Advances in Applications of Radar Micro-Doppler Signatures

Instructors:
Dr. Victor C. Chen, Radar Division, Naval Research Laboratory, Retiree; v.c.chen@ieee.org
Dr. Shobha Sundar Ram; Dept. of Electronics and Communication; Indraprastha Institute of Information Technology; New Delhi, India - 110020

Abstract:

Radar micro-Doppler signature represents a distinctive characteristic of the intricate frequency modulations generated from a target with micro motions, which provides unique complementary target features. This tutorial is to provide attendees a working knowledge of radar micro-Doppler signatures. Since 2011, Dr. Chen has given a number of tutorials in radar relevant conferences to present introduction on radar micro-Doppler concept and basic applications. This tutorial will concentrate on the current advances of radar micro-Doppler signatures with on-site demonstrations using MATLAB tools and real Micro-Doppler Radar Equipment.

We first briefly review the development of the concept, basic principles and applications of radar micro-Doppler signatures. Then, we introduce and demonstrate with MATLAB tool to show how to reveal micro-Doppler effect in radar, how to set up models of micro moved targets, and how to extract and analyze micro-Doppler signatures. The main part of the tutorial is to introduce the state-of-the-art in applications of radar micro-Doppler signatures to surveillance, security, industry, and medical monitoring. An on-site real micro-Doppler radar demonstration will be conducted in the presentation.

Intended Audience:

Tutorial attendees can be from beginner to intermediate and even advanced level professionals, including university graduate students, research associates and professors, research center scientists, and industry professionals, engineers and managers, who wish to understand the basic applications of micro-Doppler effect in radar, learn the procedure and methods of analyzing micro-Doppler effect in radar, simulate radar micro-Doppler signature of targets using MATLAB tool, collect and process real micro-Doppler radar data into micro-Doppler signature, and especially study current advances in applications of radar micro-Doppler signature, are likely to benefit from this tutorial.

Undergraduate training in radar signal processing is assumed. Attendees are welcome to, but not required to, bring a laptop to the tutorial for on-site exercising MATLAB simulation source codes.

Learning Outcome:

For beginner attendees, understand the basic concept, principle, and applications, learn MATLAB simulations and micro-Doppler radar, and overlook advanced applications. For intermediate attendees, review the basic concept, principle, and applications, learn MATLAB simulations and micro-Doppler radar, and have knowledge of advanced applications. For advanced attendees, review the basic concept, principle, and applications, dig into MATLAB simulations and micro- Doppler radar systems, and gain skill in advanced applications.

Detailed Description:

Since the micro-Doppler effect in radar was introduced decades ago, numerous related publications appear in radar conference proceedings and journals, including the annual IEEE radar conference. The motivation of our tutorial is to review current advances in the applications of micro-Doppler effect in radar, exploit potential opportunities of applying radar micro-Doppler signatures in the real world, and provide user-friendly tools for further studying radar micro-Doppler signatures. Based on examples provided in the tutorial, researchers are capable to make modifications to other extended applications of interest.

Comprehensive Outline of Proposed Content:

Part I: (30 min) Introduction

- Brief History of Micro-Doppler Effect in Radar
- Basics of Micro Motions and Micro-Doppler Signatures
- Basic Applications of Radar Micro-Doppler Signatures

Part II: (30 min) Basics of Radar Micro-Doppler Signature

- Micro-Doppler signatures of rigid body and non-rigid body motion
- EM scattering from a non-rigid body motion MATLAB simulation of rigid and non-rigid body motions and micro- Doppler signatures
- Case study

Part III: (60 min) Applications of Radar Micro-Doppler Signature

- Human gaiting analysis
- Helicopter rotor blades analysis
- Signature decomposition
- Recognition of space, air, and ground moving targets
- CW and FMCW micro-Doppler radar for extraction of micro-Doppler signatures
- Case study with MATLAB simulation

Part IV: (120 min) Advances in Applications of Radar Micro-Doppler Signatures

- Advances in micro-Doppler signature decomposition
- Advances in vital sign analysis for finding survivors trapped in rubble
- Advances in wind turbine analysis
- Gesture sensing and gesture control
- 3-D through-wall frontal imaging of human activities
- Case study with real FMCW micro-Doppler radar demonstration

Prior Presentations:

Dr. Chen has given a number of tutorials related to radar micro-Doppler signatures as follows.

