International Specialist Meeting "Electromagnetic Waves and Wind Turbines 2018"

December 6-7, 2018

Delft University of Technology {TU Delft) Science Centre,
Mijnbouwstraat 120, Mekelzaal, Delft, The Netherlands

Program and Abstracts

Day 1 - December 6, 2018

09:00 Registration and coffee

10:00 Opening

10:15 ***Keynote Speaker: "Wind Turbine-Radar Interference and Opportunities at the ARM Southern Great Plains Site: Identification, Characterization, and Mitigation" (A1)***

Bradley Isom,
Pacific Northwest National Laboratory, U.S.A.

11:15 ***"Windfarms and radar, various judgement processes" (A2)***

Arne Theil, Onno van Gent
TNO The Hague, The Netherlands

11:45 ***"Comparison of CEM Methods for fast Simulation of Rotating Wind Turbines" (A3)***

Frank Weinmann[1], Stefan O. Wald[1], and Peter Knott
[1] Dept. Antenna Technology and Electromagnetic Modelling AEM Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Wachtberg, Germany

12:15 ***"Impact of wind farms on low-frequency radio astronomy observations with LOFAR." (A4)***

M.J. Bentum, W. van Cappellen and M. Brentjens,
ASTRON, The Netherlands

12:45 Lunch at Botanical garden in Delft

14:00 ***"Deep Adversarial Training with micro-Doppler signatures of wind-turbines and mini-UAVs" (A5)***

Lorenzo Cifola, Ronny Harmanny
Thales Nederland B.V., The Netherlands

14:30 ***"Precision Signal-in-space Measurements of Terrestrial Navigation Systems using Multicopter" (A6)***

Thorsten Schrader[1], Jochen Bredemeyer[2], Marius Mihalachi[1], Thomas Kleine-Ostmann[1]
[1]Physikalisch-Technische Bundesanstalt (PTB), Fachbereich Hochfrequenz und Felder, Germany
[2]FCS Flight Calibration Services GmbH, Braunschweig, Germany

15:00 ***"Radar echoes of individual wind turbines measured in L, S and C band" (A7)***

Jochen Bredemeyer[1], Thorsten Schrader[2], Marius Mihalachi[1]
[1]FCS Flight Calibration Services GmbH, Braunschweig, Germany
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15:30 Coffee break

16:00 [*“Stealth Technologies to Reduce the Impact of Wind Turbines on Radar Systems” (A08)*]

Vince Savage
Radar Impact Assessment, QinetiQ, UK

16:30 [*“Spectral Polarimetric Filter Design for Wind Turbine Clutter Suppression”(A9)*]

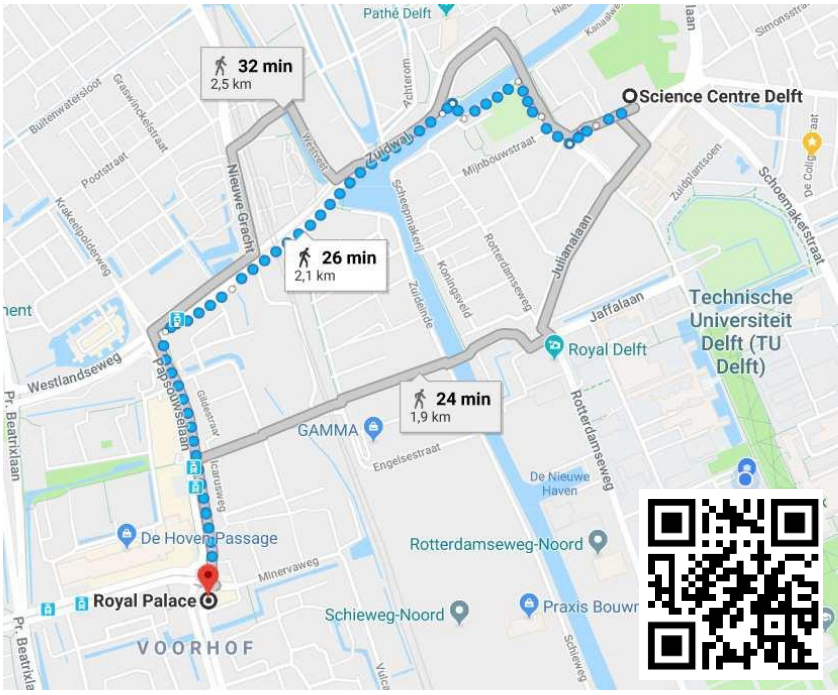
Jiapeng Yin, Christine Unal, Herman Russchenberg
Delft University of Technology, the Netherlands

