Advanced Optimised target detection techniques of low observables

Krishna Venkataraman

Defence Science and Technology Group,
Department of Defence,
Edinburgh, Australia

Em: Krishna.Venkataraman@defence.gov.au
Ph.: +61 404 238 476

Abstract / Background:

Detection of low RCS (Radar Cross section) targets (e.g small boats, periscope, drones etc) submerged in Sea clutter, has always been a challenge in modern times. But there is a critical requirement to detect intruders (slow moving small boats) entering into the territorial waters, UAVs (Unmanned Aviation Vehicles) over land and sea involved in EW assignments, detection of submarine periscopes exposed just above the water surface etc. Also of recently, birds flying low at critical heights above the ground, have become potential aviation safety hazards too, during aircraft takeoff and landing. These targets have significantly low RCS with weak reflected/scattered power, masked by strong correlated sea clutter (at high sea states) /ground clutter returns. Hence, extracting such weaker, unpredictable and unstable target returns (in strong clutter background) require efficient, reliable and robust Small Target detection methods and techniques. This tutorial will discuss the challenges and applicable advanced techniques and fixes in detail.

The small moving targets exhibit low Doppler frequencies and conventional Doppler detection processes used in surveillance system may not always be useful due to dwell length limitations to get sufficient Doppler information with sea returns exhibiting the same velocity range as that of the targets of interest. To alleviate such hurdles in doppler processing we have other options open to us like various Track- before-detect methods like Dynamic programming, Particle Filters, MHT (Multi-hypothesis Tracking) etc, pulse-to-pulse and scan-to-scan integration techniques coupled with distribution-free CFAR supported by the research outcomes of K-distributed clutter modelling.

Recent research exploited and refined scan-to-scan integration combined with sliding window CFAR process and binary integration with remarkable success. The other notable detection techniques that will be discussed too, are the Radon transform, cross correlation techniques etc. The various such techniques will be supported by case studies, evaluation trials and data analysis.

This tutorial will discuss the sea clutter distribution functions at low grazing angles as viewed from surface platforms and also at high grazing angle viewed from airborne platforms, like KK and Weibull distribution along with their characterisation and applicable integration, correlation and CFAR methods to extricate weak target signals.

In recent times, several research outcomes have shown considerable improvements in the detectability of weak targets in heavy sea clutter with netted (distributed) radars based detection

process, featuring data capture/analysis/processing of the same target returns at various aspect angles, thanks to the availability of low cost surveillance radar systems in the market. The netted radar architecture improves system sensitivity multifold, as compared to single sensor detection. This tutorial will also discuss

Yet another upcoming technology to deploy multinode/multi-static radars to exploit the advantages of netted radar systems. Coherent detection signal processing in multistatic/multisite radar systems as applicable to small targets will also be discussed briefly including the recent research outcomes. This includes the sensitivity models of netted radars and phase and temporal synchronisation concepts /techniques in multistatic radar systems for efficient and effectve detection.

Extraction of low observable targets also relies on the Receiver noise performance of the RF front end. Hence, modification/tuning up of the RF front end circuitry helps to pre-process the target returns for enhanced SNR of targets of interest fed into the subsequent signal/data processing chain for optimising target detection performance. Discussions include the RF processing like Tracking STALO techniques to optimise SNR at the pre-processing stages.

This tutorial will start with an overview of the radar detection theory combined with detailed discussions on various CFAR processing techniques. It will elaborate the various algorithms/techniques employed for small target detection for ground based, sea borne and airborne platforms with illustrations, models and case studies with captured data in trials.

It will also elaborate further studies and research work undertaken among the radar community including the potential applications in this area. The delivery of the tutorial is aimed for about 3 hours through Power Point presentation and brief interactive sessions.

