration based detection using accelerometerscannot be used to find potholes ahead of the ego vehicle. In this paper, we study the feasibility of pothole detection usingautomotive radar by estimating and contrasting the potholeradar cross-section (RCS) with the backscatter from a flat road.We estimate the two-dimensional RCS of potholes from thescattered electric field simulated using finite difference timedomain techniques. Our results show that the potholes give rise tosignificant backscatter only when the electrical properties of thepothole material are sufficiently different from the neighboringground material. The size, depth and curvature of the potholesgive rise to only slight variations in the RCS. Also, the RCS frompotholes filled with air and rainwater are comparable due to thelow dielectric constant and conductivity of rainwater.

13:40 Beam Squint Correction for Phased Array Antennas using the Tansec Waveform

Oren Longman, Gaston Solodky, Igal Bilik
General Motors, Israel

A phased array antenna controls its beam steering direction by phase differences between signals transmitted from multiple antenna elements. These phase differences are determined by antenna geometry and carrier frequency. Radars with frequency-modulated waveforms and phased array antennas operating with a large bandwidth suffer from beam steering direction errors, denoted as squint. This work proposes to use the nonlinear frequency-modulated Tansec waveform. Where, proper design allows to compensate for beam squint. A method for Tansec waveforms selection is derived and its ability to mitigate beam squint is demonstrated with simulations.

Wednesday, April 29th, 2020

14:00 On the Measurement of Range and its Time-Derivatives in LFMCW Radar

Peter E. Asuzu
Veoneer Inc., United States

This paper examines the simultaneous measurement of range and its time-derivatives in Linear Frequency Modulated Continuous Wave (LFMCW) radar. A signal model is developed to highlight the influence of velocity modulations on estimating higher range derivatives. Experimental results demonstrate the validity of the signal model and the merits of simultaneously estimating range and its derivatives such as acceleration and jerk.

14:20 Accurate Time Synchronization for Automotive Cooperative Radar (CoRD) Applications

Ofer Bar-Shalom, Nir Dvorecki, Leor Banin, Yuval Amizur
Intel Corp., Israel

The increasing amount of automotive radars makes mutual radar interference a prominent problem. Cooperation between the radars could not only minimize their mutual level of interference but would also enable remote radar nodes to operate synchronously for jointly improving their performance. The concept of Collaborative Time of Arrival (CToA) has recently been proposed for enabling distributed wireless network synchronization. In this paper, we explore the application of CToA to automotive radar systems for achieving sub-nanosecond level synchronization between radar nodes. The proposed scheme, dubbed ``cooperative radar'' (CoRD), opens a wide range of applications including bistatic automotive radars.

Notes:

Wednesday, April 29th, 2020

PASSIVE RADAR II

13:00 – 14:40
ROOM 2
CHAIR: JONATHON BLUESTONE, *BAE SYSTEMS*
HUGH GRIFFITHS, *UNIVERSITY COLLEGE LONDON*

13:20 Estimation of Transmitter Position based on Known Target Trajectory in Passive Radar

Mateusz Malanowski, Krzysztof Kulpa, Marcin Żywek, Maciej Wielgo
Warsaw University of Technology, Poland

The paper deals with the problem of estimating the unknown transmitter position in passive radar. It is assumed that the radar is using an illuminator of opportunity, whose position is not known, but the bistatic measurements of a target or targets are obtained. If the Cartesian trajectories of those targets are known, e.g. from GPS or ADS-B, the transmitter position can be found by matching converted trajectories into the bistatic domain.

13:40 Tackling the Different Target Dynamics Issues in Counter Drone Operations using Passive Radar

Tatiana Martelli, Francesca Filippini, Fabiola Colone
Sapienza University of Rome, Italy

This paper deals with the detection of small drones in high-density target scenarios such as airport terminal areas. In such conditions, strong reflections by high RCS targets are likely to prevent the detection of very weak target echoes. The work aims at overcoming this issue by taking advantage of long coherent integration times and by implementing a CLEAN-like algorithm to remove the strongest target contributions. The effectiveness of the proposed strategy is first demonstrated against simulated data. Then, a preliminary experimental result is shown, obtained against data collected by the DVB-T based AULOS ® passive radar developed by Leonardo S.p.A..

14:00 Experimental Results of Polarimetric Passive ISAR Exploiting DVB-S2 Illumination

Iole Pisciottano[1,2], Diego Cristallini[1], Debora Pastina[2], Fabrizio Santi[2]
[1]Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany; [2]Sapienza University of Rome, Italy

This paper shows a first analysis of polarimetric passive ISAR images exploiting a geostationary satellite. The data collected by means of an experimental system over a cooperative target have been firstly processed by means of backprojection to obtain ISAR images at each polarimetric channel. Then two different representations in the polarimetric domain are considered: a color coding based on a modified Pauli decomposition and the evaluation of the determinant of the Sinclair scattering matrix. Different scattering mechanisms within the same target behave differently in the polarimetric domain, assessing the usefulness of the polarimetric information in passive ISAR images.

Wednesday, April 29th, 2020

14:20 Ground Mapping using Active and Passive UHF-Band SAR

Lars M.H. Ulander, Per-Olov Frölind, Anders Gustavsson, Anders Haglund, Rolf Ragnarsson, Thomas Sjögren
Swedish Defence Research Agency, Sweden

Synthetic-aperture radar (SAR) is normally used in an active mode for ground surveillance. Passive SAR has also been demonstrated using DVB-T (Digital Video Broadcasting – Terrestrial) signals from TV-broadcasting masts as illuminators of opportunity. However, simultaneous active and passive SAR have not yet been demonstrated. In this paper, we compare active and passive SAR and describe a system which can perform acquisition of both active and passive UHF-band SAR-data onboard an airborne platform. We also show, for the first time, active and passive SAR images processed from data acquired during the same flight.

Notes:

Wednesday, April 29th, 2020

ELECTRONIC WARFARE

13:00 – 14:40
ROOM 3
CHAIR: LORENZO LO MONTE, *TELEPHONICS*
PIOTR SAMCZYNSKI, *WARSAW UNIVERSITY OF TECHNOLOGY*

13:00 An Adaptive Spectrogram and Accelerogram Algorithm for Electronic Warfare Applications

Karol Abratkiewicz, Piotr Samczyński
Warsaw University of Technology, Poland

This paper presents a novel adaptive approach to spectrogram and accelerogram calculation based on the signal chirp rate. Such a method may be useful in electronic intelligence, electronic warfare and electronic reconnaissance or in passive bistatic radar systems where waveform parameters are unknown. The proposed approach was tested and verified using real-life signals coming from the Air Traffic Control (ATC) radar.

13:20 Adaptive Subspace Mappings for Super-Resolving Multiple Main-Beam Targets in Jamming

Manuel F. Fernández[1], Kai-Bor Yu[2]
[1]Independent Researcher, United States; [2]Shanghai Jiao Tong University, China

We show how to super-resolve multiple main-beam targets in the presence of interfering signals such as those due to jamming or clutter returns. This is done via low-dimensionality adaptive mappings that insert nulls at the interfering locations while preserving the target-containing spatial-response region of interest. The outputs resulting from applying such mappings to a snapshot of array data are then used to populate a couple of matrices whose generalized eigenvalues provide the super-resolved spatial locations of the main-beam signals of interest.

13:40 Open-Set Radar Waveform Classification: Comparison of Different Features and Classifiers

Rohit V. Chakravarthy[1], Haoran Liu[2], Anne M. Pavy[3]
[1]The Ohio State University, United States; [2]Indiana University Bloomington, United States;
[3]Air Force Research Laboratory, United States

Performing open set classification of radar waveforms is a difficult problem due to issues including varying signal to noise ratio (SNR), complexity of the data, lack of separability between classes of interest, as well as the crowded nature of the spectrum. In addition, the evolving spectrum may lead to a situation where not every waveform is present in the training library. This paper addresses these challenges by the combination of obtaining machine learning features directly from the waveform, subsequently followed by a classification algorithm. The machine learning technique used in this paper is a discriminative network, specifically a convolutional neural network (CNN), for feature extraction. The classifier employed is SV-Means, a quantile one-class support vector machine-based algorithm (q-OCSVM), with the ability to reject unknown waveform classes while also providing an estimation of the likelihood of the class of interest being a member of the waveform library. A combination of these two methods results in a system of high credibility taking into account the challenges noted.

Wednesday, April 29th, 2020

14:00 Sparsity-Based Time-Frequency Analysis for Automatic Radar Waveform Recognition

Shuimei Zhang, Ammar Ahmed, Yimin D. Zhang
Temple University, United States

In this paper, we develop a novel pre-processing algorithm to achieve effective signal denoising for improved recognition of noisy radar signals. The algorithm is considered in the instantaneous autocorrelation function domain in which time or lag slices are converted to a Hankel matrix, and an atomic norm-based method is applied to mitigate the impacts of noise. Cross-terms are suppressed by using a time-frequency kernel, such as the Choi-Williams distribution, and sparsity-based reconstruction technique is utilized to obtain a high-resolution time-frequency distribution of the radar waveforms. Simulation results verify the effectiveness of the proposed method.

14:20 A Tensor-Based Localization Framework Exploiting Phase Interferometry Measurements

Farzam Hejazi, Mohsen Joneidi, Nazanin Rahnavard
University of Central Florida, United States

In this paper, we propose a framework for localization of multiple co-channel transmitters using phase difference measurements between two antennas mounted on sensors of a sensor network. To pursue localization, we use temporal cross-correlations between the received signals of the first and the second antennas to extract the phase differences between each antenna pairs, named as phase interferometry measurements (PIMs), provoked by each PUs using tensor decomposition. We calculate Cramer-Rao lower bound of error of localization using PIMs. Our simulation results show that highly accurate estimations can be achieved using PIMs. We also compare the accuracy of our proposed technique with a sensor network that exploits highly directional linear array antennas and shows that the proposed technique can perform similar to a network that employs large antenna arrays.

Notes:

Wednesday, April 29th, 2020

ARRAY PROCESSING

15:10 – 16:50
ROOM 1
CHAIR: ALFONSO FARINA, *LEONARDO (RTD)*
LAURA ANITORI, *TNO*

15:10 Sparse Array Design for Transmit Beamforming

Syed A. Hamza, Moeness G. Amin
Villanova University, United States

The main emphasis on sparse array design thus far has been from the perspective of sparse receiver optimization. In this paper, we examine sparse array design for transmit beamforming. The main task is to design the beamformer to direct the bulk of the transmitted power to target locations. This, in turn, enables improved receiver performance which strives to maximize the signal-to-interference plus noise ratio (MaxSINR) of the radar returns. In order to realize an environmental-dependent adaptive design, it is incumbent that the directed signals towards different targets are maximally mutually independent. The optimum sparse active array design problem is formulated as quadratically constraint quadratic program (QCQP) alongside the regularization term. The semidefinite relaxation (SDR) of QCQP is used to enhance the sparsity of the beamformer through iterative re-weighting based on prior iterations. It is shown that the proposed approach can efficiently utilize the available array aperture to achieve the desired transmitted beampattern characteristics.