17:00 [*"Noise Radar Measurements of Turbines in a Wind Farm" (A10)*]

Christoph Wasserzier,
Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany

18:00 Dinner (Dinner will be served at 18:30)

Address: Royal-Palace, Minervaweg 4-8, 2624 BZ Delft



Day 2 - December 7, 2018

9:00 ***Keynote speakers: "Small UAVs and their Buzz…. How micro-Doppler makes the difference!" (A11)***

J.J.M. (Jacco) de Wit[1] and Ronny Harmanny[2]
[1]TNO, The Hague, Netherlands
[2]Thales Nederland B.V., The Netherlands

10:00 ***"Comparing analytical and numerical simulations of the radar micro-Doppler signatures of multi-rotor UAVs" (A12)***

Peter J. Speirs[1], Arne Schröder[1], Matthias Renker[2], Peter Wellig[2] and Axel Murk[1]
[1]Institute for Applied Physics, University of Bern, Bern, Switzerland
[2]armasuisse Science and Technology, Thun, Switzerland

10:30 Coffee break

11:00 ***"U-space field trials results for drone discrimination with a staring radar" (A13)***

Mohammed Jahangir[1,3], (presenter) Frederic Barbaresco[2]
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[2]Thales Land&Air Systems, GBU LAS, Advanced Radar Concepts, Limours, France
[3]University of Birmingham, School of Engineering, Birmingham, UK B15 2TT

11:30 ***"Wind turbine shutdown-on-demand using radar - Progress and challenges" (A14)***

Rob van der Meer, Siete Hamminga
ROBIN radar systems B.V., The Hague, The Netherlands

12:00 ***"Exploring complex time-series representations for Riemannian machine learning of radar data"(A15)***

Daniel A. Brooks[1,2], Olivier Schwander[2], Frederic Barbaresco[1], Jean-Yves Schneider[1], Matthieu Cordy[2]
[1]Thales Land&Air Systems, GBU LAS, Advanced Radar Concepts, Limours, France
[2]Sorbonne Universite, CNRS, Paris, France

12:30 Lunch

13:15 ***"On wind-turbine robust radar systems" (A16)***

Arne Theil,
TNO The Hague, Netherlands

13:45 ***"Mitigation techniques for wind turbine induced primary radar performance degradation" (A17)***

Bram Faes
Intersoft Electronics NV, Olen, Belgium

14:15 ***"Smart-CFAR, a machine learning approach to floating level detection in radar" (A18)***

Marc Vizcarro i Carretero[1], Ronny Harmanny[2], Roeland Trommel[2]
[1]Delft University of Technology, the Netherlands
[2]Thales Nederland B.V., The Netherlands

14:45 Coffee break

15:00 ***"Polarimetric Estimation of the Wind Turbines Angular Velocity" (19)***
Valantis Kladogenis, Hans Driessen, Oleg Krasnov, Alexander Yarovoy
Delft University of Technology, the Netherlands

15:30 ***"Theoretical and Experimental Investigation of Drone's Micro-Doppler Patterns" A(20)***
Yefeng Cai, Oleg Krasnov, Alexander Yarovoy
Delft University of Technology, the Netherlands

16:00 Closing

Wind Turbine-Radar Interference and Opportunities at the ARM Southern Great Plains Site: Identification, Characterization, and Mitigation

