Microwave Sensing, Signals and Systems (MS^3) group

Department of Microelectronics

Faculty of Electrical Engineering, Mathematics and Computer Science

Topics for research MSc projects

Delft - 2022

Very Important Note

If you did not find in this booklet a topic that is interesting for you, visit any faculty member of the MS3 group for your interests discussion.

We have much more ideas to research!

Master projects – Alexander

http://radar.tudelft.nl/People/bio.php?id=11

- Development of electromagnetic models of distributed (and moving) targets and feature/parameter retrieval algorithms for **remote sensing**.

- Concrete **examples** you may work on? Subsurface object detection and classification, EM modelling of moving distributed targets (e.g., bicyclists, drones), simultaneous MIMO systems using orthogonal waveforms

- Keywords = **competences** you will have & develop for/in these projects: physical understanding of electromagnetic wave interaction with objects; electromagnetic theory and computational electromagnetics, experimental studies (COVID permitting); usage EM design tools and programming in MATLAB.

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Master theses projects – Bert Jan Kooij

- Imaging techniques that are an extension of the classical radar technique and are able to reconstruct not only the location of the reflection, but go beyond that location of the reflection. Some of these techniques are able to reconstruct the permittivity and conductivity of a scattering object. The goal is to find imaging techniques that fill the gap between radar-imaging (fast, low quality of image) and full wave inversion techniques (very slow, high quality). The techniques that are used are based on the Maxwell-equations and require some basic knowledge of these equations in order to do research in collaboration with me, to find fast and good images with minimal artifacts.
- The research is carried out using Matlab. All is done with the aid of computer simulations, so there are no measurements involved.

- Keywords = **Mathematical competences, Matlab experience, Maxwell equations and Interest in Theoretical Research**

-> Check the **booklet** on our website radar.tudelft.nl

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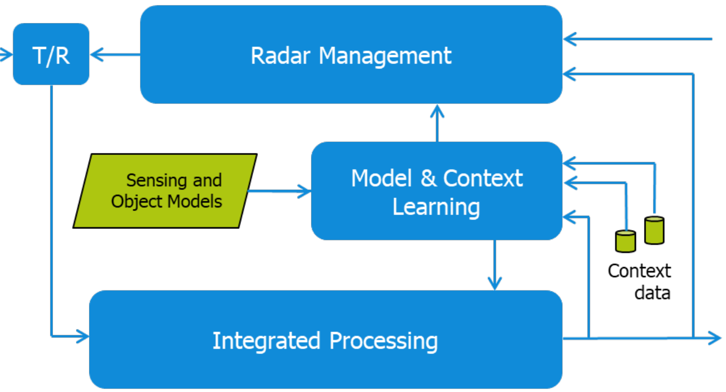
Master projects – Hans Driessen

http://radar.tudelft.nl/People/bio.php?id=347



<u>Context of the topics</u>

- We treat radar as an active sensor for building situational awareness
- Phased array, multi-function
- We investigate novel concepts for signal and data processing, radar management, and machine learning in dynamic systems

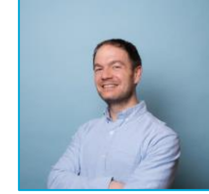
<u>Just a few example topics</u>

- Statistically sound techniques for dealing with extended objects, and the environment, such as the sea surface and propagation effects;
- Extending radar management with object search;
- Extending the current concept of dynamic detection and estimation with machine learning techniques such as Gaussian Process Models

Topics can be tuned to individual student wishes!

Master theses projects – Francesco 1

http://radar.tudelft.nl/People/bio.php?id=661



- You will see projects where radar is a tool for **situational awareness**: not just measuring distance, velocity, position of objects, but discovering their "*identity*", and/or *classifying* the presence/lack of certain phenomena.

- Concrete **examples** you may work on? Healthcare (human activities recognition; gestures classification; normal/abnormal gaits and vital signs); automotive (pedestrian/cyclist vs vehicles; obstacles vs object to drive over); surveillance (drones vs birds; drones models; payloads on drones), …

- Keywords = **competences** you will have & develop for/in these projects: radar theory & signal processing; machine learning & AI applied to radar data/classification problems; experiment design & data collection (COVID permitting); programming MATLAB-Python.

A few **project descriptions** follow. These can be shorter Extra Projects and/or expanded into a full MSc thesis. Please get in touch if interested for a first discussion.

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Master theses projects – Francesco 2

http://radar.tudelft.nl/People/bio.php?id=661

1) Human activity classification using Spiking Neural Networks.

WHAT. Spiking Neural Networks are considered to be the 3rd generation of NNs, particularly suited for on-edge processing because of low energy consumption. Some initial examples in the literature for radar classification exist, but they are rather limited with respect to the input format of the radar data, the architecture of the network, and the training approach for the network. In this project you will learn and explore how SNNs can be used in human activity classification problems with radar and their pros/cons vs more conventional deep learning and neural networks.

WHO. For this project you need to have some background in FMCW/mm-wave radar, i.e. how it works and what kind of data it produces, but also willingness to engage with programming and understanding SNNs, something that is most likely new (but exciting!).

-D. Banerjee et al., "Application of Spiking Neural Networks for Action Recognition from Radar Data," 2020 International Joint Conference on Neural Networks (IJCNN), 2020, pp. 1-10, doi: 10.1109/IJCNN48605.2020.9206853.

-M. Arsalan, A. Santra, M. Chmurski, M. El-Masry, G. Mauro and V. Issakov, "Radar-Based Gesture Recognition System using Spiking Neural Network," 2021 26th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), 2021, pp. 1-5, doi: 10.1109/ETFA45728.2021.9613183.

-Tsang, I.J.; Corradi, F.; Sifalakis, M.; Van Leekwijck, W.; Latré, S. Radar-Based Hand Gesture Recognition Using Spiking Neural Networks. Electronics 2021, 10, 1405. https://doi.org/10.3390/electronics10121405.

2) Gait analysis using mm-wave MIMO radar.

WHAT. How a person walks can tell a lot about their general health. While estimating gait parameters requires highly specialised biomechanical lab, recently researchers are looking at contactless radar measurements to identify unobtrusively such parameters. In this project you will have a good starting point in the reference below, which can be improved by using different processing of the MIMO radar data (e.g. detector, clustering, super-resolution in angle) and extended to unconstrained walking without treadmills.