1) "Micro-Doppler signatures, processing and applications", 2011 EuRad Tutorial and Survey in EuRad conference in Manchester, UK
2) "Challenges and perspectives in research on radar micro-Doppler signature", 2011 IEEE International Radar Conference in ChengDu, China
3) "Micro-Doppler signatures – principle and applications", SPIE 2011 in Orlando, FL and Baltimore, MD
4) "Micro-Doppler signatures – principle and applications", SPIE 2012 in Baltimore, MD

The proposed tutorial for IEEE 2016 Radar Conference is totally different from the previous tutorial. Through previous presented versions and feedbacks from attendees, we propose a new version. The first half of the presentation describes the basics of concepts, principles, and applications along with MATLAB demonstration, which is specially designed for attracting beginners and intermediate level attendees. For advanced level attendees, the first half presentation can make them emphasize their knowledge and experience with MATLAB demonstration. The second half of the presentation on advances in applications will become the most interesting part to the advanced level attendees through interactive real micro-Doppler radar demonstration and discussion. For beginners and intermediate level attendees, they can oversee the radar demonstration and open their eye to further advanced applications.

Bio-sketches:

Dr. Victor C. Chen, Fellow of the IEEE, is internationally recognized for his work on micro-Doppler signatures and time-frequency analysis. He received a Ph.D. in Electrical Engineering from Case Western Reserve University, Cleveland, Ohio. He worked for 20 years in the Radar Division, US Naval Research Laboratory while he collaborated with international participants for US Navy S&T projects, served as US Panel Member of TTCP (The Technical Cooperation Program) and NATO Technical Group working on time-frequency processing for ISAR imaging, non-cooperative target identification, radar detection and identification of small vessels, vehicles, and dismounts. In 2001, he was invited by the Norwegian Defense Research Establishment to give a series of seminars on time-frequency applications to radar. He served as a Technical Program Committee Member and Session Chair for IEEE, SPIE, and other conferences and also served as a guest editor for several journals. He dedicated 6 years to serve as an Associate Editor for IEEE Transactions on AES (Aerospace and Electronic Systems) for radar systems. After retired from NRL in 2010, he became a consultant, contractor to DoD, and consultant to industries. Currently he becomes the Technical Director, Ancortek Inc, Fairfax, VA, U.S.A. He has published more than 150 papers and articles in books, chapters in books, journals and proceedings including books: *The Micro-Doppler Effect in Radar* authored in 2011 and *Radar Micro-Doppler Signatures - Processing and Applications* edited in 2014.

Dr. Shobha Sundar Ram received her B.Tech. degree in electronic and communication engineering from University of Madras in 2004, and her M.S and Ph.D. degrees in electrical engineering from University of Texas at Austin in Austin, Texas, USA in 2006 and 2009, respectively. She is presently an Assistant Professor at Indraprastha Institute of Information Technology, New Delhi. Dr. Ram's principal areas of research are in the conceptualization, modeling, design and development of electromagnetic sensors. In particular, she has focused on developing viable solutions for through-wall radar sensing of humans. Her work has been published in journal publications such as IEEE Aerospace and Electronic Systems, IEEE Geoscience and Remote Sensing, IEEE Antennas and Wave Propagation, IET Electronic Letters and Journal of Franklin Institute. She has actively participated in several conferences such as IEEE Radar Conference and IEEE Antennas and Propagation Society International Symposium. She has won

two best paper awards at the student paper competitions at the IEEE Radar Conference in Rome, Italy in 2008 and in San Diego, USA in 2009. She was awarded the Continuing Fellowship by the University of Texas at Austin for the academic year 2008-2009 for outstanding academic and research achievements. Her research is currently funded by DST Inspire fellowship award for faculty. Dr. Ram has 3.5 years of work experience as a Research Scientist in Baker Hughes Inc. in Houston Texas. During her stint at Baker Hughes Inc., Dr. Ram was instrumental in the conceptualization, modeling, design and testing of low frequency narrow and broadband antennas for sensing formation resistivity for hydrocarbon exploration. Her work in this area resulted in two patent applications.