BRADLEY ISOM[1]

[1] Pacific Northwest National Laboratory, USA

Wind turbine clutter (WTC) is a difficult-to-mitigate form of interference caused by wind turbines that can appear on radars. The dynamic nature of the clutter means it occupies the same Doppler/frequency domain as is typical with atmospheric or moving target returns, and normal stationary clutter filtering techniques do not apply. While WTC has been a known issue for over a decade, the problem remains a relevant research topic within the RF and signal processing community due to the economic and public impacts. This talk will first provide a brief overview of the 2016 and 2017 EMWT symposiums, followed by a discussion of the current state of WTC research around the world. The final portion of the talk will focus on the opportunities for WTC studies at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site located within the central continental United States. SGP is home to an extensive collection of wind farms and multiple radar systems that operate at a number of frequencies and are available for collaborative research efforts.

Windfarms and radar, various judgement processes

Arne Theil, Onno van Gent
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Abstract
The Netherlands Organisation for Applied Scientific Research TNO is regularly tasked to perform windfarm-radar impact studies. The requests most often come from windfarm operators in Europe, but studies for an operator based in Australia have also been performed. Referring to terminology introduced by Eurocontrol's wind-turbine task force (WTTF), both simple engineering assessments (SEAs) and detailed engineering assessments (DEAs) are conducted. Certain civilian or military ANSPs (air navigation service providers) do, however, not follow Eurocontrol's guideline, in which case a DEA is conducted, regardless of the distance between the radar system and the windfarm. The analyses may involve both primary and secondary radar systems.

The main ingredients of TNO assessments are briefly sketched. Subsequently, the judgement process, *i.e.*, the criterion upon which the verdict on windfarm construction is based, is discussed. It is observed that ANSP's do not always utilize a well-defined criterion, which gives rise to subjectivity.

Comparison of CEM Methods for fast Simulation of Rotating Wind Turbines

Frank Weinmann[1], Stefan O. Wald[1], and Peter Knott
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This paper highlights the application and performance of Computational Electromagnetics (CEM) approaches to the simulation of EM effects caused by rotating wind turbines, and compares the benefits and drawbacks of the different methods.

In most of the relevant cases, a wind turbine is an electrically very large target, which is too large for EM computation using full-wave methods. Consequently, only high-frequency methods remain, such as Geometrical Optics (GO) and Physical Optics (PO).

A common implementation of a GO/PO approach is Shooting-and-Bouncing-Rays (SBR) for estimating surface currents and PO for integration of the currents over the lit surface. However, this method has some drawbacks when phase accuracy is required, e.g., for further post-processing of the simulation data to obtain ISAR images.

A fast alternative to the SBR part is the direct calculation of the incident field strength using GO. In the basic form of the algorithm, reflections on a flat ground are included but other multi-path reflections are neglected. This approach allows for an extremely fast calculation of field strengths for a large number of time steps, while the phases are accurate for post-processing. Higher-order reflections can also be implemented, but significantly slow down the computations.

Title: Impact of wind farms on low-frequency radio astronomy observations with LOFAR.

M.J. Bentum, W. van Cappellen, M. Brentjens
ASTRON

Presenter : Mark Bentum

Abstract (approx. 200 words}:

The LOw Frequency ARray (LOFAR} – developed by ASTRON, the Netherlands Institute for Radio Astronomy – is the world's largest and most sensitive low-frequency radio telescope. It is a network of geographically distributed antenna stations, each containing hundreds of 'low-band' (LBA} and 'high-band' (HBA) dipole antennas. LOFAR stretches across Europe, from Ireland to Poland, with a dense `core' in Exloo, the Netherlands. LOFAR is opening one of the last unexplored regions of the spectrum for astronomy – very low radio frequencies, from 30 to 240 MHz.