WHO. For this project you need to have some background in FMCW/mm-wave radar, i.e. how it works and its signal processing, and a willingness to engage with experimental work.

-D. Wang, J. Park, H. -J. Kim, K. Lee and S. H. Cho, "Noncontact Extraction of Biomechanical Parameters in Gait Analysis Using a Multi-Input and Multi-Output Radar Sensor," in IEEE Access, vol. 9, pp. 138496-138508, 2021, doi: 10.1109/ACCESS.2021.3117985.

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Master theses projects – Francesco 3

http://radar.tudelft.nl/People/bio.php?id=661

3) Multiple radar nodes positioning in a network for human observation.

WHAT. How to position N nodes in a radar network observing a certain area, or how to handover some radar tasks to the most suitable pairs of radars? An approach can look at the CRLB (Cramer Rao Lower Bound) of the estimation of position and velocity for each node, and select the nodes closer to the theoretical optimum. In this work, you will start from such approach proposed in the references below and port/expand it to the case of an extended targets (e.g. human in indoor area) for which micro-Doppler is present.

WHO. For this project you need to have some background in FMCW/mm-wave radar, i.e. how it works and its signal processing, and a willingness to engage deeper in radar signal processing.

-M. Jahangir et al., "Advanced cognitive networked radar surveillance," 2021 IEEE Radar Conference (RadarConf21), 2021, pp. 1-6, doi: 10.1109/RadarConf2147009.2021.9455245.

-B. Griffin, A. Balleri, C. Baker and M. Jahangir, "Optimal receiver placement in staring cooperative radar networks for detection of drones," 2020 IEEE Radar Conference (RadarConf20), 2020, pp. 1-6, doi: 10.1109/RadarConf2043947.2020.9266555.

4) Adaptive/RISR formulations of spectrograms for classification.

WHAT. One of the limitation of classic time-frequency analysis with Short Time Fourier Transform is the trade-off in resolution given by a fixed window length. Alternative approaches looked at different time-frequency distributions (e.g. wavelets, Wigner-Ville, and others), but the reference below proposes yet a different adaptive estimation technique for spectrograms based on Reiterative Super Resolution (RISR).

You are tasked to understand and reproduce this technique and verify its utilisation for spectrograms in time-frequency analysis, first simply on signals and then on realistic radar data of moving targets.

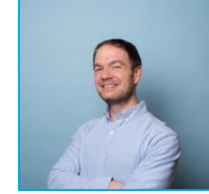
Nota that this is meant to be *an extra project* task primarily.

WHO. For this project you need to have some background in FMCW/mm-wave radar, i.e. how it works and its signal processing, and a willingness to engage deeper in advanced radar signal processing as in the reference below.

-C. Jones et al., " An Adaptive Spectrogram Estimator to Enhance Signal Characterization", Accepted for IEEE Radar Conference 2022, http://www.ittc.ku.edu/~sdblunt/papers/IEEE_RC22-FreqRISR.pdf

Master theses projects – Francesco 4

http://radar.tudelft.nl/People/bio.php?id=661



5) Investigation of detectors for mm-wave radar & better point clouds.

WHAT. A key challenge in using mm-wave MIMO radar is the unstable and sparse nature of the point clouds generated from these sensors. An important pre-processing step for such generation is the choice of the detection algorithm and on which radar format this is applied (e.g. range-angle vs range-Doppler, etc). Specifically, the reference below compares many CFAR and non-CFAR based detectors.

Your task is to understand and implement these detectors at first, and then suggest modifications to improve the point-cloud generation for subsequent mm-wave applications.

WHO. For this project you need to have some background in FMCW/mm-wave radar, i.e. how it works and its signal processing, and a willingness to engage deeper in radar signal processing.

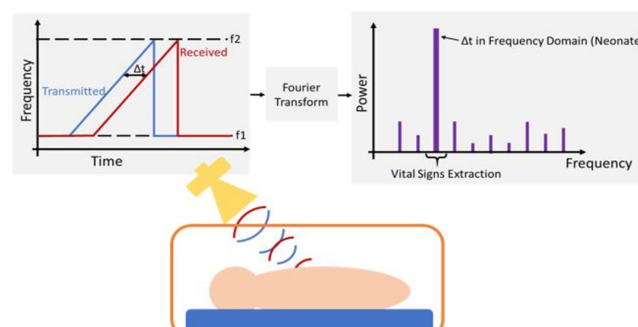
-A. Safa et al., "A Low-Complexity Radar Detector Outperforming OS-CFAR for Indoor Drone Obstacle Avoidance," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 9162-9175, 2021, doi: 10.1109/JSTARS.2021.3107686.

6) Neonatal Monitoring with FMCW Millimeter Wave Radar

A collaboration with the NICU of Erasmus MC

Contactless monitoring of preterm neonates

- Measure body movements
  - Heart rate, respiratory rate, pulse wave transit time, 3D lung aeration map
- Detect physiological changes
  - Blood perfusion, tissue oxygenation, sepsis detection



Contact points at Erasmus c.ramsey@erasmusmc.nl
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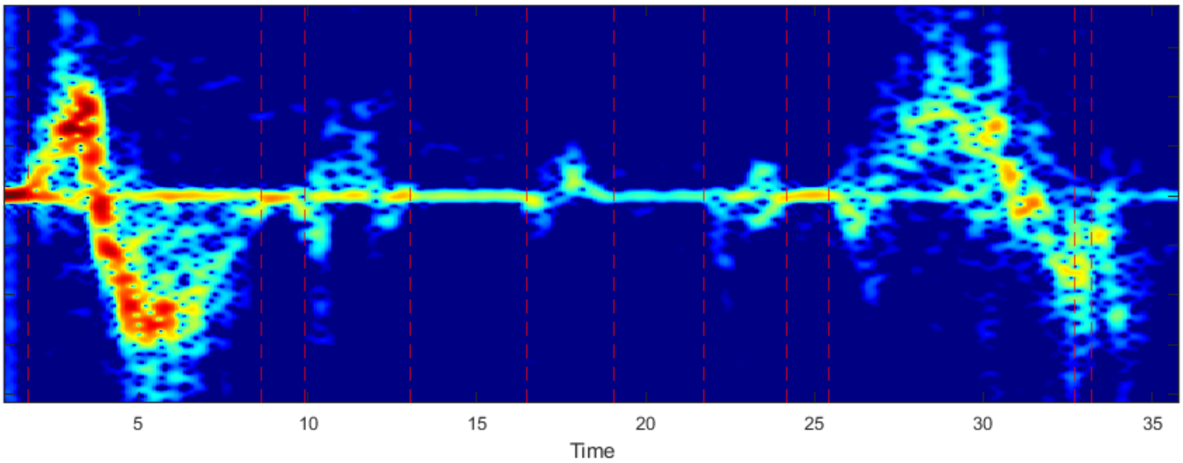
TU Delft · Erasmus MC · medical delta