15:30 Matrix Pencil Method for DoA Estimation with Interpolated Arrays

Christian Greiff, Fabio Giovanneschi, Maria A. Gonzalez-Huici
Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany

The Matrix Pencil Method is combined with techniques for Array Interpolation to create a fast and high-resolution Direction-of-Arrival estimation algorithm for use with arbitrary array geometries. Employing only a single snapshot is especially suitable in dynamic scenarios, where only an insufficient number of snapshots for subspace methods are available. Simulations show that the proposed Interpolated Matrix Pencil Method outperforms an implementation of Orthogonal Matching Pursuit at moderately high SNR values in terms of metrics such as estimation accuracy and probability of resolution. Feasibility with realistic data is confirmed through measurements collected with an experimental MIMO radar system of optimized sparse topology.

15:50 Nonlinear Array Processing via a Nested Array: Theory and Experimental Evaluation

Hatim F. Alqadah, Dan P. Scholnik, Jean De Graaf
United States Naval Research Laboratory, United States

Array processing by means of using the difference coarray as a virtual uniform linear array (VULA) has become a popular approach, mainly due to the claim of obtaining O (N2) degrees of freedom (DOF) from a N element sparse array. In this work we seek to understand if and how this type of nonlinear array processing (NAP) approach could be used for direction of arrival (DOA) estimation and adaptive beamforming from the perspective of a pulsed radar system. More specifically, our study seeks to validate some of the theoretical aspects and challenges of NAP through an experimental emulation of the receive side of a monostatic 6 element nested array radar.

16:10 Dynamic Range Considerations for Modern Digital Array Radars

Nicholas Peccarelli, Blake James, Caleb Fulton, Nathan Goodman
University of Oklahoma, United States

This paper reviews several different dynamic range definitions and evaluates their overall ability to accurately define radar performance in light of impairments that occur, especially in recently developed digital arrays. Additionally, while digital arrays can experience dynamic range improvement on the order of 10log10(N), where N is the number of transceivers, this improvement has been shown to be limited by the correlation of spurious products. Methods for decorrelating these spurs and the remaining nonlinear distortions are briefly mentioned in pursuit of their relationship to the overall system dynamic range. Ultimately, the goal of this paper is to take a system-level approach to evaluating the dynamic range of modern digital array radar systems that make use of the most recent advancements in digital signal processing techniques.

Notes:

Wednesday, April 29th, 2020

EMERGING TECHNIQUES & APPLICATIONS IN PASSIVE RADARS

15:10 – 16:50
ROOM 2
CHAIR: FABIOLA COLONE, *SAPIENZA UNIVERSITY OF ROME*
PHILIPP WOJACZEK, *FHR FRAUNHOFER*

15:10 Transfer Learning from Audio Deep Learning Models for Micro-Doppler Activity Recognition

Kimberly T. Tran, Lewis D. Griffin, Kevin Chetty, Shelly Vishwakarma
University College London, United Kingdom

This paper presents a mechanism to transform radio micro-Doppler signatures into a pseudo-audio representation, which results in significant improvements in transfer learning from a deep learning model trained on audio. We also demonstrate that transfer learning from a deep learning model trained on audio is more effective than transfer learning from a model trained on images, which suggests machine learning methods used to analyse audio can be leveraged for micro-Doppler. Finally, we utilise an occlusion method to gain an insight into how the deep learning model interprets the micro-Doppler signatures and the subsequent pseudo-audio representations.

15:30 MIMO-FM: Some New Experimental Results Proving the Concept Feasibility

Dominique Poullin, Olivier Rabaste, Michel Menelle, Bruno Urbani, Maxime Goujon
ONERA, France

In this paper, we consider the MIMO-FM concept. This particular setting enables to retrieve the elevation of targets in FM passive radar by exploiting the presence of multiple transmitting antennas located at different heights on the same pylon and transmitting signals at different frequencies, without the need for a vertical reception array. We present new results obtained with an improved receiver, thus proving the feasibility of the MIMO-FM concept.

15:50 Passive Bistatic Radar based on VHF DVB-T Signal

Marek Płotka, Mateusz Malanowski, Piotr Samczyński, Krzysztof Kulpa, Karol Abratkiewicz
Warsaw University of Technology, Poland

This paper presents the preliminary results of experiments utilizing the VHF DVB-T signal to detect flying targets in a passive coherent location system. Utilizing commercial wideband transmitter working with a relatively long wavelength it is possible to obtain foliage penetration, maintaining high resolution. The radar hidden in the forest was able to detect an aircraft. The possibility of detection with radar hidden under foliage was compared to those obtained in the open field, which confirms the advantages and usability of the VHF DVB-T system as an illuminating signal for the PCL systems.

Wednesday, April 29th, 2020

16:10 GNSS-Based Multistatic Passive Radar Imaging of Ship Targets

***Fabrizio Santi*[1], *Debora Pastina*[1], *Michail Antoniou*[2], *Mikhail Cherniakov*[2]**
[1]Sapienza University of Rome, Italy; [2]University of Birmingham, United Kingdom

This work brings forward a framework for passive radar imaging of ship targets by exploiting the reflections of navigation satellite signals. The specific objective is taking advantage of the inherent multistatic nature of the system for the ship passive imagery. To this aim, a bistatic image formation stage is first defined. Then, the bistatic images obtained over multiple baselines are mapped in a domain independent on the particular satellite viewing angle. Finally, different combination rules of the multiple images are defined in order to enable multistatic imagery with enhanced quality, potentially enabling finer feature extraction procedures for ship classification. The proposed approaches are validated and compared via an experimental campaign comprising multiple Galileo satellites and a commercial ferry undergoing different kinds of motion.

16:30 DVB-S2 Passive Bistatic Radar for Resident Space Object Detection: Preliminary Results

***Luca Gentile*[1], *Amerigo Capria*[2], *Anna Lisa Saverino*[2], *Zenalda Hajdaraj*[1], *Marco Martorella*[1]**
[1]University of Pisa, Italy; [2]National Inter-University Consortium for Telecommunications, Italy

The observation of objects residing at Earth orbit is of fundamental importance from the military and civil point of view. This paper investigates the feasibility of a DVB-S2 passive bistatic radar for detection of RSOs in LEO orbit. An experiment set-up will be introduced and the main features of DVB-S2 signal will be analysed. An echo target signal related to the ISS will be emulated from an experimentally acquired reference signal and the related range-Doppler map will be calculated to assess the expected detection results. This work should be considered preliminary to a RSO detection test to be performed with a DVB-S2 passive bistatic radar.

Notes:

Wednesday, April 29th, 2020

MACHINE LEARNING FOR RADAR

15:10 – 16:50
ROOM 3
CHAIR: FULVIO GINI, *UNIVERSITY OF PISA*
MOENESS AMIN, *VILLANOVA UNIVERSITY*

15:10 Waveform Recognition in Multipath Fading using Autoencoder and CNN with Fourier Synchrosqueezing Transform

Gyuyeol Kong[1], Minchae Jung[2], Visa Koivunen[1]
[1]Aalto University, Finland; [2]Virginia Polytechnic Institute and State University, United States

In this paper the problem of recognizing radar waveforms is addressed for multipath fading channels. Waveform classification is needed in spectrum sharing, radar-communications coexistence, cognitive radars, spectrum monitoring and signal intelligence. Different radar waveforms exhibit different properties in time-frequency domain. We propose a deep learning method for waveform classification. The received signal is first equalized to mitigate the effect of multipath fading channels by using a denoising auto-encoder (DAE). Then, the equalized signal is processed with Fourier synchrosqueezing transform that has excellent properties in revealing time-varying behavior, rate of, strength and number of oscillatory components in signals. The resulting time-frequency description is represented as a bivariate image that is fed into a convolutional neural network. The proposed method has superior performance over the widely used the Choi-Williams distribution (CWD) method in distinguishing among different radar waveforms even at low signal-to-noise ratio regime.

15:30 An Initial Investigation into using Convolutional Neural Networks for Classification of Drones

Holly Dale[1], Chris Baker[1], Michail Antoniou[1], Mohammed Jahangir[1,2]
[1]University of Birmingham, United Kingdom; [2]Aveillant Limited, United Kingdom

The use of convolutional neural networks (CNNs) in drone and non-drone classification is investigated in this paper. A classifier is trained on radar spectrograms obtained using an L-band staring radar and the performance is assessed and compared with a machine learning benchmark. Initial results have shown the CNN to achieve a correct classification performance of up to 98.89\%.

15:50 Deep Interference Mitigation and Denoising of Real-World FMCW Radar Signals

Johanna Rock[1], Mate Toth[1,2], Paul Meissner[2], Franz Pernkopf[1]
[1]Graz University of Technology, Austria; [2]Infineon Technologies Austria AG, Austria

We combine real measurements with simulated interference in order to create input-output data suitable for training the CNN-based model. We analyze the performance to model complexity relation on simulated and measurement data, based on an extensive parameter search. Further, a finite sample size performance comparison shows the effectiveness of the model trained on either simulated or real data as well as for transfer learning. A comparative performance analysis with the state of the art emphasizes the potential of CNN-based models for interference mitigation and denoising of real-world measurements, also considering resource constraints of the hardware.

Wednesday, April 29th, 2020

16:10 Deep Convolutional Autoencoder Applied for Noise Reduction in Range-Doppler Maps of FMCW Radars

***Marcio L. Lima de Oliveira*[1], *Marco J.G. Bekooij*[2]**
[1]University of Twente, Netherlands; [2]NXP Semiconductors, Netherlands

In this paper, we discuss the usage of deep Convolutional Autoencoders (CAE) for denoising Range-Doppler maps of an FMCW radar in a near-field situation with pedestrians and cyclists as moving objects.

16:30 Robust Drone Classification using Two-Stage Decision Trees and Results from SESAR SAFIR Trials

***Mohammed Jahangir*[1], *Bashar I. Ahmad*[2], *Chris J. Baker*[1]**
[1]University of Birmingham, United Kingdom; [2]Aveillant Limited, United Kingdom

Non-cooperative surveillance of drones is an important consideration in the EU SESAR vision for the provision of U-space services. The Aveillant Gamekeeper multiple beam staring radar utilises extended dwells to be able to detect small drones at ranges of several kilometres. However, target discrimination is necessary with such non-cooperative surveillance system as the increased detection sensitivity against low RCS targets, such as birds and surface objects (e.g., pedestrians and vehicles), extenuates the problem of false target reports. A simple two-stage supervised learning approach is proposed in order to discriminate drones from other confuser targets. This approach is based on a decision tree classifier and is shown to be effective at filtering out non-drone, targets. Field trials from the SESAR SAFIR trials to test initial U-space services in realistic urban environments shows that the two-stage decision tree classifier provides robust discrimination with minimal false positives.