A broad and tentative list of topics that is proposed to be covered is as under:

- ◘ Introduction
- ◘ Target detection theory and CFAR processing
- ◘ Small Target Detection (STD) Techniques - overview
- ◘ Advanced STD techniques (TkBD, Scan-to-Scan Integration)
- ◘ Distributed/Netted radar sensing
- ◘ Multi-static radar systems
- ◘ RF front end optimisation
- ◘ Simulation, Modelling and algorithm development with case studies and trials
- ◘ Summary/Conclusion
- ◘ References

Intended Audience / prerequisites (if any), learning outcomes;

The attendees will acquire adequate knowledge and skills to design and implement successfully the advanced and optimum small target detection techniques, in their radar systems. As a new feature, this tutorial will also discuss, in detail, the concepts of multistatic /multisite configuration and adapting detection techniques suitably for multistatic/multisite applications in addition to introducing the synchronisation techniques.

The intended audience could be, but not limited, to the active practitioners or those proposed to be involved, in evolving and implementing signal/data processing algorithms and/or re-configuring radar hardware/software, to optimise small target (low SNR) detection performance. They can also be experienced radar engineers, members of academia and students involved in radar research and development activities.

Brief biography of the tutorial presenter:

Krishna Venkataraman is a Radar Systems Engineer/Radar Specialist in Defence Science and Technology Group, Department of Defence, Australia and Project S&T Advisor to the DoD, supporting various defence radar acquisition projects.

His current research interests include low observable target detection (intruder/non-cooperative), early detection of biological targets in air bases, netted radar sensing, phase noise in radar systems, radar performance modelling/ assessment, analysis and mitigation of intentional/non-intentional RF interferences (Wind farms) on surveillance (ATC) radar performance which had emerged as a serious threat to the detection performance lately.

Krishna has more than 50 years of radar experience and his past activities in defence industries include, leading research and development of signal processing algorithms for naval surveillance (S and L band) radars, Doppler tracker for instrumentation (C band) radars for space surveillance, AEW radar signal processor, critical measurements of (Aeolian) phase noise in OTH radars, ATC radars etc

Krishna has presented/published several technical papers/ reports in International conferences, symposiums and journals. He is a regular reviewer of Radar Conference and Journal papers. He delivered several tutorials/workshops/planery talks in various international radar conferences worldwide and workshops for military personnel. He chaired Tutorial committees in RADAR2008 and RADAR2013 conferences held in Australia.

Krishna is also an author of a book on 'Advanced target detection techniques' soon to be published by IET.

Krishna Venkataraman is a **FELLOW - FIE(Aust)** and Chartered Professional Engineer (**CPEng**) of the Institution of Engineers (Australia).

He is also a **SENIOR MEMBER** of the IEEE, USA. (**SMEEE**)

FIEAust CPEng NER APEC Engineer IntPE(Aus), SMIEEE

Tutorial History

Previous Editions

This proposed tutorial on "Advanced Small target detection techniques" was offered in various different international radar conferences held in 2017, 2019 and 2022 in the last SIX years, as per the details below:

September 2017 - RADAR 2017 International Radar Conference in Belfast, Ireland. The tutorial was attended by about 16 participants comprising of students, engineers and scientists and industry

personnel. The tutorial was well received and evoked plenty of interest among the audience with questions, discussions etc

October 2019 - RADAR 2019 International Radar Conference in Toulon, France. The tutorial was attended by about 15 participants comprising of students, engineers and scientists. The tutorial was well received again and evoked lot of interests among the audience with questions, consultations, discussions etc

December 2019 - IRSI 2019 (International Radar Symposium- India 2019) on **Advanced Small target detection techniques.** On this occasion it was attended by more than 50 participants.

October 2022 – Radar 2022 (International Radar Conference) – Edinburgh, UK, on **Advanced Detection techniques of low observable targets,** participated by 25 radar personnel.

During the period 2013-17, this tutorial based on 'Small Target detection techniques' was also presented on SIX different occasion at various radar conferences and forums, because of a surge in research interests shown in this topic across the globe.

The contents of the tutorials were always updated in every new edition, to include the new research outcomes and achievements in small target detection arena. It is also intended to update tutorial contents for RADAR2024 at Rennes, to include more case studies using captured data on several trials in addition to coherent signal processing and synchronisation aspects/techniques in multistatic and radar network applications as applicable to the detection of low observable target detection.

On all occasions, the participants were comprising of students, practicing engineers and scientists, armed forces and industry personnel etc. As always, these tutorials were popular among the participants and well attended and followed up with very fruitful discussions and proposals.

--- ---