Automating Human Activity Labelling

Human Activity Recognition is an important topic of research in fields such as healthcare and security. Falls, attempts at self-harm, and suspicious behaviours are all examples of human activities that should invoke a response from respective professionals, but continuous human monitoring is not always feasible due to technological and privacy constraints. Radar sensors are under investigation as a platform for activity classification due to, among others, their non-contact nature, their functioning in low-light conditions, and their low privacy impact when compared to camera systems.

In order to develop effective algorithms for radar activity classification, experimental samples of human motions and activities are of great importance. The activities in these samples need to be labelled in order to use supervised learning techniques, a time-consuming task if done by hand. In this project, you will study state of the art computer vision methods in order to automate the activity labelling process and their possible usage to help with radar-based experiments .



Your tasks will include a literature study to evaluate the current possibilities of camera-based activity classification, and the application of this knowledge to develop the necessary tools to facilitate the data-labelling process of a real data set.

For this project, a background in machine learning is preferred, as well as experience in the MATLAB programming language. You are interested in cross-disciplinary work between Computer Science and Radar Sensing, and are keen to develop new tools that aid experimental work in the field.

This piece of work is initially envisaged as an extra project of 10-15 ECTS, that can possibly be expanded into a full thesis proposal.

Contact: N.C.Kruse@tudelft.nl (*Nicolas Kruse, PhD candidate*)

Master Projects – Oleg Krasnov

http://radar.tudelft.nl/People/bio.php?id=22

- You will see projects where **modern flexible digital radar technology** provides an opportunity to extend the dimensions of sensing signals features space and **improve the sensing quality** via *radar architecture, waveforms and processing algorithms optimization* to **user goals, interests and applications.**
- Concrete **examples** you may work on? *surveillance* (small drones improved detection and identification (drones vs birds); phase noise effects in phased array radar, their simulation and mitigation); *Doppler polarimetry* (model-based algorithms for improved target detection, for advanced atmospheric remote sensing)*; digital design of modern radar* (MIMO/polarimetric/multichannel FPGA-based FMCW receivers; digital architecture of cognitive rada); …
- Keywords = **competences** you will have & develop for/in these projects: radar theory & signal processing; statistical signal/data processing for detection, estimation and classification; experiment design & data collection (our radars are working even during COVID); programming MATLAB-Python.

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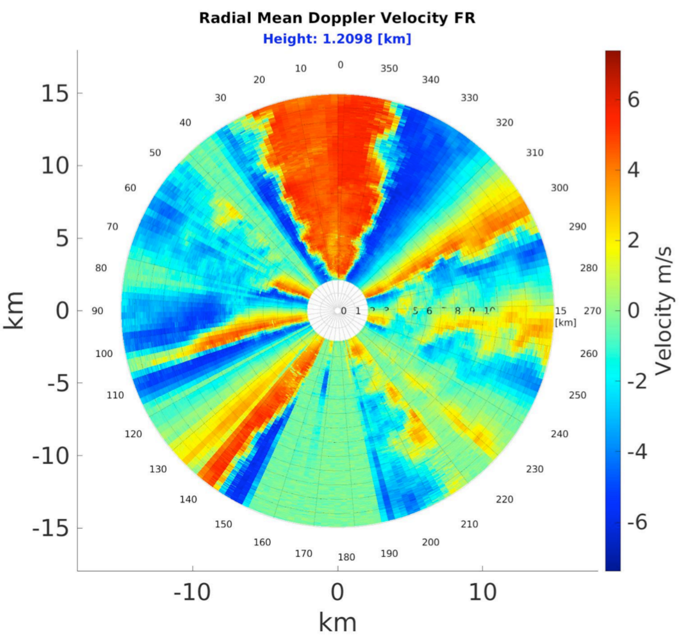
De-aliasing of Doppler spectrum for a fast scanning phased array weather radar

In radar remote sensing applications of weather phenomena, estimating wind velocity and direction is a challenge. This is due to the fact that radar can only resolve the radial velocity component of the target motion. With the introduction of the EFRO project, new ways and means are explored to make use of the existing radars which are developed for point target detection, to even detect extended weather objects and resolve their Doppler velocity spectrum. The existing X-band radar has 1 ms pulse repetition time, which leads to a 7.5 m/sec maximum unambiguous velocity. This leads to Doppler velocity aliasing/ folding.

Challenges for the MSc thesis

- For radial wind speeds faster than 7.5 m/sec, the Doppler spectrum is usually folded/ aliased. The challenge is to develop the de-aliasing algorithm(s) that uses the available azimuthal dependency of the Doppler velocity spectrum and to improve the Doppler moments estimation accuracy.
- Due to the fast scanning nature of the radar, the number of sweeps per beamwidth is low. For example, for a 60 rpm scanning speed on azimuth, the number of sweeps per a beamwidth of 1.8° equals to only 5. Due to a very small time on target, the Doppler moments estimation suffers from low resolution. This results in a broadening of the Doppler spectrum. The challenge is to de-alias Doppler velocity spectrum for a fast scanning radar to estimate the Doppler moments accurately.
- The next challenge is to deal with missing data. De-aliasing of Doppler velocity retrieval is smooth when data is available for all azimuthal sectors in space. However, this is not the case in reality always. The challenge is to how to determine the de-aliased Doppler velocity spectrum when data is missing.
- The final challenge is to apply the algorithms of the Doppler spectrum de-aliasing developed in the thesis to real data collected from Max3D phased array fast scanning radar. A toolbox is already available that can be used to process the raw data collected from Max3D [1]



An example of the Doppler velocity aliasing for the rain event on 8 Dec 2021. The folding occurs from 20° to 350° azimuth angles through 0° azimuth

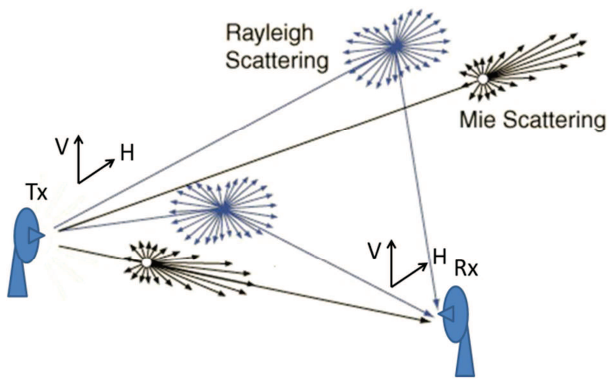
References

[1] Alexandru Gırdianu. *Weather Targets Doppler Processing in Phased Array Radar with Fast Azimuthal Scanning*. Technical report, 2021.

