Radar Sea Clutter - Modelling and Applications

Instructors:
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Abstract:
This tutorial will provide an introduction to the modelling of radar sea clutter and its application to modern maritime radar design.
Maritime radars operate in a challenging environment and the design of radars that can reliably detect small targets on the sea surface remains at the forefront of radar research. A major part of the challenge is the need to discriminate between returns from targets and those from the sea surface, i.e. the sea clutter. In order to design better detection systems, predict performance, test systems with simulated data and assess operational performance, considerable attention is paid to the mathematical modelling of sea clutter. This tutorial will provide the background to this modelling and introduce the latest research results in this still-evolving field.
Simon Watts has presented tutorials on radar sea clutter and modelling at over 12 radar conferences since 1997. Luke Rosenberg has presented related material at two radar conferences in 2015.

Intended Audience:
The tutorial is aimed at researchers and engineers working in the field of maritime radar. It will provide a basic introduction for those new to this topic and lead into a description of the more advanced modelling methods. This will require some understanding of signal processing, probability and statistics.

Learning Outcome:
Following the tutorial, attendees should have been exposed to the methods used to model sea clutter (characterizing its reflectivity, amplitude statistics, Doppler spectra and spatial correlation) and how these models are used in different ways through the life-cycle of a radar to predict performance, design detection algorithms and simulate realistic sea clutter returns for testing radar systems. In addition, the audience will be acquainted with the latest research results in this field.
Detailed Description:

Maritime radars operate in a challenging environment and the design of radars that can reliably detect small targets on the sea surface remains at the forefront of radar research. A major part of the challenge is the need to discriminate between returns from targets and those from the sea surface, i.e. the sea clutter. In order to design better detection systems, predict performance, test systems with simulated data and assess operational performance, considerable attention is paid to the mathematical modelling of sea clutter. This tutorial will provide the background to this modelling and introduce the latest research results in this still-evolving field.

The first part of the tutorial will introduce the methods used to describe radar clutter and show how physical and empirical models are developed. The second part of the tutorial describes the nature of the backscatter from the sea surface and the models that have been developed to characterize it under different conditions. The third part of the tutorial will describe how clutter models are used to develop realistic computer simulations of radar signals. Finally, the prediction of performance using these models of clutter will be described for both non-coherent and coherent radar detection processing. The main topics to be covered are listed below:

1. Clutter definitions (a basic introduction for those new to this topic)
   1.1. Reflectivity
   1.2. Polarization scattering matrices
   1.3. Amplitude statistics
   1.4. Spectrum
   1.5. Spatial correlation
2. Sea Clutter models
   2.1. Reflectivity models
      2.1.1. Low grazing angle (RRE, GIT, Sittrop, TSC, Hybrid, Nathanson)
      2.1.2. Medium/high grazing angles (Nathanson, TSC, Ulaby, Masuko etc)
   2.2. Clutter spikes
      2.2.1. Characterization of clutter spikes in the time and frequency domains
   2.3. Amplitude statistics
      2.3.1. Evidence for compound models
      2.3.2. K, Pareto, K+R, and added thermal noise
      2.3.3. Empirical parameter models
   2.4. Doppler spectra
      2.4.1. Mean Doppler spectrum models
      2.4.2. Doppler spectra of spikes
      2.4.3. Modelling the time-varying and range-varying nature of Doppler spectra
      2.4.4. Empirical parameter models
   2.5. Spatial correlation
      2.5.1. Nature of spatial correlations
      2.5.2. Models
3. Simulation of sea clutter
   3.1. Generating correlated gamma variates
   3.2. The non-stationary characteristics of Doppler spectra
   3.3. Simulating Doppler spectra and their variation over range and time
   3.4. Simulating coherent time series data
   3.5. Simulating coherent multi-channel radar data and spikes

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4. Prediction of radar performance
   4.1. Use of clutter models in performance prediction
   4.2. Radar equation
   4.3. Pd and Pfα calculations in K, K+N, P+N etc.
   4.4. Performance prediction with coherent processing

**Prior Presentations:**

Simon Watts has presented different aspects of this subject in over 14 tutorials since Radar ’97, most recently at Radar 2012 (jointly with Keith Ward; 30 attendees), Radar 2013 (20 attendees) and Radar 2014 (in shortened form, 15 attendees) and Radar 2015 (c. 15 attendees). Attendee numbers have always been good in relation to other tutorials at the conferences. The basic principles remain the same and are relevant to new audiences from different communities. The tutorial material has also been updated to reflect the latest research results, particularly related to the modelling of Doppler spectra of sea clutter and the prediction of detection performance in coherent processing of sea clutter returns.