There are plans to erect a large wind turbine farm near this central core, at distances down to 2 km from the LOFAR core area. The windfarm will have a negative impact on LOFAR's measurements. Several mechanisms have been identified that affect the LOFAR data: direct interference from the turbine; diffraction of external signals on the turbine's blades and structure; reflection of external signals on the turbine. Measurements on existing remote wind farms have been done to quantify the impact of the planned nearby wind farm, both with external equipment as well as with LOFAR itself.

Together with the Agentschap Telecom a system is proposed to independently measure the impact of wind turbines.

In the presentation we will present the effects of the wind turbines on the astronomical measurements with LOFAR; the mechanism which will impact these measurements and the system to analyse the impact of wind turbines.

Deep Adversarial Training with micro-Doppler signatures of wind-turbines and mini-UAVs.

Authors:	Lorenzo Cifola Ronny Harmanny	*Thales Nederland B.V.* *Thales Nederland B.V.*
Keywords:	Radar, micro-Doppler, Wind-turbines, mini-UAVs, Deep Learning, Adversarial Training	

Detection means separating what is interesting from what is not, where in the radar world the former is traditionally referred to as 'targets' and the latter are represented by 'background' or 'clutter'. In many military or civilian surveillance radars, beamforming, range and Doppler signal processing occurs prior to detection. This allows - in the end - the detection decision to be made on the basis of an amplitude difference between a target and its background, which is usually done in the range-Doppler domain by means of comparing the values of each radar cell with respect to a predetermined threshold. In general, in the event the target eventually does not stand out to e.g. strong clutter return, detection probability reduces to practically zero.

In the case of static or narrow-band clutter, detection of relatively fast targets can be performed by means of Doppler processing, while micro-Doppler represents a very powerful feature for distinguishing targets as UAVs from birds [1]. However, it is also well known that detection and classification of targets based their on micro-Doppler signatures can be negatively impacted by the presence of strong clutter objects whose micro-Doppler is characterized by large bandwidth, like in the case of presence of wind turbines [2].

In the present work, we show how novel Deep Learning algorithms can be used to learn characteristics and generalize on micro-Doppler signatures, in this case obtained from measurements performed on wind turbines and drones, and the two combined. A well-trained network can then be used to disentangle the combined return of targets and clutter, in order to improve the overall detection as well as classification performance in challenging conditions.

References

[1] Harmanny, R., De Wit, J., & Premel-Cabic, G. (2015). Radar micro-Doppler mini-UAV classification using spectrograms and cepstrograms. International Journal of Microwave and Wireless Technologies, 7(3-4), 469-477. doi:10.1017/S1759078715001002

[2] Krasnov, Oleg & G. Yarovoy, Alexander. (2015). Radar micro-Doppler of wind turbines: Simulation and analysis using rotating linear wire structures. International Journal of Microwave and Wireless Technologies. 7. 1-9. 10.1017/S1759078715000641.

Precision Signal-in-space Measurements of Terrestrial Navigation Systems using Multicopter

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The project *WERAN* aimed to determine the interaction of wind turbines (WT) with signals of terrestrial navigation systems such as VHF omnidirectional radio ranges (VOR) and RADAR. One of the main goals of the project was to quantify the additional VOR bearing error caused by wind turbines by means of measurement and numerical simulations. In this presentation we will discuss the results of on-site measurements and compare those with numerical simulations. A remote-controlled multicopter with precision localization has been used as measurement platform. It carries a compact but capable high frequency instrumentation and integrated antennas to measure simultaneously both the AM reference signal and the FM signal of a Doppler VOR as true signal-in-space. Actual position, time stamp and measurement data are simultaneously stored at the platform. These measurements give insight into the signal content and signal integrity of VOR with and without WT. Furthermore, varying operational conditions of WT such as rotation vs idle state or angular movement of the nacelle may have different influence on the additional bearing error.

During the follow-up project *WERAN plus* we will use the measurement data and simulation results to derive a model-based assessment tool. This will allow for prediction of the degree of interference (additional bearing error) of additional WT in the area around VOR with given topology.