Contact: **Tworit Dash (T.K.Dash@tudelft.nl) & O.Krasnov (o.a.krasnov@tudelft.nl)**

Potential benefits of polarimetric Doppler weather radars with the bi-static configuration

The polarimetric capabilities are nova-days widely accepted as "must have" features of the Doppler weather radars. At the same time there are currently an active national and international processes of the development and installation of dense networks of high-resolution meteorological radar network that will improve sensing coverage areas, its space and time-resolution. Currently such networks are developing for the operation as independent monostatic polarimetric Doppler radars with post-processing cross-radar data fusion at the product data level.

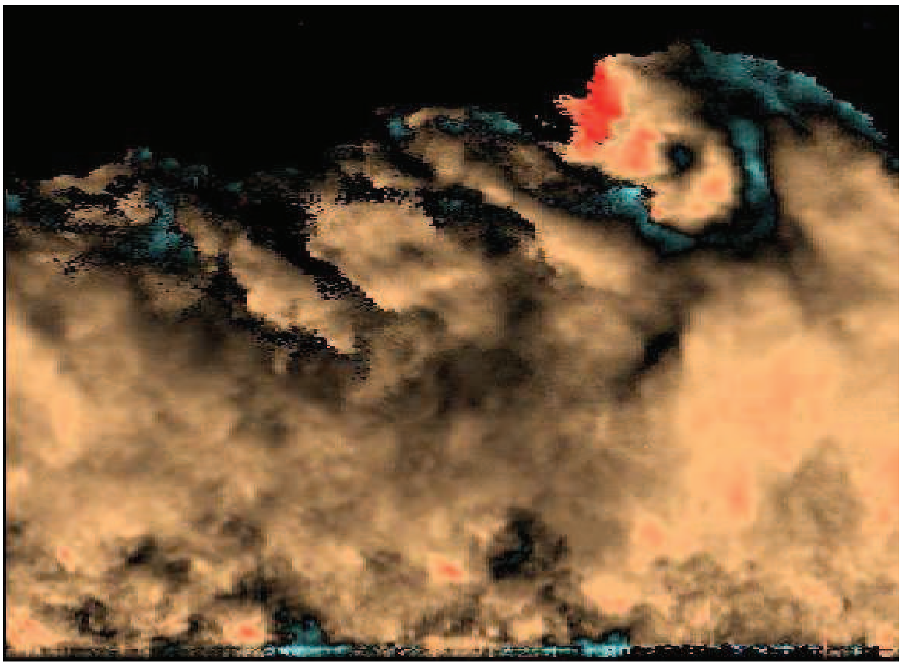


From technological and signal processing point of view it is clear that such radar network can produce much more data if radars will be used in bi-static or even multi-static configurations like distributed MIMO sensing system. At the same time it is still not well studied what additional information about cloud and precipitation microphysics can be extracted from bi-static polarimetric Doppler characteristics of sensing signals, how well such characteristics can be measured using classical polarimetric radars architecture. These research topics can be used as initial formulation of the research questions for the MSc research project.

The master thesis project will consist of several parts:

- Bistatic weather radar: possible configurations and related characteristics of bistatic scattering on small water drops (e.g. two horizontally scanning systems within an arbitrary or only forward-scattering sectors, vertical profiler and horizontally scanning systems, etc.)
- Calculation and analysis of the bistatic polarimetric Rayleigh and Mie scattering characteristics of water drops
- Simulation and analysis of polarimetric characteristics for signals that are scattered on ensembles of drops with random sizes
- Simulation and analysis of the relations between precipitation microphysics and traditional polarimetric Doppler weather observables (Zdr, Ldr, Kdp, etc.) in bistatic cases
- Can be proposed any new polarimetric characteristics/observables for the retrieval of precipitation's microphysics and/or meteorological parameters that are based on bi-static radar measurements?

Contact: dr. Oleg Krasnov (o.a.krasnov@tudelft.nl), HB21.280

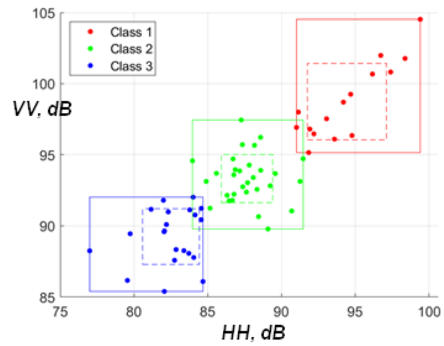


Radar-measured Doppler velocity vertical field above the EEMCS building during a rain event

Automotive Targets Classification using Polarimetric Radar Measurements

A databases of moving cars' polarization characteristics in range-Doppler space can be created using an existed multiple target tracking software and available/new measurements with the PARSAX radar.

The created for this study databases can be blind, without exact information about type of the specific car observed and tracked on a highway, or can be created using the radar observation of the road without intensive traffic, with sequentially observed cars that can be labelled using parallel video records. The second type of the database can be used for detail study and interpretation of observed polarimetric characteristic while the first can give a massive, statistically meaningful characteristics.



Initially expected research tasks:

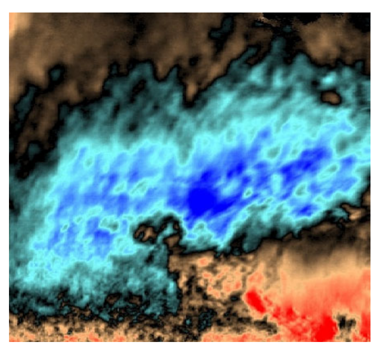
TAKEN

- Data collection, processing and blind and labelled databases creation;
- Statistical processing and analysis of collected data and derivative features;
- Performance estimation of using polarimetric parameters and derivative features for moving cars classification.