Notes:

Wednesday, April 29th, 2020

HARMONIC RADAR & ITS APPLICATIONS

15:10 – 16:50
ROOM 4
CHAIR: BRUCE G. COLPITTS, *UNIVERSITY OF NEW BRUNSWICK*
ANASTASIA LAVRENKO, *CANTERBURY UNIVERSITY*

15:10 Compact Low-Cost FMCW Harmonic Radar for Short Range Insect Tracking

Greg Storz[1], Anastasia Lavrenko[2]
[1]Greg Storz Consulting, New Zealand; [2]Scion, New Zealand Forest Research Institute Limited, New Zealand

In this work, we present two frequency modulated continuous wave (FMCW) harmonic radar prototypes for application in insect tracking. One operates in the maritime radar allocation of the S-band and the other one at X-band. Short-range operation ensures that the modules are compact enough to be used as portable instruments or even to be mounted onto a UAV. Given the output power of 3 and 10W, respectively, the S-band prototype provides up to 40m of range while the X-band one has a maximum range of 15m. Both systems have a range resolution of approximately 1m and can run of general purpose batteries. Our results support an observation that harmonic tags exhibit highly non-linear behaviour at low incident power levels. As a result, harmonic radar systems become increasingly more inefficient in terms of the maximum detection range relative to the transmit power at higher frequencies.

15:30 An Harmonic Radar Prototype for Insect Tracking in Harsh Environments

Daniele Milanesio[1], Stefano Bottigliero[1], Maurice Saccani[1], Riccardo Maggiora[1], Alessandro Viscardi[2], Marco Matteo Gallesi[2]
[1]Politecnico di Torino, Italy; [2]Università degli Studi di Torino, Italy

Harmonic entomological radars have been used in the last decades to track small and lightweight passive tags carried by various insects, usually flying at low altitude and over flat terrain. This paper reports the evolution over five years of a new entomological radar prototype within the frame of the European LIFE project STOPVESPA, whose aim was to stop the proliferation of the yellow-legged Asian hornet in Italy.

15:50 Nonlinear Junction Detection vs. Electronics: System Design and Improved Linearity

Gregory J. Mazzaro
The Citadel: The Military College of South Carolina, United States

This paper summarizes recent work performed by those who have been evaluating nonlinear junction detection to address commercial devices and other collections of electronics. A transceiver, consisting of only off-the-shelf components, is simulated. By implementing absorptive passive filtering and feedforward filter reflection, the simulated design achieves harmonic distortion below 200 dBc.

16:10 Evaluation and Improvement of the Performance of Harmonic Radar Transponders

Ramin Ala, Bruce G. Colpitts, Nicholas Kozma
University of New Brunswick, Canada

Efficiency of the harmonic radar tag depends on its physical shape and the attached diode. Tag performance means to efficiently convert the incident radio wave into a transmitted harmonic. In this study, performance of wire-based tags are evaluated based on resonant frequencies, absorption cross-sections, and radiation properties. Tag architectural features including loop offset, wire diameter, and deformation are examined. Results show that an arm ratio of 2:1 is optimal, that small diameter wire is preferable, and that some deformation of the dipole may improve coverage. The derived information is useful and expandable for the optimization of transponders.

Notes:

Thursday, April 30th, 2020

DETECTION & ESTIMATION II

9:20 – 10:20
POSTER AREA 1
CHAIR: FULVIO GINI, *UNIVERSITY OF PISA*
LUKE ROSENBERG, *DEFENCE SCIENCE AND TECHNOLOGY GROUP*

Estimating Radar Detection Coverage Probability of Targets in a Cluttered Environment using Stochastic Geometry

Shobha Sundar Ram, Gaurav Singh, Gourab Ghatak
Indraprastha Institute of Information Technology Delhi, India

We analyze the performance of a radar in an environment where clutter is constituted by discrete scatterers whose radar cross-sections are comparable to that of the target. An indoor radar deployment to detect humans in the presence of furniture is an example of such a scenario. We propose a figure of merit called the radar detection coverage probability to indicate the likelihood of the signal to clutter and noise ratio at the radar being above a predefined threshold under diverse radar, target and clutter conditions. We provide analytical expressions derived from stochastic geometry formulations to derive the metric. Based on our analyses, we find useful insights regarding the optimal choice of the transmitted power and radar bandwidth. We also study the sensitivity of the performance of the radar to clutter density, clutter cross-section and path loss under both line-of-sight and non-line-of-sight conditions. Our results are verified through Monte Carlo simulations.

Simulating Correlated K-Distributed Clutter

Ellis Humphreys[1], Michail Antoniou[1], Chris Baker[1], William Stafford[2]
[1]University of Birmingham, United Kingdom; [2]BAE Systems, United Kingdom

A novel method of simulating the long term temporal and spatial correlation in k-distributed sea clutter data has been developed using interpolation and rotation of a correlated Gaussian surface which is then transformed using an MNLT (Memoryless Nonlinear Transform) to a Gamma ”texture” which forms k-distribution data. The short term speckle element of k-distributed sea clutter then has its temporal and spatial correlation simulated by a novel convolution method. This provides a fast, flexible means of generating realistic K-distributed data.

Large-Scale Spectrum Occupancy Learning via Tensor Decomposition and LSTM Networks

Ismail Alkhouri, Mohsen Joneidi, Farzam Hejazi, Nazanin Rahnavard
University of Central Florida, United States

A new paradigm for large-scale spectrum occupancy learning based on long short-term memory (LSTM) recurrent neural networks is proposed. Studies have shown that spectrum usage is a highly correlated time series over multi-dimensions. Therefore, revealing all these correlations using one-dimensional time series is not a trivial task. In this paper, we introduce a new framework for representing the spectrum measurements in a tensor format. Next, a time-series prediction method based on CANDECOMP/PARAFAC (CP) tensor decomposition and LSTM recurrent neural networks is proposed. Our proposed method is computationally efficient and is able to capture different types of correlation within the measured spectrum. Moreover, it is robust to noise and missing entries of sensed spectrum. The superiority of the proposed method is evaluated over a large-scale synthetic dataset in terms of prediction accuracy and computational efficiency.

Thursday, April 30th, 2020

A Novel, Graphical Representation of the Classical Radar Range Equation

Paul S. Rose, A.C. Robinson, Tony Kinghorn
Leonardo MW Ltd., United Kingdom

The classical radar range equation has been around since the beginning of radar. While there are various forms of the equation for different radar types it has not been expressed in a graphical form until now. Leonardo MW Ltd has developed a novel means of expressing the equation in a form that provides insight into radar performance. In essence, the graphical format splits the contribution of detection into components for the radar and those for the target; both components are scaled precisely in range.

Soft Iterative Method with Adaptive Thresholding for Reconstruction of Radar Scenes

Dmitrii Kozlov[1], Peter Ott[1], Otmar Loffeld[2], Marco Altmann[1]
[1]Heilbronn University of Applied Sciences, Germany; [2]University of Siegen, Germany

A proper use of the advances of compressed sensing (CS) theory in radar systems may lead to data rate reduction, energy saving and measuring improvement. Using, e.g., randomly placed chirps and CS reconstruction algorithms, the velocity unambiguously measured by FMCW-Radars can be increased. In this paper, we propose to use the soft Iterative Method with Adaptive Thresholding (soft-IMAT) for the reconstruction of the radar scene. Its performance is analyzed in different scenarios and compared with the original IMAT with respect to detection probability and computational complexity. A modified soft-IMAT is proposed in order to reduce the computational overhead caused by the soft-based decision.

Improved Covariance Matrix Estimation using Riemannian Geometry for Beamforming Applications

Hossein Chahrour[1], Richard Dansereau[1], Sreeraman Rajan[1], Bhashyam Balaji[2]
[1]Carleton University, Canada; [2]Defence Research and Development Canada, Canada

The estimation of interference plus noise covariance (INC) matrix for beamforming applications is considered from a Riemannian space perspective. A new INC estimation technique based on regularized Burg algorithm (RBA), Riemannian mean and Riemannian distance is proposed to maintain a stable performance in presence of angle of arrival mismatch and small sample size with high and low signal to interference plus noise ratio (SINR). The RBA is exploited to generate Toeplitz Hermitian positive definite (THPD) covariance matrices. The estimated INC is formulated as a linear combination of THPD covariance matrices of the interference plus noise excluding potential target snapshots. The weights of the linear combination operation are based on the Riemannian distance between the Riemannian mean and each THPD covariance matrix. The largest distance (potential target) will have zero weight and the smallest distance will have maximum weight. Simulation results demonstrate the performance of the proposed technique in comparison with sample covariance and Riemannian mean covariance under steering vector mismatch and small sample size in presence of high and low SINR.

A Quantitative Comparison of the Littoral Clutter Model (LCM) to Collected Data in the Ku-Band

Bryant Moss, Jennifer Sposato, Terry L. Foreman
Naval Surface Warfare Center, United States

This paper presents a method of comparing LCM simulated data to empirical radar clutter data in the Ku-band. The comparison method quantifies the ability of LCM to simulate site-specific clutter data on the basis of the median of multiple samples. The 75th percentile of the delta-median ECDF was proposed as a metric of performance. Additionally, a method of correcting for the effects of scanning loss and beam broadening on clutter power was discovered which could be incorporated directly into LCM in the future.

Thursday, April 30th, 2020

SINR Modeling for Evaluating the CRLB for ATSC Signal based Passive Radar Systems

Moayad Alslaimy, Robert J. Burkholder, Graeme E. Smith
The Ohio State University, United States

Passive radar systems, which are inherently bistatic, can use multiple transmitters of opportunity that are spatially distributed to improve the detection and tracking performance. The Cramér-Rao lower bound (CRLB), which bounds the error variance of the radar range and velocity estimates, provides a quantitative way to evaluate the performance of a multistatic radar system by selecting the emitter that provides the best estimation accuracy for the radar parameters. The range and velocity modified Cramér-Rao lower bound (MCRLB) was derived for the advanced television system committee (ATSC) signal which is the digital television standards in North America. This work discusses the effect of varying the signal to interference noise ratio on the MCRLB as a result of using multiple transmitters with different geometries and a moving target, by accounting for the direct signal interference (DSI) component which results from the continuous nature of the passive radar signals.