Radar echoes of individual wind turbines measured in L, S and C band

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In the project *WERAN* it is also aimed to determine the interaction of wind turbines (WT) with radar signals. The evaluate the strength of single a single WT reflecting radar transmissions, measurement campaigns with multicopters (UAS) have been carried out at various radar sites in the L (Air Defense), S (AD and ATC) and C band (Precipitation radar). The presentation focusses on radar echoes received at different UAS flight altitudes and distances to the scatterers. It is useful to analyse the radar return both in the time and frequency domain to detect static and time variant signal components. Some results will be shown and discussed.

In the follow-up project *WERAN plus* there are some additional airborne vehicles in use to carry the measurement equipment. Some ideas of what can be expected from measurements at higher altitudes and moving at horizontal speed will be shared.

Stealth Technologies to Reduce the Impact of Wind Turbines on Radar Systems

Vince Savage

Technical Lead, Radar Impact Assessment, QinetiQ, UK

QinetiQ has investigated the topic of wind farm radar interference since for over 15 years, undertaking research activities and providing consultancy services. Principles of radar cross-section (RCS) reduction using stealth technologies are discussed. The strengths and weaknesses are considered in the context of other mitigation approaches. The actual and potential benefits of stealth wind turbines for different types of radar system are considered.

Vince Savage has been the technical lead for the QinetiQ Radar Impact Assessment (RIA) team since 2011. Vince has more than 20 year's experience in radar and RCS modelling, for civil and military applications. Main research topics and areas of interest include the development of high frequency RCS models; the application of chaos theory to scattering from complex cavities; and the practical application of stealth technologies to wind turbines.

Spectral Polarimetric Filter Design for Wind Turbine Clutter Suppression

Jiapeng Yin, Christine Unal, Herman Russchenberg

Delft University of Technology, the Netherlands
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Nowadays, there is an intensive use of wind turbines worldwide to generate green and renewable energy. In addition, the sizes of wind turbines keep increasing for higher efficiency. However, echoes from wind turbines are severe clutter for weather radar, deteriorating its performance significantly. In this work, the spectral polarimetric filters (SPFs) are designed to mitigate wind turbine clutter (WTC). The SPFs consist of the moving double spectral linear depolarization ratio (MDsLDR) filter [1] and the object-orientated spectral polarimetric (OBSpol) filter [2], which have been previously proposed to mitigate the narrow-band clutter (both stationary and moving) for polarimetric radar with and without cross-polar measurements, respectively. Data collected by a polarimetric Doppler weather radar known as the IRCTR Drizzle Radar (IDRA) are used to validate the performance of the proposed algorithm. Mounted on the top of a 213m tower in Cabauw Experimental Site for Atmospheric Research, the Netherlands, the X-band operational research radar is still affected by wind turbines which are 120m in height and 3400m far away. Different case studies demonstrate the good performance of the SPFs in sidelobe WTC suppression. Moreover, these filters can be applied in real time due to its low computation complexity.

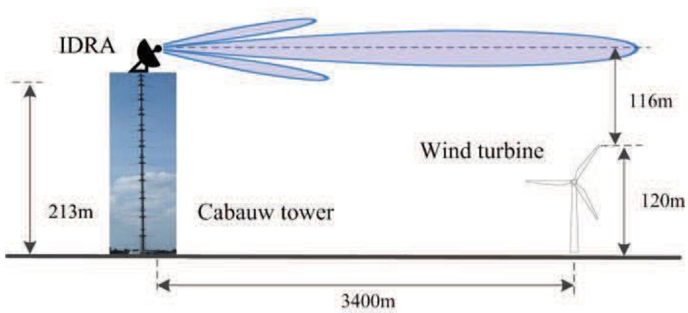

Figure. 1 The geometry of IDRA and wind turbine.

[1] J. Yin, C. Unal, and H. Russchenberg, "Narrow-band clutter mitigation in spectral polarimetric weather radar," IEEE Trans. Geosci. Remote Sens., vol. 55, no. 8, pp. 4655 – 4667, 2017.

