

**Tutorial title**

Air and Maritime Target Recognition: Dream, Theory and Practice

**Outline of the Tutorial:**

Radar target recognition has long been an active area of research in radar, but little has been published about practical aspects and the actual results people achieve on large data sets, as opposed to simple academic examples. This tutorial provides a view of the techniques used to extract information about targets (specifically for air and maritime targets), and the level of classification performance one can expect to achieve, as well as providing a view of the considerations to take into account when designing target recognition modes (or even complete radars).

**Intended Audience:**

The tutorial is aimed at practicing radar engineers wanting to step into the field of NCTR as well as MSc and PhD students embarking on R&D activities within this domain.

**Learning Outcomes:**

The main outcome is for the attendee to develop a sound theoretical underpinning for the radar phenomenology which can be exploited to support non-cooperative target recognition and the various approaches for practically exploiting these effects.

**Tutorial Schedule:**

The tutorial intends to cover the topic in 5 main sections of approximately 40 minutes each, focusing on

- a) The need for NCTR, information available in the sensed radar signals under various conditions, waveforms, the classical view of an ATR system and modern day implications to the system hardware and system block diagram, considerations in designing radars for NCTR.
- b) The use of information sensed from high range resolution data towards classification of such targets as ships and airborne targets, practical issues to deal with in achieving high dynamic range high range resolution measurements and techniques for extracting information from the HRR data.
- c) Recent insights in the development of information theoretic approaches to understand performance limitations in radar NCTR systems and the impacts this has on achievable levels of recognition performance.
- d) Overview of the principles and techniques for the formation of ISAR images of targets. Practical problems encountered in this process. The use of ISAR images for classification and recognition.
- e) The use of Doppler information in NCTR, information available in the micro-Doppler signature of targets and how that can be used in classification and recognition tasks.

A significant portion of the results presented are based on datasets collected by the CSIR over the last 13 years in this field, which moves the tutorial from being only theory based to really sharing insights gained from the practice of NCTR in the field. The tutorial also draws on results from open literature where possible so as to provide a balanced view between CSIR results and that achieved in literature as far as possible.

**Detailed Topics and Schedule:**

Introduction (~5 min) (WN)

Section 1: Setting the Scene (~25 mins) (WN)

1.1 Introduction

1.2 Fundamentals

1.3 Features used for NCTR

1.4 The Radar NCTR System

Section 2: Extracting and using Features from target body using High Resolution Radar (~35 mins) (JC)

2.1 HRR Waveforms and Techniques

2.2 HRR based feature extraction

2.3 Applications of HRR information

Section 3: Information theoretic limits (~50 mins) (JC)

3.1 Mutual Information Theory

3.2 Examples in HRR radar

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Section 4: ISAR based NCTR (~40 mins) (WN)

4.1 ISAR imaging fundamentals

4.2 ISAR processor

4.2 Feature extraction

4.4 Examples of classification

Section 5: Extracting and using features from moving parts using Micro-Doppler (~50 mins) (WN)

5.1 Helicopter Blade Flash Detection

5.2 Helicopter Blade Tip imaging

5.3 Propeller- and Jet Engine-Modulation

5.4 Classification of Aircraft into H/P/J

5.5 Micro-Doppler from other targets / clutter

Section 6: Conclusions (~20 mins) (WN)

6.1. Combining HRR and micro-Doppler

6.2: Modern NCTR View

6.3: Some concluding remarks

### Suggested Prerequisites:

At least a working knowledge of the principles of radar as well as a good grounding in undergraduate signal processing.

### Biographies of Presenters:



**Willie Nel** is a principal radar researcher at the Council for Scientific and Industrial Research in South Africa and also appointed in the role of Technology and Innovation Manager for the radar research group. He holds MSc in Digital Image Processing from the University of Cape Town and has been working passionately in the field of radar since 1999. His areas of expertise include radar system design, target recognition and imaging radar and radar signal processing. He has published several papers in the area of radar target recognition and imaging and acts as a reviewer for several radar journals and conferences. In 2015 he was technical chair of the IEEE radar conference when it was held in South Africa for the first time. In 2016 he was elected to serve on the IEEE AESS Radar Systems Panel and is a Senior Member of the IEEE.



**Jacques Cilliers** received his B.Eng. and M.Eng. degrees in electronic engineering from the University of Pretoria in 1994 and 2002 respectively. He has worked for Kentron, a division of Denel Aerospace, designing CFAR detectors for imaging infrared air-to-air missiles and for the Laboratory for Advanced Engineering (LGI), affiliated with the University of Pretoria, developing high speed, spectrally efficient digital modulation techniques and digital equalization techniques. He has been employed by the Defence, Peace, Safety and Security (DPSS) operating unit of the Council for Scientific and Industrial Research (CSIR), Pretoria, South Africa since 1999 as a Principal System Engineer and Signals/Systems Analyst in the field of Radar and Electronic Warfare. His research interests include adaptive signal processing, radar signal processing, array signal processing, MIMO radar, tracking radar, radar cross section (RCS) calculation, detection in sea clutter, clutter modelling, hardware in the loop (HIL) testing of radars and radar based target recognition. He completed his PhD at the University College of London (UCL) in the field of information theory applied to radar target recognition in 2018.

## Tutorial history:

This current tutorial was developed and presented at the 2015 International Radar Conference in South Africa and was broadly based on research conducted at the CSIR's Radar Research team in South Africa, as well as applicable examples from open literature. In 2016 an updated version was presented at the CIE Radar Conference in China. Versions of the tutorial were also presented at several Chinese universities and research institutes in 2016. Revised versions were presented at 2017 Radar conference in Belfast and at the 2018 Radar conference on Brisbane. The tutorial has always been well attended with typically more than 20 attendees (At Brisbane there was approximately 40 attendees).