For objects classification within proposed multidimensional features spaces can be used the classic Bayesian approaches or modern ML/AI methods.

The retrieval of the vertical air velocity from the high resolution coherent radar measurements in zenith direction

A microwave radar could not measure the air velocity directly – it is sensitive only to the scattered on raindrops signals. The velocity of raindrops is defined by the terminal velocity of drops in the gravitation field of our planet in superposition with the air motion. If we can measure the radar reflectivity (the power of scattered signal) and first two moments of the Doppler spectrum, we can estimate two-parameters drop size distribution and expected integral terminal velocity of the set of raindrops within an observed rain volume. The difference of such estimation with measured mean Doppler velocity will give the own velocity of the air. The correctness of such retrieval approach can be influenced by many factors related to initial assumptions, to the non-ideal nature of rain and atmosphere, and to the measurements accuracy.



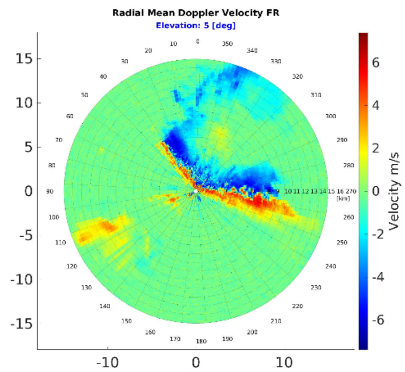
Initially expected research tasks:

TAKEN

- Develop the retrieval technique that is based on the assumption of a rain that has two-parameters drop size distribution and uses Doppler radar measurable for the case of zenith rain profiling.
- Estimate the potential accuracy of this technique in relation of physical parameters of the model and accuracy of the radar measurements.
- Implement proposed algorithms as the matlab (or python) codes and run them for long-term high resolution vertical profiles of atmosphere using the PARSAX radar.
- Analyze statistically the whole set of results and in details a few interesting cases (cold/warm fronts).

User-centric signal processing of high-resolution meteorological phased array radar

Meteorological radar as a remote sensing instrument has to provide to end-users an understandable for them preprocessed information with clarified quality. It means that for the user's needs satisfaction it is necessary to establish the reliable processing chain that combine mostly standard or adapted algorithms for conversion of measured radar signals into set of user-defined derivative variables that are related only to the sensing objects of user's interests, and have some specified accuracy and/or quality. Only such data can be used effectively by end-users to approach their sensing goals. As result, the total processing chain has to include not only standard processing algoritms for final product formation (like beamforming and Doppler processing) but also user-oriended/dependent algorithms for de-noising and de-cluttering, calibration, data quality characterization, archiving in standardized format(s), and (meta)documentation with quicklook support for search and overview.



Initially expected research tasks:

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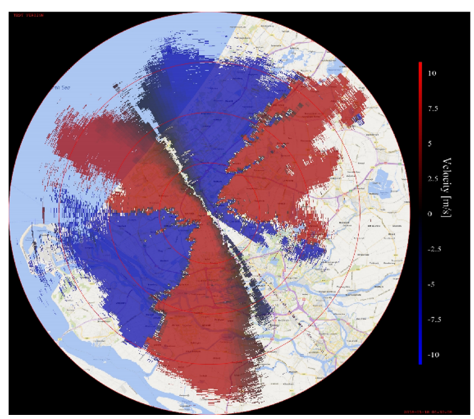
- Define the hierarchy and structure of the products for high-resolution meteorological phased array radar.
- Develop the processing chains for defined above products, adapt or develop necessary specific processing algorithms (beamforming, Doppler processing, denoising/clipping, decluttering, calibration, etc), define the content and format of product's data files and metadata (quick looks, data description/documentation).
- Implement the proposed processing chain as the matlab script (or GUI) using existing and/or adapted implementations of partial processing algorithms into general program, validate it's quality and performance using available database of phased array radar measurements.

Spatial statistics of meteorological radar observations

From general point of view it is possible to assume that the rain presence and intensity do not depend from the location within the area of some reasonable scale around any arbitrary point on the earth surface. This hypothesis can be tested using the statistical analysis of scanning meteorological radar observations a during long time. The duration of analyzed time interval have to be long enough to cover all scanning area with the rain of different intensities. Any departure of the final spatial statistics from the spatially-uniform distribution can be related to specific condition of the radar signal propagation that also characterize the actual radar operational field of view. Such information is itself quite interesting as soon it characterizes the real performances of maintained radar.



Initially expected research tasks:

TAKEN

- Develop a script for statistical processing of a long time series of scanning meteorological radar observations, taking into account measurement completeness, resolution and accuracy.
- Collect spatial statistics of specific radar observation and analyze its statistical completeness/representability/reliability in relation to observed phenomena parameters (e.g. the rain intensity, radar power budget and signal attenuation)
- Analyze spatial statistics of the radar observation using homogeneity criteria, find statistically meaningful local disturbances and relate them to specific conditions of radar signal propagation (terrain profile, earth surface type, high obstacles, etc).

Electromagnetic interference (EMI) of wind turbines on nautical radio communication

Introduction

In the Netherlands production of renewable energy to reduce the use of fossil energy is high on the agenda. Many plans are made for windfarms, both in the North sea and on shore. Rijkswaterstaat wants to know, if and to what extent wind turbines along waterways (shipping lanes and rivers/canals) cause EMI on nautical radio communication.

Nautical radio systems

In the table below, the radio frequencies are given for the systems that are in use for nautical communication (and positioning). Transmitting power can differ. For instance, radio telephone is transmitted with 0,5 Watt on inland waters and 25 Watt at sea.

System	Radio frequency [MHz]
GMDSS	0,49 / 0,518 / 2,1875 / 4,2095 / 6,215 / 8,25 / 12,290 / 16,420 / 18,795 / 22,060 / 25,097
VDES (= VDE, AIS, ASM)[1]	156 – 164
Radiotelephone (VHF)	156 - 164
C2000	380 – 400
IMT2020	800, 900, 1500, 1800, 2100, 2600, 3500
GNSS[2]	multiple frequencies between 1164 and 1616

Graduation research

Different from radar, there is limited insight in the potential electromagnetic disturbance of radio communication by wind turbines. In the report of PIANC Working Group 161 is stated 'offshore wind farm structures may also affect communications systems operating in the marine environment. This includes vessel-to-vessel, vessel-to-shore and vessel-to-space links.
Examples of systems that potentially may be affected include GPS (global positioning system, 1.6 GHz) for navigation, VHF (160 MHz) radio for marine communications, and AIS (automatic identification system on 160 MHz) for vessel identification and tracking' (1). Some experience stems from the sensitive ASTRON LOFAR radio telescopes, that are protected in nearby zones by limits for electromagnetic radiation from wind turbines (2).