Transversal Velocity Measurement of Multiple Targets based on Spatial Interferometric Averaging

Pengcheng Wang[1], Huaiyuan Liang[1], Xiangrong Wang[1], Elias Aboutanios[3]
[1]Beihang University, China; [2]University of New South Wales, Australia

The linear velocity of an arbitrary moving target comprises two orthogonal components with reference to the observing radar, these are radial and transversal velocities. The transversal velocity can be measured by an interferometric radar directly. When measuring multiple targets, there exist cross-terms which have no physical meanings and interfere the extraction of the useful frequency. In this paper, we propose a new method utilizing a uniform linear receiving array with three antennas based on spatial interferometric averaging to suppress the cross-terms and measure the transversal velocity of multiple targets simultaneously. The basic idea of spatial interferometric averaging is to use subarrays of a uniform linear array to obtain an averaged correlation output, the phase terms of which contain the pure transversal velocity. Simulation results are provided to validate the effectiveness of the proposed method.

Radar Resource Allocation: Higher Rate or Better Measurements?

Y. Wang, W.D. Blair
Georgia Institute of Technology, United States

In this paper, the tracking of maneuvering targets with a nearly constant velocity Kalman filter is considered and the maximum mean squared error (MMSE) in position and velocity are utilized to study the impacts of doubling the measurement accuracy or rate. For each measurement case and the maximum acceleration of a maneuvering target, the process noise variances that minimize the MMSE in the filtered and the one-step predicted track state are used to assess the impacts of doubling the measurement accuracy or rate. The analysis shows that doubling the measurement accuracy gives the greater reduction in MMSE in filtered position and velocity, while doubling the measurement rate gives the greater reduction in the MMSE in the one-step predicted position and velocity. Process noise variances that minimize the MMSE in the one-step predicted position and velocity estimates are also new in this paper.

Thursday, April 30th, 2020

Spatiotemporal Density-Based Clustering for Dynamic Spectrum Sensing

Christopher Ebersole[1], Anthony Buchenroth[1], David Zilz[2], Vasu Chakravarthy[1]
[1]Air Force Research Laboratory, United States; [2]Booz Allen Hamilton, United States

Dynamic spectrum access is one promising model for managing spectrum congestion and ensuring primary users, such as essential radar systems, unimpeded access to spectral resources. However, this requires the secondary user to identify the temporal and spectral resources consumed by primary users. Thus, in a congested radar environment, the secondary user must be capable of resolving multiple emitter waveforms in the presence of channel noise, waveform ambiguities, and pulse-on-pulse artifacts. We propose a new kernel density estimator-based clustering technique which uses the time of arrival of radar pulses in addition to other features, such as angle of arrival, center frequency, and pulse width, to identify patterns in radar pulse trains with a wide range of possible pulse repetition frequencies, which is a weakness of many density-based clustering techniques, in the presence of measurement error and outliers.

Notes:

Thursday, April 30th, 2020

LOW-COST, EMERGING & MMW TECHNOLOGIES

9:20 – 10:20
POSTER AREA 2
CHAIR: FRANK ROBEY, *MIT LL*
PHILLIP CORBELL, *AFIT*

Interference Suppression and Signal Restoration using Kalman Filter in Automotive Radar Systems

Jaehoon Jung[1], Sohee Lim[1], Jinwook Kim[1], Seong-Cheol Kim[1], Seongwook Lee[2]
[1]Seoul National University, Korea; [2]Samsung Advanced Institute of Technology, Korea

We propose a signal processing technique to restore signals distorted by mutual interference in an automotive radar system to increase the reliability of target detection. First, since it is necessary to recognize the period where the interference occurred, a method to find the period of interference based on peak detection is presented. Then, the Kalman filter is employed to recover the distorted signal in the interference region. In simulations using two frequency modulated continuous wave radar systems, the influence of interference was effectively mitigated with our proposed method and target information was correctly estimated.

MmWave Radar Point Cloud Segmentation using GMM in Multimodal Traffic Monitoring

Feng Jin, Arindam Sengupta, Siyang Cao, Yao-Jan Wu
University of Arizona, United States

In the multimodal traffic monitoring, we gather traffic statistics for distinct transportation modes, such as pedestrians and cars, in order to improve people's daily mobility. The radar sensor is a suitable for this application because of its robustness to light/weather. We propose to use an mmWave radar to obtain a radar point cloud representation for a traffic monitoring scenario. We also propose to use the Gaussian mixture model (GMM) on a new feature vector to do the segmentation, i.e. 'point-wise' classification, in an unsupervised approach. The experimental results demonstrated a good segmentation performance in terms of the intersection-over-union (IoU) metric.

FMCW Radar Prototype Development for Detection and Classification of Nano-Targets

Safiah Zulkifli, Alessio Balleri
Cranfield University, United Kingdom

Detection and classification of nano-targets (less than 5 cm in size) is becoming a technical challenge as nano-targets are largely invisible to conventional radar. Nano-drones, for example, may soon become a tangible threat capable of providing short range stealthy surveillance and similarly, insect pests are posing a significant risk to agricultural. Frequency Modulated Continuous Wave (FMCW) radar is a technology that can provide short range detection, with no blind range and very high resolution, at a relatively low cost. This paper presents latest results of an ongoing project aiming at designing and developing a low-cost and bespoke millimetre-Wave (mm-W) FMCW radar prototype to enable detection of nano-targets. A home-brew S-band FMCW radar prototype has been initially designed and developed to demonstrate the feasibility of our proposed solution and inform all mm-W future activities. Several experimental tests have been carried out and results have shown targets could be successfully detected. Their micro-Doppler signatures extracted using Short-Time Fourier Transform (STFT) techniques.

Thursday, April 30th, 2020

Exploring Gesture Recognition with Low-Cost CW Radar Modules in Comparison to FMCW Architectures

Alan Bannon, Richard Capraru, Matthew Ritchie
University College London, United Kingdom

Radar-base gesture recognition is an area receiving a significant amount of interest in recent years due to the rapid increase in the availability of low-cost low-footprint radar systems. Frequently the preferred radar configuration is Frequency Modulated Continuous Wave (FMCW). Continuous Wave (CW) radar is not receiving as much attention. In this paper we explore the use of extremely low cost CW radar modules for gesture recognition. In doing so a set of signal processing electronics is developed, implemented, and used to supply the resulting signal to PC audio input for recording. A dataset of gestures was recorded and gesture recognition accuracy was compared to FMCW recordings to show that CW systems can provide a high accuracy for gesture recognition at a very low cost.

Next-Generation Software Defined Radar: First Results

Evan Zaugg, Alexander Margulis, Maximillian Margulis, Joshua Bradley, Alexander Kozak, Jeffrey Budge
ARTEMIS, Inc., United States

ARTEMIS, Inc. has begun flight testing a new radar system called the SlimSDR (for Slim, Software Defined Radar). This successor to the ARTEMIS SlimSAR began test flights in September 2019. Like the SlimSAR, it is a compact radar system, but provides additional capabilities and flexibility. As a software defined radar, the SlimSDR is modular, multi-frequency, and applicable to multiple applications. This paper details the design and development process of the SlimSDR and shows initial results from the first flight tests of the system.

Quantum Electromagnetic Scattering and the Sidelobe Advantage

Matthew J. Brandsema[1], Marco Lanzagorta[2], Ram M. Narayanan[1]
[1]Pennsylvania State University, United States; [2]United States Naval Research Laboratory, United States

Quantum remote sensing, also known as Quantum Detection and Ranging (QUDAR), is the use of entangled photon states to detect targets at a stand-off distance. It inherently relies on sending many single photons through free space, bouncing off of a target and returning to the sensor. It is therefore necessary to understand how single photons interact and scatter from targets of macroscopic size. This paper relates quantum and classical scattering in the far field regime. Specifically, we show that due to the photon's position uncertainty, the path over which the photon traverses is not well defined, and this causes quantum interference. The result of this interference exactly replicates classical scattering behavior of electromagnetic waves. We will show that one can exactly derive the classical electric field scattering integral using a purely quantum construction. Although this paper focuses on the context of QUDAR, it is very general to any application involving far-field electromagnetic scattering.

Quantum Two-Mode Squeezing Radar: SNR and Detection Performance

David Luong[1], Sreeraman Rajan[1], Bhashyam Balaji[2]
[1]Carleton University, Canada; [2]Defence Research and Development Canada, Canada

We analyze the signal-to-noise ratio (SNR) metric in the context of quantum two-mode squeezing (QTMS) radar and find that there are actually two SNRs associated with a QTMS radar, one for the received signal and another for a signal retained inside the radar. Definitions for these SNRs are proposed which are simpler than those hitherto used in the quantum radar literature. We plot receiver operating characteristic (ROC) curves for varying values of these two SNRs. These plots show that the quality of the matched filtering performed by the radar, as quantified by the SNR of the retained signal, can have a strong impact on detection performance.

Thursday, April 30th, 2020

Development and Testing of a Low Cost Audio based ISAR Imaging and Machine Learning System for Radar Education

N.D. Blomerus[1], J.E. Cilliers[2], J.P. de Villiers[1]
[1]University of Pretoria, South Africa; [2]Council of Scientific and Industrial Research, South Africa

This paper describes the development and testing of low cost Inverse Synthetic Aperture Radar (ISAR) turn table system with a machine learning back-end. The ISAR sensor is based on audio components which mimic the functioning of a radar system but at a much lower cost. The system is also compact enough to fit on a single desk for classroom demonstrations and experiments. The system can record range lines as the turn table revolves and for ISAR images. These images can then be used to train machine learning algorithms to demonstrate the accuracy of such algorithms. The system thus allows for classroom demonstrations of the sensor to classifier chain in a way that is immediately accessible to students.

Enabling In-Band Coexistence of Millimeter-Wave Communication and Radar

Hardik B. Jain, Ian P. Roberts, Sriram Vishwanath
GenXComm, Inc., United States

The wide bandwidths available at millimeter-wave (mmWave) frequencies have offered exciting potential to wireless communication systems and radar alike. Communication systems can offer higher rates and support more users with mmWave bands while radar systems can benefit from higher resolution captures. This leads to the possibility that portions of mmWave spectrum will be occupied by both communication and radar (e.g., 60 GHz industrial, scientific, and medical (ISM) band). This potential coexistence motivates the work of this paper, in which we present a design that can enable simultaneous, in-band operation of a communication system and radar system across the same mmWave frequencies. To enable such a feat, we mitigate the interference that would otherwise be incurred by leveraging the numerous antennas offered in mmWave communication systems. Dense antenna arrays allow us to avoid interference spatially, even with the hybrid beamforming constraints often imposed by mmWave communication systems. Simulation shows that our design sufficiently enables simultaneous, in-band coexistence of a mmWave radar and communication system.

A High Power Compact X-Band RF Front-End for Weather Radar Applications

Vadym Volkov, Dmytro Vavriv, Volodymyr Vynogradov, Yevhenii Bulah, Andrii Kravtsov, Vladislav Ksenofontov
National Academy of Sciences of Ukraine, Ukraine

The paper presents a high power compact RF front-end for X-band weather radar applications. The front-end benefits from both a novel high efficiency GaN SSPA with a 900 W peak output power and a low noise receiver design. The front-end includes circuits allowing accurate calibration and self-diagnostics. The front-end hardware is fitted into a standard 19”, 4U enclosure, enabling for a rather compact radar layout. Essential design solutions of the front-end are described as well as the test results.