[2] J. Yin, C. Unal, and H. Russchenberg, "Object-orientated filter design in spectral domain for polarimetric weather radar," IEEE Trans. Geosci. Remote Sens., Accepted.

Noise Radar Measurements of Turbines in a Wind Farm

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Noise Radar Technology {NRT) has a very strong feature: as its waveform is an un-periodic signal, NRT faces the absence of any ambiguities in range domain. In contrast to in linear frequency modulated waveforms there is no Range-Doppler coupling in NRT. Both characteristics offer great opportunities for measuring moving or rotating targets as in NRT signal processing the range profile update rate {equivalent to PRI) can be chosen independently from the range scope.
Experiments are presented for illustrating the advantages and disadvantages of noise radar in the context of rotating targets based on real-world data. The experimental data have been obtained by a noise radar demonstrator inside a wind farm. This particular trial location was chosen due to the permanent presence of moving scatterers. Yet, the center of motion remains at defined positions.

Small UAVs and their Buzz.. How micro-Doppler makes the difference!

J.J.M. (Jacco} de Wit[1] and Ronny Harmanny[2]
[1]*TNO, The Hague, Netherlands*
[2]*Thales Nederland B.V., The Netherlands*

Radars for air and surface picture compilation are very good at detection, localization and tracking of objects in a large volume. For identification and classification however, other means are necessary, like transponders on-board airborne and surface platforms. If those are not available, Non-Cooperative Target Recognition (NCTR) techniques can be used to learn more about the radar contacts. If available… Our research work demonstrates the potential of combining micro-Doppler radar measurements with smart algorithms for the purpose of advanced NCTR in typically time critical radar systems.

Micro-Doppler signatures provide informative features on which fast and reliable classification can be performed. In addition, it can be measured with minimal impact on the radar hardware. Classification is done by feeding the measured signatures to smart, notably AI-based algorithms.

In this work we give a research overview performed by the strategic alliance between Thales Nederland B.V. and TNO, called D-RACE, on how micro-Doppler is exploited, for instance for anti-drone capabilities, in Thales Nederland’s state of the art radars.

Comparing analytical and and numerical simulations of the radar micro-Doppler signatures of multi-rotor UAVs

Peter J. Speirs[1], Arne Schroder[1], Matthias Renker[2], Peter Wellig[2] and Axel Murk[1]
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Whilst for some applications sample measurements of unmanned aerial vehicle (UAV) micro-Doppler signatures will be sufficient, it is also important to also be able to simulate such signatures. This can be done at differing levels of complexity: from simple analytic consideration of the combined scattering from idealised rotating blades, through to numerical simulation of the scattering from CAD models of varying levels of detail. With increasing complexity comes increasing cost in terms of CAD complexity and simulation time, so it is desirable to be able to use as simple a model as is fit for purpose.

ln this presentation we will show the results of simulation of the micro-Doppler signature from quad-, hexa- and octocopters using an analytic approximation, as well as Method of Moments (MoM) simulations applied to both simple and complex models of the UAVs. The MoM UAV RCS values will be validated against anechoic chamber measurements of quadcopters and a hexacopter (with stationary rotors). We will then test the utility of the analytic approximation by attempting to apply a machine-learning algorithm, trained on the analytic approximation micro-Doppler signatures, to identify the number of rotors present in both other analytic data and the MoM-derived signatures.

U-space field trials results for drone discrimination with a staring radar

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Abstract: Non-cooperative surveillance of drones is an important consideration in the EU SESAR vision for the provision of U-SPACE services. Aveillant Gamekeeper multiple staring radar utilises extended dwell to be able to detect small drones at the range of several kilometres. However, target discrimination is necessary with such surveillance system as the increased detection sensitivity against low RCS targets extenuates the problem of false reports of targets such as birds and surface objects such as vehicles etc. Machine learning classifiers are used to remove confuser targets such as birds to provide real-time tracks of drones. Field trials from live drone flights against a number of test scenarios for U-Space are used to train and test a decision tree classifier working on both trajectory and micro-doppler features. Results show that a high level of classifier accuracy is achieved across a range of flight profiles for a rotary wing drone.