In this exploring graduation project, the aim is to analyze to what extent the different systems aforementioned are electromagnetically disturbed by wind turbines, and if so, under which conditions.
The research can be carried out by literature study, simulations, and preferably, –as far as it can be arranged, - field measurements.
The graduate is very welcome for an internship at Rijkswaterstaat WVL, that can provide in expertise and information.

References

1. Interaction between offshore wind farms en maritime navigation, PIANC WG 161, 2018.
2. ASTRON LOFAR radiotelescopes (https://www.astron.nl/beschermingszones/).

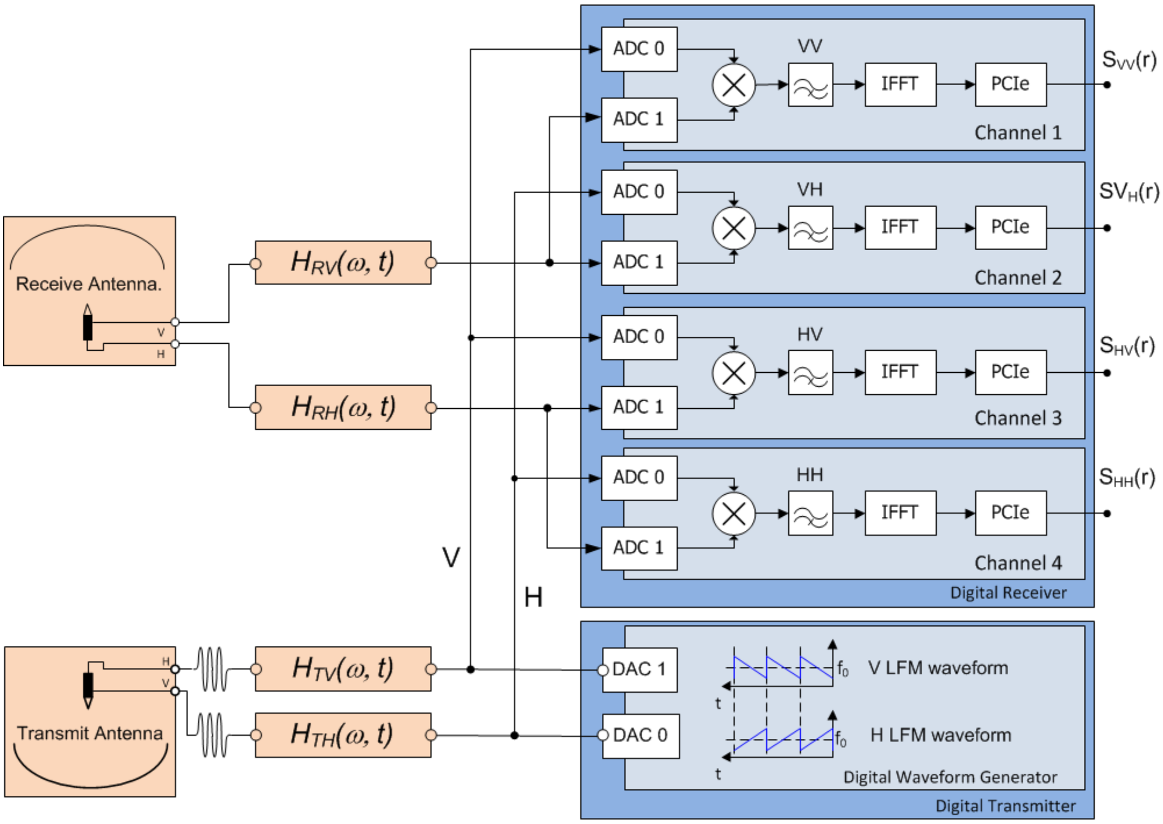
Otto Koedijk, TU Delft/Rijkswaterstaat, 19-08-2022.

Contact: O.Krasnov, o.a.krasnov@tudelft.nl

[1] Technical characteristics for a VHF data exchange system in the VHF maritime mobile band (itu.int)
[2] Global positioning system - Wikipedia

THESIS PROJECT – *Polarimetric FMCW radar Receiver in one FPGA*

About 10 years ago has been designed and developed the software-defined polarimetric FMCW radar PARSAX, that sampling transmit and receive signals on IF with sampling rate 400 MS/s and make further real-time processing (mixing, down sampling and FFT-based range compression) within FPGA. As result the radar receiver have very high sensitivity, wide dynamic range, providing the capability for targets detection and their parameters estimation for many such applications as atmospheric remote sensing, traffic controls in airspace and on highways, moving and rotated targets detection at long ranges. The current block-diagram of the radar presented in the figure below.



Block-diagram of the polarimetric FMCW radar

As can be seen, the real-time processing of signals in four parallel polarimetric channels is currently done within digital receiver that includes four parallel PCB's, each with two ADC's and one FPGA (Xilinx Virtex 5). At the same time, the technological progress resulted in appearing on the market the PCB's with the necessary amount of ADC's and much more powerful novel FPGA that rise a hope that the whole polarimetric 4-channel receiver can be implemented within one such PCB.

The feasibility study of the implementation of multi-channel signal processing within one modern FPGA is the subject of this project. It will start with the design of FPGA IP that demonstrate the feasibility to implement 4-channels receiver in one Xilinx last generation FPGA. Finally, there will be a possibility to adapt the digital receiver's design to one of available on market PCB from selected vendor.

Requirements: This project requires deep knowledge of and experience in the Xilinx FPGA design using modern software tools.