Thursday, April 30th, 2020

Notes:

Thursday, April 30th, 2020

ANTENNAS & ARRAY PROCESSING

9:20 – 10:20
POSTER AREA 3
CHAIR: ALEX CHARLISH, *FKIE FRAUNHOFER*
MAI NGO, *NRL*

Performance Modelling of a Cost Effective COTS UHF Log-Periodic Antenna

C. Blaauw, M. Potgieter, J.E. Cilliers
Council of Scientific and Industrial Research, South Africa

Commercial off the shelf antennas make it possible to do rapid initial system tests and proof of concepts. This paper reports on the antenna performance of a cost effective commercial off the shelf printed Lop-periodic antenna. This antenna is said to works in the UHF band with a bandwidth of 600 MHz (400 MHz to 1 GHz).

KOSPAW Test Bed – A Phased Array Radar for Space Situational Awareness

Jiwoong Yu, Sungki Cho, Jung Hyun Jo
Korea Astronomy and Space Science Institute, Korea

Recently, the number of space objects has increased exponentially leading to a possibility of an increase in the number of space hazards; therefore, the Space Situational Awareness Program based on radars is currently being developed to counteract these events. The Korea Space Surveillance Active Phased Array Radar Window (KOSPAW) test bed is being developed to test radar technology in a phased array and detect radar cross section (RCS) of 5 m2 for space objects at an altitude of 750 km. The designed radar can effectively operate in tracking and searching modes. This paper describes the results of the operational test of a KOSPAW to verify the sensitivity of space objects in the characteristics of the satellite catalogs and relative range and velocity from the propagated orbits of the TLE. In this study, methods, such as increasing the number of arrays and the transmission power, to improve the number of space objects detected are proposed, and the number of predicted space objects is confirmed. In addition, design improvements are made and the operating modes are simulated. The KOSAPW test bed will be tested in 2023 by technically verifying the accessibility of its components.

Fixed Probe based Digital Phased Array Calibration using Virtual Probe Location

Shajid Islam, Caleb Fulton
University of Oklahoma, United States

An inclination towards low cost phased array antenna technology has been observed in recent years while signal digitization also become closer to the antenna elements. This ongoing trend sets the necessity of calibrating phased arrays into utmost importance. In this work, a quasi-near-field fixed probe based calibration scheme has been introduced, which is capable of calibrating a phased array faster than any traditional method. This paper proposed the theory, mathematical framework, and simulated results for phased array antenna calibration using a fixed probe and virtual probe location estimation.

Studies of Front-End Distortion Characterization via Mutual Coupling Measurements in Phased Array Systems

Matthew Herndon, Mark Yeary, Robert Palmer
University of Oklahoma, United States

In pursuit of digital-at-every-element phased array radars, research is ongoing investigating the application of memory-polynomial predistortion for correcting nonlinear distortion effects observed in high-power amplifiers operating in saturation. This paper describes the motivation behind and several experiments from a project exploring whether distortion models may be trained using data captured from an active array via mutual coupling between elements, a method which could theoretically provide a complete description of the distortion affecting each element from the digital-to-analog converter to antenna. For the first time, this paper addresses the concept of combining mutual coupling with digital predistortion.

Notes:

Thursday, April 30th, 2020

ADAPTIVE PROCESSING

10:20 – 12:00
ROOM 1
CHAIR: MICHAEL PICCIOLO, *ENSCO*
SHANNON D. BLUNT, *UNIVERSITY OF KANSAS*

10:20 A Modified Least-Squares Mismatched Filter for use in Radar Applications with Additive Noise

Jerrod Kempf, Julie Ann Jackson
Air Force Institute of Technology, United States

Waveforms used for passive synthetic aperture radar applications typically have poor range resolution which leads to difficulty distinguishing between small targets within a scene. This problem is magnified when there are high sidelobes in the filter response. This paper formulates a modified least-squares mismatched filter used on noisy, oversampled, OFDM signals in lieu of a traditional matched filter. This paper considers the role of signal oversampling on the filter's performance and evaluates the mismatched filter against the matched filter in various noise environments. Range profiles are presented and then image formation is carried out over a narrow aperture to demonstrate the superior sidelobe suppression of the modified least-squares mismatched filter in the presence of additive noise.

10:40 Language-Based Cost Functions for Fully Adaptive Radar under Imprecise Performance Standards

Paul G. Singerman[1], Sean M. O'Rourke[2], Ram M. Narayanan[1], Muralidhar Rangaswamy[2]
[1]Pennsylvania State University, United States; [2]Air Force Research Laboratory, United States

There is a push to create radar systems that optimize their own performance in real time. In order to accomplish this, the radar system's operating context must be known. In this paper, we propose a method to optimize the performance of a fully adaptive radar (FAR) target tracker when there are multiple performance metrics and multiple tunable sensor parameters. We use a previously developed method of encoding context known as language based cost functions (LBCFs). Unfortunately, in adaptive target tracking, processing time is severally constrained and the final objective function is often non-convex. Therefore, we develop a catch-all iterative algorithm utilizing a clever initialization scheme, followed by a local search to find relaxed, efficient solutions. The algorithm is then tested on a basic simulation of a human running. Results show that the combination of LBCFs and the optimization algorithm allow the radar to far outperform a classical non-adaptive radar. Results also show that the specific initialization scheme used vastly changes the radar's ability to find satisfactory solutions which in turn can dramatically alter the tracker's performance.

11:00 Adaptive Digital Predistortion for Radar Applications using Convex Optimization

Randall Summers[1], Mark Yeary[1], Hjalti Sigmarsson[1], Rafael Rincon[2]
[1]University of Oklahoma, United States; [2]NASA Goddard Space Flight Center, United States

Much of the research to date in predistortion design and implementation has been focused on communication applications. While useful for radar applications, the approaches that work well for communications waveforms do not necessarily result in optimal utilization of computational resources. To this end, a special case of the memory polynomial model is explored. As time alignment of signals can pose a problem for predistortion parameter estimation, a method of calculating the ideal predistortion coefficients using frequency-domain techniques is explored.

Notes:

Thursday, April 30th, 2020

SAR
10:20 – 12:00
ROOM 2
CHAIR: DAN P. SCHOLNIK, *NRL*
RAGHU RAJ, *NRL*

10:20 A Comparison of Autofocus Algorithms for Backprojection Synthetic Aperture Radar

Aaron Evers[1,2], Julie Ann Jackson[1]
[1]Air Force Institute of Technology, United States; [2]Radial R&D, United States

In this work, the performance and efficiency of variations of two autofocus algorithms for backprojection algorithm (BPA) synthetic aperture radar (SAR) are evaluated and compared through a Monte Carlo simulation. The two considered autofocus algorithms are maximum sharpness autofocus (MSA) and generalized phase gradient autofocus. With the Monte Carlo simulation, the root mean squared error and run-time of each autofocus algorithm is evaluated over different transmitter/receiver position errors (i.e., different phase errors), different signal-to-noise ratios (i.e., different noise realizations), and different SAR scene types. The results demonstrate the trade-off between performance and efficiency among each of the autofocus algorithms.

10:40 Multichannel Coprime SAR/GMTI (CopGMTI)

Abdulmalik Aldharrab, Mike E. Davies
University of Edinburgh, United Kingdom

CopSAR and OrthoCopSAR have been recently proposed in the literature to reduce the amount of data to be stored and processed and to extend the maximum swath width that can be imaged without introducing any degradation to the azimuth resolution. Such a High-Resolution Wide-Swath (HRWS) imaging capability is achieved by sampling the synthetic aperture using multiple interlaced sub-Nyquist PRFs. However, a limitation in such imaging modalities is in the assumption that the scene contains only stationary targets. Consequently, moving targets will appear shifted from their true location mostly in the azimuth direction. In this paper, CopGMTI is proposed to detect ground moving targets and estimate their radial velocities when the synthetic aperture is sampled at a sub-Nyquist rate according to CopSAR or OrthoCopSAR. This allows identifying the true azimuth location of such moving targets. Theoretical results provided in this paper are validated using the publicly available Air Force Research Laboratories (AFRL) multichannel SAR GMTI Gotcha data set.

11:00 SAR Image Formation via Subapertures and 2D Backprojection

Callin Schone, Nathan A. Goodman
University of Oklahoma, United States

A novel subaperture-based imaging algorithm is proposed, which forms images by coherently summing the returns from the range-Doppler map of each subaperture. This algorithm lends itself to shared processing steps with GMTI techniques.

Thursday, April 30th, 2020

11:20 Deep Learning for Joint Image Reconstruction and Segmentation for SAR

Samia Kazemi, Birsen Yazici
Rensselaer Polytechnic Institute, United States

We present an approach for joint image reconstruction and foreground-background separation for synthetic aperture radar (SAR) using deep learning (DL). Network structure of the deep model is derived by unwrapping the stages of an iterative algorithm that solves an underlying optimization problem. This leads to physical model based deep network with learned network parameters having meaningful interpretation. Combined image reconstruction and segmentation approach allows joint optimization of both tasks that enhances performance and prevent inadvertent loss of useful information. Numerical results are included to show feasibility of the proposed approach.

11:40 Advanced Techniques for Robust SAR ATR: Mitigating Noise and Phase Errors

Nathan Inkawhich[1], Eric Davis[2], Uttam Majumder[3], Chris Capraro[2], Yiran Chen[1]
[1]Duke University, United States; [2]SRC Inc., United States; [3]Air Force Research Laboratory, United States

We present an evaluation of a robust training technique for Deep Neural Networks (DNNs) for SAR-ATR called Adversarial Training. We show how the training technique can increase robustness in Extended Operating Conditions, leverage multi-polarization information, and how DNN architecture influences robustness.

Notes:

Thursday, April 30th, 2020

SPECTRUM SHARING II

10:20 – 12:00
ROOM 3
CHAIR: CHRIS MOUNTFORD, *LEONARDO UK*
PATRICK MCCORMICK, *USAF*

10:20 Computationally Efficient Narrowband RFI Mitigation for Pulse Compression Radar

Neal W. Smith, Mark T. Frankford, Richard M. Thompson
Northrop Grumman Corporation, United States

Mitigating in-band, continuous-wave (CW) radio frequency interference (RFI) is a common problem for radar systems which themselves may employ continuous-wave waveforms. When the RFI sources are unanticipated or unavoidable, there is motivation to mitigate them in a responsive manner. Consequently, the described algorithm is applied on receive only, in contrast to methods that anticipate frequencies to avoid and modify the transmit waveform in order to eliminate spectral content. A computationally efficient RFI cancellation method for receive is described here which recovers radar sensitivity in the presence of narrowband RFI and preserves pulse compression time sidelobe levels.

