Noise Radar – New Challenges in SISO and MIMO Radars

Instructor:
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Abstract:
The tutorial will present the concept of continues wave radar emitting noise or pseudo-noise waveform. Noise waveforms have significant advantages over the classical radar waveforms, as they do not have range nor Doppler ambiguities and can be used in dense electromagnetic environment without significant interferences with other devices using this some spectrum. However, noise radars suffer from a near-far problem, so it would be difficult to design long range CW noise radar. The signal processing in noise radar is more complicated than in classical radar since all targets echoes are received simultaneously and have to be resolved. Since the targets are illuminated for long times, it is not only possible to detect and track targets using noise radar but also to perform non-cooperative identification using micro-Doppler analyses and to create ISAR images of the targets. To increase the power density on the target and provide spatial diversity of the illuminating signal, noise radar can be used in MIMO configurations using co-located as well as spatially separated antennas.

Prof. Kulpa has given several tutorials in the past on noise radar technology. The last was held during the EURAD 2014 conference, but the similarity will be less than 25%.

Intended Audience:
Scientists and engineers interested in novel noise radar technology; learning outcomes - better understanding of basic phenomena and problems related to noise radars.
Military forces, higher rank government and industrial representatives; learning outcomes - understanding the noise radar technology, potential fields of applications, understanding the difference between pulse, FMCW and noise radars and their possible symbioses.
General knowledge about radars, radar signal processing and radar applications is assumed.

Learning Outcome:
Understanding of basic phenomena and problems related to noise radars.
Understanding the noise radar technology, potential fields of applications.
Understanding the difference between pulse, FMCW and noise radars and their possible symbioses.

Detailed Description:
Active pulse radars are mature technology used widely used in civil and military application. However, that technology has several drawbacks; namely, the range and Doppler measurements are ambiguous and the radar has to emit very high power (kW or even MW) to achieved long range detection. Thus, in military applications, they can’t be stealthy, and can’t be localized in densely populated areas. For LPI radars, the use of noise radar technology is one
possible solution. The continuous wave noise radar does not show any range or Doppler ambiguity and, using low transmitted power, can detect far targets. One of limitation of noise radar is its high requirement of computational power. However, thanks to Moore’s law, computational power is increasing rapidly, so even now, it is possible to design real time noise radar processors.

The noise waveform, which is very non-specific and hard to detect, will be used in the near future to make the radar less detectable. Due to long integration, illuminating power can be reduced significantly, so the radar will be able to operate in densely populated environments and in dense spectrums The noise radar technology is one of the emerging technologies in last decade. The research on noise technology is carried out in a number of universities and research centers all over the world. The development in some countries will lead to introduction such radars in the service in near future. Based on the number of recently published papers and discussions within the radar community, it is likely that noise radars will be in service within the next decade.

This tutorial will present recent developments in Noise Radars with practical examples and implementations. It will start with noise radar technology fundamentals. Then the target models and related signal processing algorithms will be presented. Then the idea of multistatic and MIMO noise radar will be presented. That idea leads to better utilization of available spectrum, better spatial diversity of illuminating signals, better detection probability and higher spatial resolution of radar.

The detailed plan of the tutorial is as follows:
1) Introduction to noise radar technology
   Noise radar fundamentals, noise radar range equation, basic physical phenomena in noise radar.
2) Target detection in noise radar:
   Target motion models, correlation based detection, ambiguity function based detection, range and velocity walk mitigation
3) Target identification in noise radar
   Micro-Doppler analyses, SAR and ISAR imaging in noise radars, sparse imaging
4) Operations in crowded spectrum
   Wideband noise radars, sparse spectrum radars, illuminating signal shaping, side lobe control using non-matched filtration
5) MIMO noise radars
   Advantages of MIMO approach to noise radars, spatial diversity of illuminating signals, clutter cancelation in MIMO radars, waveform optimization. Collocated MIMO versus multistatic approach
6) Noise radar applications
   Surveillance radars, security barriers/fence, space technology, LPI, noise imaging

Prior Presentations:
Although this tutorial is new, Prof. Kulpa has organized and participated in the following prior noise radar tutorials:
1) Noise Radar: monostatic, multistatic and MIMO, EURAD 2014, Italy, 10.10.2014
These prior tutorials were presented jointly by 4 persons. This tutorial will be presented by a single instructor and will have less than a 25% overlap with these prior tutorials.
Bio-sketch:

Prof. Krzysztof S. Kulpa received his M. Sc., Ph.D. and Dr Sc. degrees from the Department of Electronic Engineering, Warsaw University of Technology (WUT) in 1982, 1987 and 2009 respectively. From 1985 to 1988 he worked at the Institute of Electronic Fundamentals, WUT, and in the years 1988-1990 he was Associate Professor at the Electrical Department of the Technical University of Białystok. In the period 1990-2005 he worked as a scientific consultant in WZR RAWAR. Since 1990 he has been an Associate Professor at the Institute of Electronic Systems (WUT). He is now the head the Radar Technology Research Group at WUT. Since 2011 he has held the position of Scientific Director of the Defense and Security Research Center of the Warsaw University of Technology. In 2014 he obtained the title of State Professor, granted by the President of Poland.

His research interests are in the digital signal processing area, particularly radar signal processing. His research covers noise and passive radar signal processing, radar imaging, detection and tracking. A significant part of his activity has been devoted to application problems. The results of his work have been implemented in several radars produced by the Polish radar industry, and he was involved in the creation of the first Polish SAR radar. He has managed several research projects, and for the past 15 years, his main area of research has been in airborne passive radars.