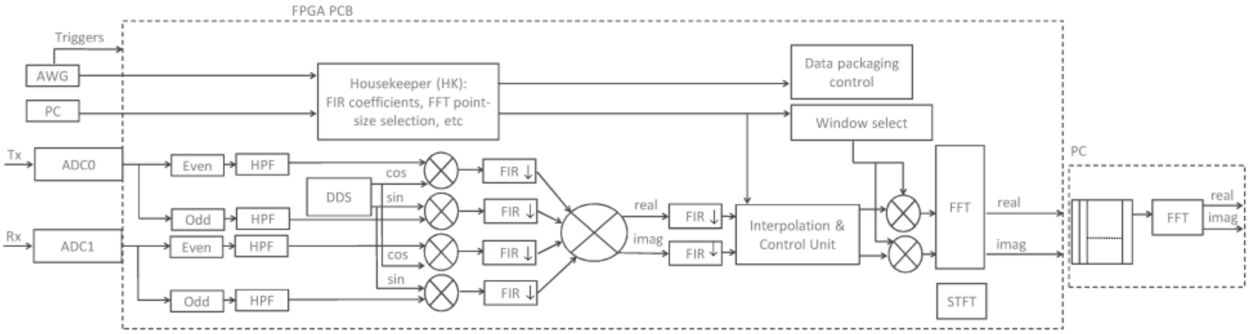
Contact: Dr. Oleg Krasnov, Assistant Prof (o.a.krasnov@tudelft.nl).

THESIS PROJECT – *A Fully Flexible Single-Side-Band Radar Deramping Receiver on FPGA for polarimetric Doppler FMCW radar*

At the present time, there are different radars for different sensing goals. These radars have different architectures and unique processing chains. This has undesired implications, such as financial and power consumption. Current radars - in academia - can switch between a library of waveforms (WF1: search, WF2: track, etc.), or arc hard-coded for specific purposes. It is therefore desired that switching between configurations happen in a more continuous manner for different applications. Receiver-chain blocks need to facilitate and allow their own adaptability, by being reconfigurable on request from a radar-management block. The management-block will also have to dictate the waveforms in use, and their supplementary signal processing, in association with a desired sensing goal.

This work focuses on the FMC\v class of radars and their waveforms, where the project addresses:

- Receiver-chain parameters, tradeoffs, design and implementation considerations.
- Implementation and testing on FPGA boards.



ADAPTIVE RECEIVER REQUIREMENTS

- Online FIR filter coefficients reload.
- Implement Short-Time Fourier Transform (STFT) on the FPGA using Xilinx blocks in Simulink
- FFT point-size online selection
- FFT window selection. Can be stored on chip/off-chip or calculated online.
- Xilinx Direct Digital Synthesizer (DDS) center frequency online reconfiguration.
- Two-way switchers between PC and FPGA using Digital I/0 (DIO).
- Arbitrary Waveform Generator (AWG) to control a few DIOs to indicate a certain functionality/command, etc. - like a switch of waveform, for example.
- Use existing Innovative Integration (II) blocks to allow read/write data from on-board (off-chip) memory(s).
- Complete change of receiver architecture based on request from PC or AWG via Xilinx partial dynamic reconfiguration (PDR). An example would be to switch from a single-sideband to a double-side-band receiver.
- Use existing II blocks and protocols for data exchange between FPGA boards (networking capability).

Note: These requirements are directly linked to a few radar system level requirements. For example, changing the Pulse Repetition Frequency (PRF) requiring the change of many parameters of the FPGA design.

Requirements: This project requires deep knowledge of and experience in the Xilinx FPGA design using modern software tools.

Contact: Dr. Oleg Krasnov, Assistant Prof (o.a.krasnov@tudelft.nl).

Master projects – Yanki – Introduction

- System-based design approach for **antenna synthesis/beamforming**

✓ Electromagnetics	✓ Circuit design	✓ Signal processing
✓ Thermal management	✓ Medium access control	

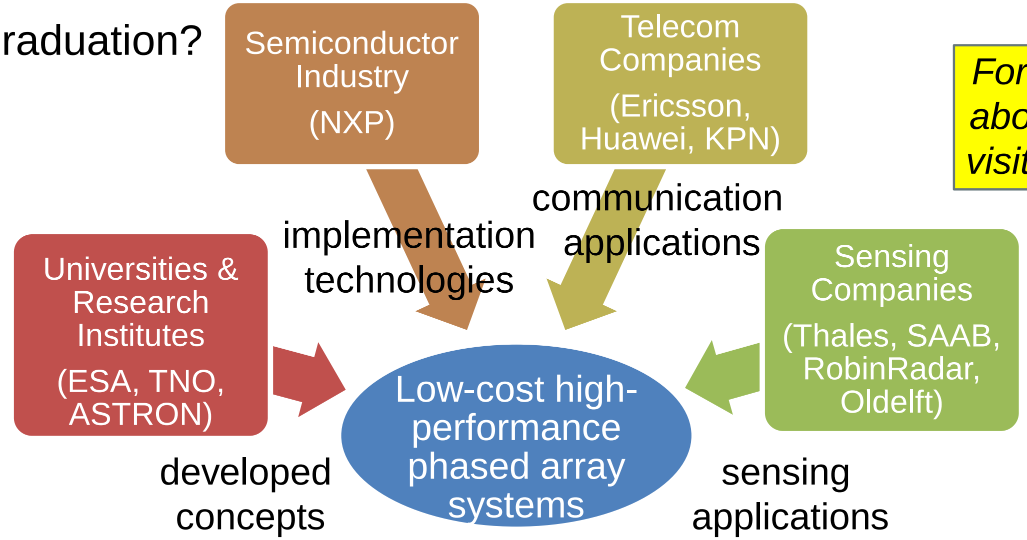
- What you can work on:

» Antenna & beamforming network design, testing	(antennas + circuits)
» Optimization techniques for large-scale antenna arrays	(antennas + DSP)
» Wireless system development	(antennas + propagation models)
» Electro-thermal antenna & front-end modeling	(antennas + transceivers)

How? → theory, simulation, experiments

Why? → to address the **cost and complexity** issues in **5G and beyond**

- After graduation?