10:40 Mitigation of Cross-Modulation Effects in Radar Receivers with Memory

Euan Ward, Bernard Mulgrew
University of Edinburgh, United Kingdom

This paper studies how introducing nonlinear memory in the radar receiver affects the cross-modulation distortion generated. It also presents a simple cross-modulation mitigation technique developed in the communications literature and applies it to the radar cross-modulation problem. As a result the communications based mitigation technique successfully corrects for cross-modulation distortion generated from a memoryless nonlinear radar receiver. However, it is ineffective when nonlinear memory effects are introduced. This is a significant result as it suggests that if the nonlinearities generating cross-modulation effects in modern radar are found to have memory then sophisticated memory mitigation techniques will have to be developed.

11:00 Multi-Pulse Processing of Dual Function Radar Waveforms Without Remodulation

Batu K. Chalise[1], Moeness G. Amin[2], Giuseppe A. Fabrizio[3]
[1]New York Institute of Technology, United States; [2]Villanova University, United States; [3]Defence Science and Technology Group, Australia

This paper proposes waveform diversity approach for a dual function radar and communication system (DFRC) without remodulating radar waveforms. In the proposed system, a radar employs code-shift keying to embed information over radar slow-time and transmits diverse waveforms to another radar. The receiving radar determines the pulse type that was transmitted and retrieves information bit, whereas target detection involves processing of reflected signals received over a number of pulses. The probability of bit error, which is a function of both signal-to-noise ratio (SNR) and the isolation between waveforms, and the detection probability for a given false alarm probability are derived.

Thursday, April 30th, 2020

11:20 Assessing Block-Sparsity-Based Spectrum Sensing Approaches for Cognitive Radar on Measured Data

A. Aubry[1], V. Carotenuto[1], A. De Maio[1], M.A. Govoni[2], A. Farina[3]
[1]Università degli studi di Napoli Federico II, Italy; [2]U.S. Army Research Laboratory, United States; [3]Technical Consultant, Italy

In this paper, we evaluate the effectiveness of certain space-frequency map recovery algorithms relying on the use of commercially-available hardware. To this end, we employ an inexpensive four channel coherent receiver using Software Defined Radio (SDR) components for emitter localization. Hence, after proper calibration of the receiving system, the acquired samples are used to evaluate the effectiveness of different signal processing strategies which exploit the inherent block-sparsity of the overall profile. At the analysis stage, results reveal the effectiveness of such algorithms.

11:40 Algorithm for Fast Simultaneous Harmonic and Fundamental Impedance Tuning in Reconfigurable Radar Transmitter Power Amplifiers

Adam Goad[1], Charles Baylis[1], Paul Flaten[2], Brian Olson[2], Robert J. Marks II[1]
[1]Baylor University, United States; [2]Naval Surface Warfare Center, United States

With the advent of high-power tunable circuitry, possibilities exist for real-time reconfiguration of the power amplifier fundamental and harmonic impedances to maximize output power and efficiency over changes in frequency and array scan angle. We present, for the first time, a search algorithm that performs simultaneous, fast tuning of the power amplifier fundamental- and harmonic-frequency load impedances. Simulation results demonstrate a 20% PAE increase for the transistor model examined over fundamental tuning alone. In addition, re-tuning after changing frequencies from 500 MHz to 300 MHz is shown to provide a 30% PAE improvement at the second frequency.

Notes:

Thursday, April 30th, 2020

TRACKING & ESTIMATION

13:00 – 14:40
ROOM 1
CHAIR: MARIA SABRINA GRECO, *UNIVERSITY FO PISA*
DAVID CROUSE, *SYSTEMS & TECHNOLOGY RESEARCH*

13:00 Bernoulli Multi-Target Track-Before-Detect for Maritime Radar

Branko Ristic[1], Du Yong Kim[1], Luke Rosenberg[2], Robin Guan[1]
[1]Royal Melbourne Institute of Technology, Australia; [2]Defence Science and Technology Group, Australia

Detection and tracking of small maritime targets using high resolution radar is a challenging problem due to the temporally and spatially varying nature of the sea surface and the spiky returns which can resemble targets. The traditional approach to radar data processing is to first detect targets using their amplitude information (by comparing the radar returns to a suitably chosen threshold) and then feed the extracted (point) measurements into a target tracking system. An alternative approach which can be exploited to improve tracking of weak targets is to process the raw radar data directly though use of a track before detect (TBD) algorithm. This paper presents the development of a multi-target TBD algorithm for maritime radar with targets that are both widely separated and also closely spaced. The algorithm is based on the Bayes-optimal single-target TBD filter, referred to as the Bernoulli TBD.

13:20 Steady-State Filter Design for Radar Tracking with Up-Chirp-Down-Chirp Waveforms

James Corwell[1], William Dale Blair[1], Yaakov Bar-Shalom[2]
[1]Georgia Institute of Technology, United States; [2]University of Connecticut, United States

Steady state characterization of target tracking utilizing fused up-chirp and down-chirp LFM waveforms. Analysis shows decreased variance compared to tracking with just up-chirped waveforms.

13:40 Orbit Determination Before Detect: Orbital Parameter Matched Filtering for Uncued Detection

Brendan Hennessy[1,2], Mark Rutten[3], Steven Tingay[1], Robert Young[2]
[1]Curtin University, Australia; [2]Defence Science and Technology Group, Australia; [3]InTrack Solutions, Australia

This paper presents a novel algorithm to incorporate orbital parameters into radar ambiguity function expressions, by extending the standard ambiguity function to match Keplerian two-body orbits. A coherent orbital matched-filter will maximise a radar's sensitivity to objects in orbit, as well as provide rapid initial orbit determination from a single detection. This paper then shows how uncued detection searches can be practically achieved by incorporating radar parameters into the orbital search-space, especially for circular orbits. Simulated results are presented which compare calculated results with ephemeris data, showing radar parameters derived from these methods match radar parameters derived from ephemeris data.

Thursday, April 30th, 2020

14:00 Single Sensor Emitter Localization based on TOA Sequence with Inter-Pulse Modulation

Xuefeng Feng, Zhen Huang, Jiazhi He, Lei Shi, Di Liu
Tsinghua University, China

Based in the periodicity of pulse trains, a stationary emitter could be located by a single moving sensor. In this paper, we proposed a single sensor localization method for radar pulse trains with specific inter-pulse modulation. The effects of inter-pulse modulation parameters on localization are discussed in detail. Theoretical analysis and numerical simulations show that the proposed method outperforms conventional methods.

14:20 Covariance-Free TDOA/FDOA-Based Moving Target Localization for Multi-Static Radar

Xudong Zhang[1], Fangzhou Wang[1], Hongbin Li[1], Braham Himed[2]
[1]Stevens Institute of Technology, United States; [2]Air Force Research Laboratory, United States

In this paper, we consider the problem of estimating the location and velocity of a non-cooperative moving target using a multi-static radar, which consists of a set of spatially distributed sensors in listening mode for now. The moving target may be transmitting, or reflecting, a source signal that is assumed to be unknown and modeled as a deterministic process. We develop a computationally efficient two-step approach to solve the localization problem. While most existing TDOA/FDOA-based methods require knowledge of the covariance matrix of the TDOA and FDOA estimates, which is usually unknown in practice, our proposed IRLS approach is covariance matrix-free.

Notes:

Thursday, April 30th, 2020

MULTISTATIC, NETWORKED & DISTRIBUTED

13:00 – 14:40
ROOM 2
CHAIR: MARK GOVONI, *ARL*
ABIGAIL HEDDEN, *U.S. ARMY RESEARCH LABORATORY*

13:00 Investigating the Effects of Bistatic SAR Phenomenology on Feature Extraction

Michael Woollard, Matthew Ritchie, Hugh Griffiths
University College London, United Kingdom

The lack of openly-available bistatic imagery and analysis of the unique artefacts which occur within it is a significant barrier to developing automatic target recognition methods for such systems. This paper addresses these issues by presenting a simulation methodology for obtaining bistatic SAR imagery of ground vehicle targets and investigating the features that occur within this imagery. Several effects unique to the bistatic case are presented, and the performance degradation of a classifier at several bistatic angles is empirically demonstrated. A version of the final database will be publicly released to promote wider research into this challenge.

13:20 Analysing Multibeam, Cooperative, Ground based Radar in a Bistatic Configuration

Pepijn B. Cox, Wim L. van Rossum
Netherlands Organisation for Applied Scientific Research, Netherlands

Recent advances in digital beam forming for phased arrays in combination with digital signal processing should enable the development of multibeam radar in a bistatic configuration. In the bistatic setting, the pulse travelling outward from the transmitter should be followed or “chased” by the receiver. During transmission, depending on the location of the transmitter, receiver, and pulse, the number of digital beams and their location at the transmitter vary. In this paper, we analyse the geometrically depending number of digital beams and the beam switching rate of the receiver needed for pulse chasing. In addition, we derive the pulse repetition frequency (PRF) for the bistatic configuration based on the desired detection range. It is shown that the PRF in the bistatic case can be increased compared to its monostatic counterpart when the distance between the transmitter and the receiver is increased. Our results are applied on the scenario of an air traffic control radar to show the feasibility of a multibeam, ground based bistatic surveillance radar.

13:40 A Multifunctional Broadband Receiver for Bistatic X-Band Radar Measurements

Michael Kohler[1], Vichet Duk[1], Matthias Weiss[1], Wojciech Brodowski[1], Josef Worms[1], Daniel O'Hagan[1], Oliver Bringmann[2]
[1]Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany; [2]University of Tübingen, Germany

This paper presents the multifunctional use of a developed two-channel broadband receiver for bistatic radar applications. Modern broadband receivers integrate more and more functionality due to their increased performance. For example, the simultaneous operation of radar, communication applications and spectrum sensing is possible with a single receiver. Broadband antenna elements, radio frequency stages and corresponding analog-to-digital converters enable the multifunctional use over a wide frequency range. This reduces the overall hardware costs as the required tasks can be performed with the same device. In this paper we therefore demonstrate the multifunctional use of the receiver for bistatic radar applications using a X-band radar as cooperative illuminator. A signal processing methodology using the sampled data from a reference and surveillance channel and the known transmit pulse parameters is presented to perform range-Doppler processing. The performance of the proposed approach is demonstrated with measurement data collected during several measurement campaigns in different rural terrain types representing the probable environment of operation for such receivers.

Thursday, April 30th, 2020

14:00 Doppler-Only Multistatic Radar via Sequential Convex Optimization

Jason Hodkin[1,2], V. Chandrasekar[2]
[1]Johns Hopkins University Applied Physics Laboratory, United States; [2]Colorado State University, United States

Localization via Doppler-only multistatic radar is addressed by the application of sequential convex programming. The optimization approach as well as the radar modality are described. Two case studies for a single receiver and multiple transmitters are shown. Additionally the localization error for this approach and a well-traveled nonlinear optimization method are compared. It is shown that the sequential convex programming method described can perform well with low signal-to-noise ratios. Potential applications are considered as well as a plausibly low cost hardware implementation.