Wind turbine shutdown-on-demand using radar - Progress and challenges

Rob van der Meer, Siete Hamminga
ROBIN radar systems B.V., The Hague, The Netherlands

Wind turbines pose several potential risks for birds: loss of habitat, the barrier effect and most importantly collision-related mortality. Due to the increasing demand for the construction of wind farms, mitigating the risks of bird mortality is needed. This, in practice, requires collecting vast amounts of data on bird flight directions, flight altitude, species and behaviour in the vicinity of wind farms. In some cases, it might even be required to shutdown (a part} of the wind farm during mass bird migration in order to reduce bird mortality to an acceptable level.

Of course, the use of radar is a powerful method to acquire this data, both for collecting data even before construction as well as for determining the high-risk periods during deployment. Our systems have been installed for this purpose in wind farms during the past years. The most recent project in which our radar is used is in the Eemshaven by our customer 'Bureau Waardenburg' in close collaboration with the University of Amsterdam.

In this short presentation, we will present an overview of this project, the technological advances in our recently developed radar and how these two meet. We will present our technological challenges in suppressing sea, precipitation and turbine clutter by showing some real-life examples.

EXPLORING COMPLEX TIME-SERIES REPRESENTATIONS FOR RIEMANNIAN MACHINE LEARNING OF RADAR DATA

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ABSTRACT

Classification of radar observations with machine learning tools is of primary importance for the identification of non-cooperative radar targets such as drones. These observations are made of complex-valued time series which possess a strong underlying structure. These signals can be processed through a time-frequency analysis, through their self-correlation (or covariance) matrices or directly as the raw signal. All representations are linked but distinct and it is known that the input representation is critical for the success of any machine learning method. In this article, we explore these three possible input representation spaces with the help of two kinds of neural networks: a temporal fully convolutional network and a Riemannian network working direcly on the manifold of covariances matrices. We show that all the considered input representations are a particular case of a generic machine learning pipeline which goes from the raw complex data to the final classification stage through convolutional layers and Riemannian layers. This pipeline can be learnt end-to-end and is shown experimentally to give the best classification accuracy together with the best robustness to lack of data.

On wind-turbine robust radar systems

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Abstract
Most modern primary radar systems used for compilation of the air picture are nowadays claimed to be 'wind-turbine robust'. An overview is given of the various techniques that are applied in these latest generation systems to obtain this robustness. It appears that the main driver that enables the applicability of such techniques is increased available computing power at the radar's signal processor. Furthermore, certain techniques that are common for surveillance radars used in the military domain, are now also applied in civilian system.

Mitigation techniques for wind turbine induced primary radar performance degradation.

Dr. Bram Faes

Intersoft Electronics, Belgium

Clutter introduced by wind turbines has a huge influence on the performance of PSR (primary surveillance radars) systems. The ever-increasing amount of wind turbines, calls for a mitigation technique which minimizes the performance degradation of the system in these high clutter areas.

Due to the complexity of the concept, and the large number of variables, there is no single solution which will solve the clutter problem in all cases. Intersoft-Electronics offers a range of mitigation techniques to cover all situations. Starting from gap fillers until new or upgraded windfarm 'resistant' sensors

The Intersoft-Electronics windfarm resistant sensors are based on the NGSP (Next Generation Signal Processor). The Intersoft Vertical Clutter Cancellation (VCC) technique enables the detection of aircrafts flying directly above turbines. Additionally, the combination of VCC, Range Azimuth Gating (RAG) and high resolution MTD (Moving Target Detector) processing is capable of minimizing the turbine induced clutter up to 40 dB. Increasing the detection probability in large windfarms and high clutter areas.