Luke Rosenberg presented a tutorial on high resolution land and sea clutter at Radar 2015, Washington DC, jointly with Maria Greco. Some of that material will be used here also. A version of this tutorial has also been given jointly by Simon Watts and Luke Rosenberg at RadarConf 2015 in Johannesburg. The tutorial for the 2016 IEEE Radar Conference will contain updated material.

**Bio-sketches:**

Prof. Simon Watts graduated from the University of Oxford in 1971, obtained an MSc and DSc from the University of Birmingham in 1972 and 2013, respectively, and a PhD from the CNAA in 1987. He was deputy Scientific Director and Technical Fellow in Thales UK until 2013 and is a Visiting Professor in the department of Electronic and Electrical Engineering at University College London. He joined Thales (then EMI Electronics) in 1967 and since then has worked on a wide range of radar and EW projects, with a particular research interest in maritime radar and sea clutter. He is author and co-author of over 60 journal and conference papers, a book on sea clutter and several patents. He was chairman of the international radar conference RADAR-97 in Edinburgh UK. Professor Watts received the IEE JJ Thomson Premium Award in 1987 and the IEE Mountbatten Premium Award in 1991. He serves on the IEEE AESS Radar Systems Panel, is an Associate Editor for Radar for the IEEE Transactions AES and a member of the Editorial Board of IET Radar, Sonar & Navigation. He was appointed MBE in 1996 for services to the UK defense industry and is a Fellow of the Royal Academy of Engineering, Fellow of the IET, Fellow of the IMA and Fellow of the IEEE.

Tutorials given by S. Watts

1997 “Radar Clutter and CFAR Detection” at Radar 97, Edinburgh, UK
1999 “Radar Clutter and CFAR Detection” at Radar 2000, Washington, DC
2002 “Radar Clutter and CFAR Detection” at Radar 2002, Edinburgh, UK
2003 “Radar Clutter and CFAR Detection” at Radar 2003, Adelaide, Australia
2004 “Radar Clutter and CFAR Detection” at Radar 2004, Toulouse, France
2007 “Sea Clutter - Scattering, the K Distribution and Radar Performance”, with K.D.Ward, Radar 2007, Edinburgh, UK
2009 “Sea Clutter - Scattering, the K Distribution and Radar Performance”, with K.D.Ward AES Society video
2009 “Sea Clutter - Scattering, the K Distribution and Radar Performance”, IEEE 2009 Radar Conference, Pasadena, California
2009 “Sea Clutter - Scattering, the K Distribution and Radar Performance”, with K.D.Ward, IEEE 2009 Radar Conference, Bordeaux, France
2013 “The impact of clutter modelling on radar performance and design”, IEEE 2013 Radar Conference; Adelaide, Australia
2014 “The impact of clutter on radar performance and design”, Radar 2014, Lille, France

Prof. Simon Watts also teaches 10 hours per year at University of Surrey on their Advanced Radar Technology short course, presenting on clutter, CFAR systems, MTI/MTD, EP & EA, SAR & ISAR and space-based radar.

Dr. Luke Rosenberg received his Bachelor of Electrical and Electronic Engineering in 1999, Masters in Signal and Information Processing in 2001 and PhD in 2006 all from the University of Adelaide in Australia. In 2000 he joined the Defense Science and Technology Organization as an RF engineer, then worked as a research scientist in the imaging radar systems group and recently in the maritime radar group. He is also an adjunct senior lecturer at the University of Adelaide and was recently on attachment at the US Naval Research Laboratory working on algorithms for focusing moving scatterers in synthetic aperture radar (SAR) imagery.

His interests are in the areas of radar signal processing and the modelling and simulation of radar backscatter. In particular, his work has covered radar image formation, adaptive filtering, detection theory, and radar and clutter modelling. He is an active member of the SET-185 NATO panel on high grazing angle sea-clutter and has published over 60 conference, journal and technical reports. He is a senior member of the IEEE.

Tutorials given by L. Rosenberg:
2008 “Interference suppression for multi-channel SAR” at European SAR conference, Friedrichshafen, Germany
2015 “High resolution land and sea clutter” at Radar 2015, Washington DC, jointly with Maria Greco
2015 “Radar Sea clutter – Modelling and Applications”, with S.Watts, RadarConf 2015, Johannesburg, South Africa