14:20 Non-Orthogonality in MIMO Radar: A Fractional Fourier Approach

Pawan Setlur, K.T. Arasu
Riverside Research, United States

Unlike conventional processing, we demonstrate that separation of waveforms at the receivers is indeed possible in the MIMO and multistatic radar setting in a fractional Fourier domain. We advocate for the simultaneous transmission of linear frequency modulated (LFM) waveforms. i.e. LFM chirps. In MIMO radar literature, a frequently employed assumption (either explicit or implicit) is that: orthogonality of waveforms is maintained for all delay and for all Doppler shifts. Our mathematical proof, via several theorems and corollaries, demonstrates that two waveforms may not have zero cross-correlations for all delays and Dopplers, even when they are strictly orthogonal.

Notes:

Thursday, April 30th, 2020

WAVEFORM & WAVEFORM DIVERSITY I

13:00 – 14:40
ROOM 3
CHAIR: ABOULNASR HASSANIEN, *WRIGHT STATE UNIVERSITY*
STEPHEN HARMAN, *THALES AVEILLANT*

13:00 Waveform Design Implemented on Neuromorphic Hardware

Patrick Farr[1], Aaron M. Jones[2], Trevor Bihl[2], Jayson Boubin[3], Ashley DeMange[2]
[1]Applied Research Solutions, United States; [2]Air Force Research Laboratory, United States;
[3]The Ohio State University, United States

Neuromorphic computing hardware mimics neurobiological architectures and promises eventual low power operation. Additionally, arbitrary waveform generator hardware permits the realization of complex radar waveform structures. In this paper, we combine these two technologies and investigate the potential of Spiking Neural Networks to generate waveforms and their suitability in dynamic environments where adaptability is paramount. We discuss the process of development, current limitations, and critical assumptions to realizing real-time waveform adaptability with this hardware. Finally, we provide simulation and a novel application of an SNN implemented on Loihi hardware to classify a matched filter dataset.

13:20 Correlation-Gradient-Descent: Efficient Optimization Methods for Unimodular Waveform Design with Desirable Correlation Properties

Khaled Alhujaili[1], Vishal Monga[1], Muralidhar Rangaswamy[2]
[1]Pennsylvania State University, United States; [2]Air Force Research Laboratory, United States

We consider the problem of designing sequences with good auto- and cross-correlation properties for multiple-input multiple-output (MIMO) radar systems. This design problem reduces to minimizing a polynomial function of the transmit waveforms. The problem becomes more challenging in the presence of practical constraints on the waveform such as the constant modulus constraint (CMC). The aforementioned challenge has been addressed in the literature by approximating the cost function and/or constraints, i.e. the CMC. In this work, we develop a new algorithm that deals with the exact non-convex cost function and CMC. In particular, we develop a new update method (Correlation-Gradient-Descent (CGD)) that employs the exact gradient of the cost function to design such sequences with guarantees of monotonic cost function decrease and convergence. Our method further enables descent directly over the CMC by invoking principles of optimization over manifolds. Experimentally, CGD is evaluated against state-of-the-art methods for designing uni-modular sequences with good correlation properties. Results reveal that CGD can outperform these methods while being computationally less expensive.

Thursday, April 30th, 2020

13:40 Generating Waveform Families using Multi-Tone Sinusoidal Frequency Modulation

David A. Hague
Naval Undersea Warfare Center, United States

This paper presents a method for generating a family of waveforms with low Auto/Cross-Correlation Function (ACF/CCF) properties using the Multi-Tone Sinusoidal Frequency Modulation (MTSFM) waveform model. The MTSFM waveform's modulation function is represented using a Fourier series expansion. The Fourier coefficients are utilized as a set of discrete parameters that can be modified to optimize the waveform family's properties. The waveforms' ACF/CCF properties are optimized utilizing a multi-objective optimization problem. Each objective function is weighted to place emphasis on either low ACF or CCF sidelobes. The resulting optimized MTSFM waveforms each possess a thumbtack-like Ambiguity Function in addition to the specifically designed ACF/CCF properties. Most importantly, the resulting MTSFM waveform families possess both ideally low Peak-to-Average Power Ratios (PAPR) and high Spectral Efficiency (SE) making them well suited for transmission on practical radar transmitters.

14:00 Matched Illumination Waveform Optimization for Radar Imaging

Zacharie Idriss[1,2], Raghu G. Raj[1], Ram M. Narayanan[2]
[1]United States Naval Research Laboratory, United States; [2]Pennsylvania State University, United States

This paper proposes a method of knowledge-aided clutter suppression in radar signals and images by crafting the power spectrum of the transmit waveform. The power spectrum is optimized to enhance the signal-to-clutter-ratio (SCR) for target matched illumination by suppressing the transmit power in dominant clutter frequencies. The power spectrum optimized using an algorithm that is developed using Taguchi optimization techniques. A vectorized version of the particle swarm algorithm (PSO) is then developed for comparison. The cost function is the mutual information between the received signal and the target frequency response conditioned upon the transmit waveform. Radar imagery is formed using the optimized waveforms to test the methodology by the coherent addition of simulated distributed target and clutter responses using the SCR as the performance metric. The results show that by transmitting a waveform tailored to the frequency response of the target and clutter, its overall 2-dimensional reflectively can be enhanced.

Notes:

Thursday, April 30th, 2020

QUANTUM RADAR: CURRENT STATUS & PROSPECTS

13:00 – 14:40
ROOM 4
CHAIR: RAVI ADVE, *UNIVERSITY OF TORONTO*
JÉRÔME BOURASSA, *UNIVERSITÉ DE SHERBROOKE*

13:00 A System Engineering Perspective on Quantum Radar

Fred Daum
Raytheon Company, United States

We compute the minimum cost for an optimal quantum radar, and we compare it with the cost of actual real world classical radars as a function of range. Our calculations show that the minimum cost quantum radar at X-Band is many orders of magnitude more expensive than the corresponding classical radar, even assuming the most optimistic broadband phased array radar architecture. We assume that the quantum radar is optimal; that is, the effective signal-to-noise ratio is 6 dB better than for a classical radar with the same transmit power and bandwidth at low photon flux per mode.

13:20 Inspiring Radar from Quantum-Enhanced Lidar

Han Liu[1], Amr Helmy[1], Bhashyam Balaji[2]
[1]University of Toronto, Canada; [2]Defence Research and Development Canada, Canada

In this paper, we theoretically analyze a prototype target detection protocol, the quantum time correlated (QTC) detection protocol, with spontaneous parametric down-converted photon-pair sources. The QTC detection protocol only requires time-resolved photon counting detection, which is phase-insensitive and therefore suitable for optical target detection. As a comparison to the QTC detection protocol we also consider a classical phase-insensitive target detection protocol based on intensity detection. We obtain an analytical expression of the receiver operating characteristic (ROC) curves. We carry out experiments using a semiconductor waveguide source. The experimental results agree very well with the theoretical prediction. Finally, our technological platform is highly scalable and tunable and thus amenable to large scale integration necessary for practical applications. We discuss extensions to microwave regime as well.

13:40 Entangled Coherent States for Quantum Radar Applications

Marco Frasca[1], Alfonso Farina[2]
[1]MBDA Italia S.p.A., Italy; [2]Technical Consultant, Italy

We propose a new device that can be used to produce entangled states between coherent states, acting like Schroedinger's cat states, useful for a quantum radar technology. The reason to use such states is to get an arbitrary number of photons entangled produced at will. The aim is to improve with respect to a common limitation of quantum radar. Such a device, dubbed Cooper-pair box (or charge qubit) in literature, is a well-known system that can be operated through a superconductive Josephson junction. Such states were recently observed in cavity quantum electrodynamics. Here we exploit their experimental implementation in strongly coupled cavities. The reference quantum radar is the one recently studied in experiments compared to a noise radar.

Thursday, April 30th, 2020

14:00 Amplification Requirements for Quantum Radar Signals

Jérôme Bourassa[1], Christopher M. Wilson[2]
[1]Université de Sherbrooke, Canada; [2]University of Waterloo, Canada

Quantum illumination radars rely on two-mode squeezing sources to produce signals with quantum-enhanced correlations. The recent demonstration of quantum-enhanced radar transmitters in the laboratory has shown promising progress in the technology. Amplification of the quantum signals is however necessary in order to make quantum radars a reality. Here we discuss the possibility of amplifying quantum signals while preserving a quantum advantage. We find that amplifying both signals equally cannot beat an ideal source of classically correlated signals, but does provide a quantum advantage over noisy classical sources. We also briefly discuss other amplifications scheme that may provide further enhancements.

14:20 Configuration-Dependent Characteristics of Virtual-Mode Quantum Sensing Systems

Marco Lanzagorta[1], Jeffrey Uhlmann[2]
[1]United States Naval Research Laboratory, United States; [2]University of Missouri-Columbia, United States

Previous works have examined the use of a distributed network of quantum illumination and sensing nodes to augment the available number of distinguishable modes with an additional set of virtual modes. It has been shown that this approach in theory can be applied to achieve a required level of target detection performance within the constraints imposed by the limited rate at which entangled microwave photons can be generated. In this paper we examine how this performance is impacted by the spatial geometry of the network of nodes with respect to the target's range and cross section.

Notes:

Thursday, April 30th, 2020

MEDICAL & BIOLOGICAL APPLICATIONS

15:10 – 16:50
ROOM 1
CHAIR: FAUZIA AHMAD, *TEMPLE UNIVERSITY*
WILLIE NEL, *CSIR*

15:10 UWB Radar Cardiac Activity Sensing : Novel Arctangent Demodulator for Direct-RF Receivers

Sharanya Srinivas, Yu Rong, Daniel W. Bliss
Arizona State University, United States

Ultra Wide Band (UWB) radars are effective in detecting subtle fluctuations of illuminated target. This attribute makes them attractive for uncovering respiration and circulation patterns from chest movements. Despite the acute range resolution offered by Doppler radars, contribution by cardiovascular pumping is quite feeble and is overshadowed by breathing. It is observed that, when chest movements were monitored using UWB pulse Doppler radars, cardiac motion is buried at least 30 dB under first harmonic of respiration. In this paper, we propose and investigate novel Arctangent demodulation method for direct-RF receivers. The proposed method offers an improvement of signal-to-noise ratio by 8-15 dB of cardiopulmonary motion signal when compared to existing algorithms. In addition, it enables adaptive suppression of respiratory artifacts using trend filtering which vastly enhances robustness in real-time non-invasive heart rate monitoring applications.