Smart-CFAR, a machine learning approach to floating level detection in radar

Authors:	Marc Vizcarro i Carretero Ronny Harmanny Roeland Trommel	*TU Delft – MS3 Thales* *Nederland B.V. Thales* *Nederland B.V.*

| **Keywords**: | uav, drone, CFAR, artificial neural network, target detection, clutter edge. | |

With the proliferation of small UAVs or drones for both military and commercial use, drone detection, classification and tracking will be essential in surveillance tasks such as the newly proposed *UTM* (USA) [1] or *U-Space* (Europe) [2]. In this context, novel radar algorithms such as those that exploit machine learning have proven to be an effective technique for drone classification. Based on micro-Doppler, radar can already distinguish birds from drones [3] and classify different sorts of small UAVs [4]. However, the first step towards classification is target detection and so far, minimal effort has been made to optimize detector performance for this application.

Traditional detection is initially based on the Neyman Pearson detector, extending it to adaptive techniques such as the CFAR (floating level threshold) [5, 6]. Any detector is expected to maximize the probability of detection, while achieving the lowest false alarm rate possible. Yet, in a drone surveillance context, due to their small size, detection can only be achieved by increasing the false alarm rate degrading the overall radar chain performance.

The work of [7] implemented machine learning techniques as an alternative to the classical CA-CFAR detector. Results did not achieve a satisfactory performance in constant false alarm and did not show any major detection improvements over CA-CFAR. Instead we propose a Neural Network detector (smart-CFAR), proving its benefits and providing an application scenario for drone detection. The presented experiments show that the smart-CFAR can achieve better performance than the traditional CA-CFAR. Additionally smart-CFAR can be trained to deal with clutter edges, such as land-sea transitions, where the signal statistics change and traditional CFARs tend to underperform.

Based on the first successful results, future steps will focus on the application of the smart-CFAR on the range-Doppler domain, sea clutter and extended targets.

References:

[1] M. Johnson, J. Jung, J. Rios, J. Mercer, J. Homola, T. Prevot, D. Mulfinger and P. Kopardekar, "*Flight Test Evaluation of an Unmanned Aircraft System Traffic Management (UTM) Concept for Multiple Beyond-Visual-Line-of-Sight Operations*", ATM2017, NASA Ames Research Center, 2017

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Wind turbines usually cause significant interference in the conventional radar operations which might degrade the detection capabilities of a radar system. Wind turbines do not only block the radar beam focusing on a specific target, thus creating shadowing effects , but also impose spectral contamina-tions due to the continuous blade rotation. Therefore in order to identify, detect and possibly mitigate the presence of Wind Turbine Clutter (WTC) , fundamental features of the blades rotation need to be estimated such as rotation (angular) velocity. This information can be easily extracted by initially evaluating the angular displacement of the blades between successive radar measurements. In this workshop a method to estimate this rotation angle is proposed and consequently the angular velocity is proposed. Moreover a detection rule which exploits this information is also presented. The whole solution might possibly validated with proper measurements obtained by PARSAX.

Theoretical and Experimental Investigation of Drone's Micro-Doppler Patterns

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In recent years, micro-Doppler patterns of specific models of drones got attention of researchers. However, variations of micro-Doppler patterns due to dynamic differences of different propeller's phases and rotation velocities have not been reported in the literature.

To tackle this problem, micro-Doppler patterns of drones with multiple propellers at different flight phases have been studied theoretically and experimentally. For theoretical analysis, an analytical thin wire model of drone propeller is considered and different micro-Doppler patterns of quadcopter, hexacopter and octocopter drones are generated. This simple model is verified with full-wave EM simulations of scattering from a plastic propeller. Good agreement between both models is observed. By neglecting effects of multiple scattering from propellers, micro-Doppler patterns of multi-copter in different flight phases are simulated for a wide spectrum of radar signal parameters. Real radar data acquired by PARSAX are used to validate the simulation predictions.