# Bistatic and Multistatic Radar Imaging

**Instructors:**

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**Abstract:**

SAR/ISAR images have been largely used for earth observation, surveillance, classification and recognition of targets of interest. The effectiveness of such systems may be limited by a number of factors, such as poor resolution, shadowing effects, interference, etc. Moreover, both SAR and ISAR images are to be considered as two-dimensional maps of the real three-dimensional object. Therefore, a single sensor may produce only a two-dimensional image where its image projection plane (IPP) is defined by the system-target geometry. Such a mapping typically creates a problem for the image interpretation, as the target image is only a projection of it onto a plane. In addition to this, monostatic SAR/ISAR imaging systems are typically quite vulnerable to intentional jammers as the sensor can be easily detected and located by an electronic counter-measure (ECM) system. Bistatic SAR/ISAR systems can overcome such a problem as the receiver can act covertly due to the fact that it is not easily detectable by an ECM system, whereas multistatic SAR/ISAR may push forward the system limits both in terms of resolution and image interpretation and add to the system resilience.

**Intended Audience:**

Attendees should have an introductory understanding of radar systems, radar phenomenology, and signal processing.

**Learning Outcomes:**

In this tutorial, elements of bistatic SAR and ISAR will be introduced in terms of system geometry, signal modeling, image reconstruction and interpretation. Bistatic scattering phenomenology will be explored through simulated examples. Applications of bistatic SAR and ISAR will also be illustrated, such as measured and emulated bistatic ISAR and passive ISAR. Multistatic radar imaging will also be introduced in terms of theoretical and conceptual aspects before presenting its applications, which will cover 3D radar imaging, challenges to multistatic visualization, imaging of non-cooperative targets immersed in clutter, multi-perspective radar imaging of moving targets, and so on.

**Detailed Description:**

Interest in bistatic and multistatic radar systems has been steadily increasing in the recent years, including those that also provide imaging capabilities. A NATO task group, namely the SET-250, on “Multidimensional radar imaging” is currently active that aims at demonstrating increased imaging capabilities of multi-static and multi-channel radar imaging systems. Also, the increased number of multi-bistatic passive radar imaging systems that are under study and development produce extra ground for multistatic radar imaging. The tutorial proposed addresses basics of bistatic and multistatic radar imaging and introduces the current state of the art and research activities in this field. The IEEE Radar conference is the optimal venue for proposing this timely subject.

1. Introduction to bistatic and multistatic radar (BRIAN)
    - 1.1. Brief history
    - 1.2. Bistatic and multistatic radar geometry
    - 1.3. Figures of merit and iso-contours

2. Bistatic Synthetic Aperture Radar (BRIAN)
    - 2.1. Bistatic SAR geometry
    - 2.2. Bistatic SAR signal modelling
    - 2.3. Bistatic SAR imaging
    - 2.4. Bistatic scattering phenomenology

3. Multistatic Synthetic Aperture Radar (BRIAN)
    3.1. Multistatic SAR geometries
    3.2. Multistatic SAR imaging
    3.3. Three-dimensional imaging
    3.4. Challenges to multistatic visualization

4. Bistatic Inverse Synthetic Aperture Radar (B-ISAR) (MARCO)
    4.1. B-ISAR geometry
    4.2. B-ISAR signal modelling
    4.3. Bistatically Equivalent Monostatic Theorem
    4.4. B-ISAR image formation
    4.5. B-ISAR applications: Emulated B-ISAR, Passive ISAR

5. Multistatic ISAR (M-ISAR) (MARCO)
    5.1. M-ISAR geometry
    5.2. Coherent vs Incoherent Multistatic ISAR
    5.3. Coherent M-ISAR: 3D-InISAR and STAP-ISAR
    5.4. Incoherent M-ISAR: Multi-perspective ISAR imaging and Image fusion

**Prior Presentations:**

This is tutorial will be a refinement of the same tutorial given at the 2015 International Radar Conference in Washington, DC, the 2016 IEEE Radar Conference in Philadelphia, the 2017 IEEE Radar Conference in Seattle, the 2018 IEEE Radar Conference in Oklahoma City and the 2019 IEEE Radar Conference in Boston. Each offering drew ~15-25 attendees. We also noticed that the number of attendees is not decreasing over the years.

**Biosketches:**

Marco Martorella received his Laurea degree (Bachelor+Masters) in Telecommunication Engineering in 1999 (cum laude) and his PhD in Remote Sensing in 2003, both at the University of Pisa. He is now an Associate Professor at the Department of Information Engineering of the University of Pisa where he lectures “Fundamentals of Radar” and “Digital Communications” an external Professor at the University of Cape Town where he lectures “High Resolution and Imaging Radar” and “Introduction to Radar” within the “Masters in Radar and Electronic Defence”. Prof. Martorella is also Director of the CNIT’s National Radar and Surveillance Systems Laboratory. He is author of more than 200 international journal and conference papers, four book chapters, a book entitled “Inverse Synthetic Aperture Radar Imaging: Principles, Algorithms and Applications” and another book entitled “Radar Imaging for Maritime Observation”. He has presented several tutorials at international radar conferences, has lectured at NATO Lecture Series and organised international journal special issues on radar imaging topics. He is a member of the IET Radar Sonar and Navigation Editorial Board, a senior member of the IEEE and a member of AFCEA. He is also a member of the IEEE AES Radar Systems Panel and of the NATO SET Panel. He is currently the chair of the research task group NATO SET-250 on “Multidimensional Radar” and co-chair of NATO SET-236 on “Robust compressive sensing techniques for radar and ESM applications”. He was also chair of the SET-196 on “Multichannel/Multistatic radar imaging of non-cooperative targets” and of the specialist meeting NATO SET-228 on “Radar Imaging for Target Identification”. He has been recipient of the 2008 Italy-Australia Award for young researchers, the 2010 Best Reviewer for the IEEE GRSL, the IEEE 2013 Fred Nathanson Memorial Radar Award, the 2016 Outstanding Information Research Foundation Book publication award for the book “Radar Imaging for Maritime Observation” and the 2017 NATO Set Panel Excellence Award. He is co-founder of a radar systems-related spin-off company, namely ECHOES. His research interests are mainly in the field of radar imaging and multichannel radar signal processing.

Brian Rigling received the B.S. degree in physics-computer science from the University of Dayton in 1998 and received the M.S. and Ph.D. degrees in electrical engineering from The Ohio State University in 2000 and 2003, respectively. From 2000 to 2004 he was a radar systems engineer for Northrop Grumman Electronic Systems in Baltimore, Maryland. Since July 2004, Dr. Rigling has been with the Department of Electrical

Engineering, Wright State University, and was promoted to associate professor in 2009, professor in 2013, and department chair in 2014. For 2010, he was employed at Science Applications International Corporation as a Chief Scientist while on leave from Wright State University. He has authored chapters for 4 textbooks and has authored more than 110 conference and journal papers. In 2007, Dr. Rigling authored the chapter on Bistatic Synthetic Aperture Radar for the book Advances in Bistatic Radar, edited by Nicholas Willis and Hugh Griffiths. Dr. Rigling has served on the IEEE Radar Systems Panel since 2009, and has been an associate editor for IEEE Transactions on Image Processing. He was the General Chair for the 2014 IEEE Radar Conference, was awarded the 2015 IEEE Fred Nathanson Memorial Radar Award, and was elevated to IEEE Fellow in 2018.