15:30 Attention-Augmented Convolutional Autoencoder for Radar-Based Human Activity Recognition

Christopher Campbell, Fauzia Ahmad
Temple University, United States

We propose an attention-augmented convolutional autoencoder for human activity recognition using radar micro-Doppler signatures. We use attention to overcome the limited receptive field of convolutional autoencoders (CAE), thereby enabling them to learn global information in addition to spatially localized features, while preserving their unsupervised pretraining characteristic. The augmentation is accomplished by concatenating convolutional local-feature maps with a set of attention feature maps that capture global dependencies. Using real data measurements of falls and activities of daily living, we demonstrate that the incorporation of the attention mechanism yields superior classification accuracy with respect to training sample size, compared to the conventional CAE.

15:50 An Examination of Frequency-Modulated Continuous Wave Radar for Biomedical Imaging

Justin G. Metcalf[1], Jay McDaniel[1], Jessica Ruyle[1], Nathan Goodman[1], Jack C. Borders Jr.[2]
[1]University of Oklahoma, United States; [2]University of Oklahoma Health Sciences Center, United States

The dominant waveforms used for high resolution biomedical imaging radar systems are stepped frequency or a frequency sampled ultrawideband pulsed waveform. Here several attractive characteristics of frequency-modulated continuous wave (FMCW) radar systems are summarized to motivate an alternative approach to biomedical imaging radar design. Motivated by these features a first-cut at a link budget analysis is presented for replacing computed tomography scans for imaging of the human paranasal sinuses. As a first approach, the achievable signal-to-noise ratio (SNR) of such a system is examined based on an initial tissue model and pertinent safety regulations. It is shown that such an FMCW mode is feasible from an SNR standpoint, but that much work is needed to compensate for distortions, account for the skin response, and validate the model.

16:10 Cardiac Sensing Exploiting an Ultra-Wideband Terahertz Sensing System

Yu Rong, Panagiotis C. Theofanopoulos, Georgios C. Trichopoulos, Daniel W. Bliss
Arizona State University, United States

In this paper, we present a novel ultra-wideband (UWB) Terahertz (THz) sensing system for cardiac monitoring and we extract cardiac pulse information from various peripheral body parts by analyzing heartbeat-related skin motions and body motions. Using our system, we demonstrate improved cardiac measurement performance by exploiting unique THz spectral features, narrow focused beam, large signaling bandwidth and superior phase sensitivity, compared to previous results on cardiac measurement. Additionally, we conduct correlation based analysis and show that the Terahertz pulse measure is highly correlated with the contact pulse reference. We compare the estimated heart rates against the reference rates to show accuracy.

Notes:

Thursday, April 30th, 2020

RADAR SIGNATURE OF UAVS

15:10 – 16:50
ROOM 2
CHAIR: MATTHEW RITCHIE, *UNIVERSITY COLLEGE LONDON*
MOHAMMED JAHANGIR, *AVEILLANT LTD*

15:10 UAV Micro-Doppler Signature Analysis using DVB-S based Passive Radar

Martin Ummenhofer, Louis Cesbron Lavau, Diego Cristallini, Daniel O'Hagan
Fraunhofer Institute for High Frequency Physics and Radar Techniques, Germany

Drones and unmanned aerial vehicles (UAVs) are increasingly popular, thus posing danger and threats to infrastructures and public safety. A technology for drone detection and classification would therefore significantly increase the level of security. In scenarios such as concerts, sport events, trade fairs, or in any situation where significant aggregation of people is present, such techniques should be non-invasive. That means they do not have to pose an additional threat to people themselves. To this end, passive radars offer an appealing solution, since they are able to offer a non-cooperative surveillance while not emitting any electromagnetic signal. On the contrary, they rely on existing transmitting infrastructure (also referred to as illuminators of opportunity, IOO), such as broadcasting signal sources (FM radio, terrestrial and satellite digital video broadcasting, cellular communication, and so on). In this work, the possibility to exploit satellite television based passive radar for UAV detection is analyzed by experimental validation. In addition, micro-Doppler signatures for drones have been extracted, which might give information for subsequent UAV classification.

15:30 Fundamental Frequency Estimation of HERM Lines of Drones

Andi Huang[1,2], Pascale Sévigny[2], Bhashyam Balaji[2], Sreeraman Rajan[1]
[1]Carleton University, Canada; [2]Defence and Research Development Canada, Canada

Collecting micro-Doppler signatures of UAVs with clear blade flashes can be difficult due to the requirement of needing high SNR and PRF. Another way of viewing micro-Doppler is through HERM lines which is derived by using a longer integration window to generate a spectrogram using STFT. This results in harmonic lines that are separated by a function of the rotation rate. Knowing the fundamental frequency can give an indication of the speed of the UAV and even act as a drone classifier. In this paper, a log harmonic summation algorithm was used to extract the fundamental frequency of HERM lines. It was shown to perform better under noise than the existing method in the literature, the cepstrum. The advantage of this method is that it can be used for low PRF radars for long range drone detection.

15:50 Measuring UAV Propeller Length using Micro-Doppler Signatures

Zeus Gannon, David Tahmoush
University of Kansas, United States

Presented here is a method using micro-Doppler radar techniques to measure the length of a UAV propeller. This method is dependent on the phenomena of blade flashes that can be observed in the radar returns of rotating objects. Simulations are shown to explain the principles and real data is examined to produce a measurement of different UAV propeller lengths with less than 1% error on blades alone and on multiple UAVs.

Thursday, April 30th, 2020

16:10 Data-Driven STFT for UAV Micro-Doppler Signature Analysis

Daniel B. Herr, Dave Tahmoush
University of Kansas, United States

The Short Time Fourier Transform (STFT) constructs the instantaneous spectrum of an observed dataset after applying a temporal taper for the sake of micro-Doppler feature extraction. Here, the temporal window applied to the STFT is adjusted proportionally to the instantaneous periodicity of the dataset as to establish more consistent UAV micro-Doppler signatures and improve the separability of relevant features. The outlined approach is developed in the context of UAV rotor blade analysis. Techniques for estimating the periodicity of the radar returns and examining the temporal correlation of the signal are presented. To demonstrate the efficacy of the proposed data-driven STFT algorithm, simulated and experimentally measured results of UAV rotor blades are analyzed.

16:30 Propeller Modulation Analysis of 4-Blade, 4-Engine Aircraft in FM-Band Multistatic Passive Radar

F.D.V. Maasdorp, J.E. Cilliers, C.A. Tong
Council of Scientific and Industrial Research, South Africa

This paper furthers the investigation into modulation effects of propeller-powered aircraft on signals sensed by multistatic FM-band passive radar sensors. Previous results have demonstrated that a passive radar system consisting of a single bistatic transmitter/receiver pair is able to detect and measure the modulation effects of a twin-blade, single-propeller aircraft. We now present supplementary results for a 4-blade, 4-engine aircraft in a single transmitter and geographically separated, dual-receiver multistatic radar system, again exploiting illuminators of opportunity in the commercial FM-broadcast band.

Notes:

COGNITIVE RADAR & MACHINE LEARNING

15:10 – 16:50
ROOM 3
CHAIR: YIMIN ZHANG, *TEMPLE UNIVERSITY*
VINCENZO CAROTENUTO, *UNIVERSITY OF NAPLES FEDERICO II*

15:10 Impulse Response Estimation for Wideband Multi-Channel Radar Systems

Sandeep Gogineni[1], Muralidhar Rangaswamy[2], Joseph R. Guerci[1], Jamie S. Bergin[1], David R. Kirk[1]
[1]Information Systems Laboratories, United States; [2]Air Force Research Laboratory, United States

In this paper, we will develop a frequency-domain algorithm for estimating the channel impulse responses corresponding to wideband multi-channel radar systems. The multiple channels can correspond to different spatial locations or polarizations. Further, we will investigate the stationarity of these radar channel impulse responses. The channel estimates computed from the algorithm can be used within the stationarity window to improve the radar performance under the cognitive radar framework. We will present extensive simulations using high-fidelity modeling and simulation software RFView to demonstrate the channel estimation results corresponding to different transmitters and polarizations.

15:30 Reinforcement Learning based Transmitter-Receiver Selection for Distributed MIMO Radars

Petteri Pulkkinen, Tuomas Aittomäki, Visa Koivunen
Aalto University, Finland

Active transmitter-receiver subset selection facilitates efficient resource use and adaptation to varying target and propagation environments in distributed MIMO radars. Previously, resource optimization based on SINR has been proposed. The observed SINR values need to be estimated assuming particular propagation and target models. In this paper, a novel machine learning approach is proposed in which no such assumptions are needed. We formulate the TX-RX subset selection as a multi-armed bandit (MAB) problem and extend it to the combinatorial MAB framework. It is shown that such algorithms can be effectively used for the TX-RX subset selection problem even in non-stationary scenarios.

15:50 Radar Human Motion Recognition using Motion States and Two-Way Classifications

Moeness G. Amin, Ronny G. Guendel
Villanova University, United States

We perform classification of activities of daily living (ADL) using a Frequency-Modulated Continuous Waveform (FMCW) radar. In particular, we consider contiguous motions that are inseparable in time. Both the micro-Doppler signature and range-map are used to determine transitions from translation (walking) to in-place motions and vice versa, as well as to provide motion onset and the offset times. The possible classes of activities post and prior to the translation motion can be separately handled by forward and background classifiers. The paper describes ADL in terms of states and transitioning actions, and sets a framework to deal with separable and inseparable contiguous motions. It is shown that considering only the physically possible classes of motions stemming from the current motion state improves classification rates compared to incorporating all ADL for any given time.

16:10 Clustering Radar Pulses with Bayesian Nonparametrics: A Case for Online Processing

Matthew Scherreik, Brian Rigling
Wright State University, United States

In a radar environment, cognitive receivers typically process raw IQ samples into sequences of pulse descriptor words (PDWs). When there are multiple emitters present in the signal, their respective PDWs are interleaved in time, necessitating specialized signal processing to deinterleave the pulse trains. Many deinterleaving solutions in the literature today utilize clustering algorithms to summarize the potentially massive amount of PDW data. Often, these clustering algorithms do not account for the fact that the number of clusters can change as a function of time. Additionally, PDW data arrives in a continuous stream, necessitating an efficient implementation. In this paper, we use Bayesian nonparametrics to address a dynamically changing radar scenario and implement an efficient online algorithm. We show that this algorithm can provide an effective solution to radar pulse clustering.

16:30 Uncertainty Function Design for Adaptive Beamsteering Cognitive Radar

Zachary W. Johnson, Ric A. Romero
Naval Postgraduate School, United States

Adaptive Beamsteering Cognitive Radar (AB-CRr) employs a real time transmit-receive system to improve the performance of radar search-and-track functions over traditional beam rasterization schemes. AB-CRr utilizes a probabilistic model of the radar channel to dynamically generate a beamsteering strategy for its environment. The channel probability model is used to form an adaptive beamsteering strategy via a user defined uncertainty function. In this paper, the formulation of uncertainty functions is introduced and their impact on beamsteering behavior and performance is investigated.

Notes:

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

R

S