For further information about my work, please visit www.yankiaslan.nl

MS^3 Microwave Sensing Signals & Systems

Master projects – Yanki – Topic list

<u>Communication system oriented projects:</u>

- System characterization of mm-wave 5G base stations with shaped elevation patterns
- Optimal system use of mixed low & high quality hardware in mm-wave RF front-ends

<u>Antenna and beamformer design oriented projects:</u>

- Series-fed antenna array design with reduced beam squint
- Reconfigurable beam forming network design for satellite terminal antennas
- Synthesis and design of irregular antenna-in-package (AiP) arrays for 6G
- Sensing through biodegradable passive/active implants for biomedical applications
- Design of self-nulling antenna elements/subarrays for grating lobe cancellation
- Design of a mm-wave dielectric resonator antenna array with additive manufacturing for Satcom

<u>Array signal processing and optimization oriented projects:</u>

- Adaptive array thinning/tiling strategies for 5G and beyond
- Machine learning assisted aperiodic array synthesis
- Multibeam antennas for joint communication and sensing (JCAS) applications

<u>Antenna cooling oriented projects:</u>

- Multiphysics (electromagnetic & thermal) simulation of mm-wave integrated antennas

Please send me an email at Y.Aslan@tudelft.nl if you are interested.

TU Delft

MSc Thesis Project Proposal – **System Performance Evaluation of Hybrid Beamforming with Shaped Elevation Patterns for mm-wave 5G Base Stations**

Introduction - Problem to resolve

At mm-waves, with very low linear power amplifier efficiencies and high consumption of ADC's and processing, active arrays (with the currently discussed sizes on the order of 8x8 or 16x16 elements) with full DBF for massive MIMO producing 3D adaptive multiple beams might not yet be competitive [1]. Therefore, as an appealing performance vs. complexity/cost trade-off, hybrid (analog+digital) beamforming strategies have been recently introduced in several different forms [2].

If we consider a communication scenario where the cell range is 200 m from a base station which is located at H=10 m above the ground, we can compute that about 90% of users (assumed to be uniformly distributed spatially) are within 3 deg. to 10 deg. from the horizon. As a result, there will be no apparent frequency re-use benefits in elevation with 15 deg. wide beams of the currently proposed 8x8, or even the 7.5 deg. wide beams of 16x16 element arrays. Thus, in such use cases, most 5G equi-height ground users in a cell will be seen from base stations within 10 deg. from the horizon, leaving little scope for spectrum re-use gains from adaptive multiple beam forming in elevation.

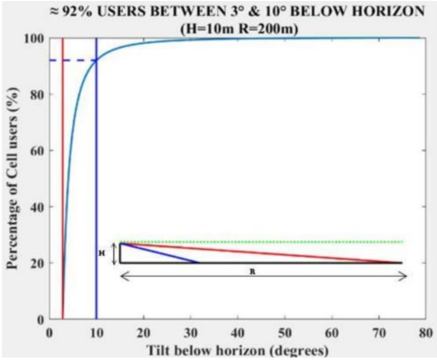


Fig. Angular distribution of base station users [3]

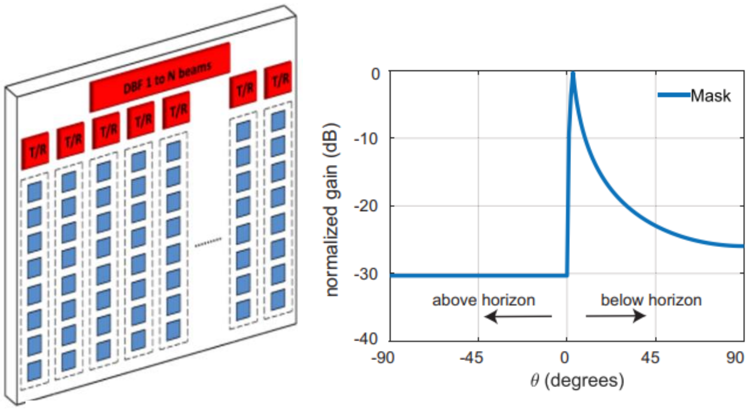


Fig. Array of vertical subarrays with shaped analog beam [5]

A promising and feasible alternative is then to use arrays of vertical sub-arrays with cosecant squared elevation patterns and adaptive multiple beams in azimuth [3]. Such a beamforming approach will help equalize both the base station transmit power and the flux received for all line-of-sight users [4]. Moreover, compared to large square arrays with 2D digital beamforming, their complexity, consumption, and cost are potentially much reduced [5].

To our knowledge, hybrid beamforming based on shaped elevation patterns has not yet been investigated in a realistic 5G multi-user system environment. The existing work only considers free-space propagation with no multipath [6]. Therefore, understanding the applicability of such beamforming approaches in close to real-life propagation scenarios require further and deeper system-level studies. This would potentially include rigorous modelling of the antenna arrays and signal propagation in a given environment [7,8] by using simulation tools (e.g. Quadriga) and tailoring these to the key performance metrics (such as throughput including AMC) with smart selection of simultaneously served users and by applying effective digital beamforming techniques in 1D [9].

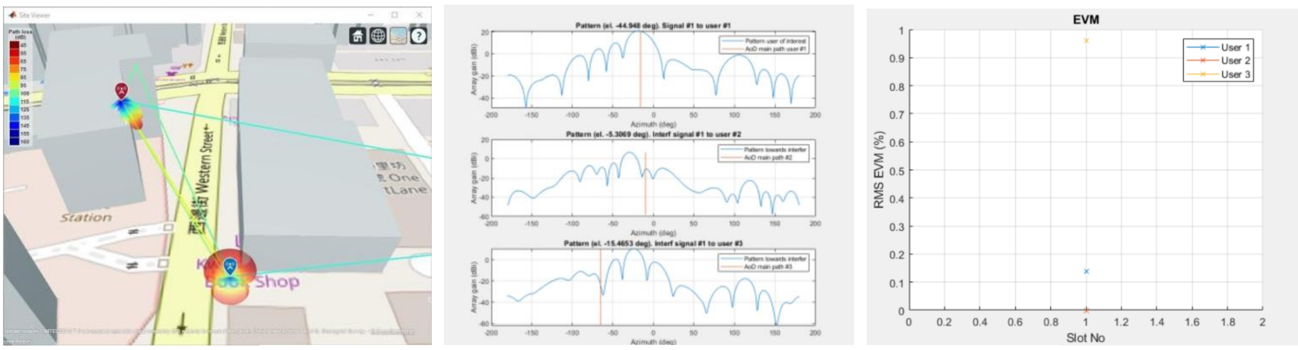


Fig. Sample 5G multi-user simulation (from Mathworks [7])

The main research question of this project is: What are the key system performance advantages/trade-offs in case of using hybrid beamforming with shaped elevation pattern as compared to the 2D digital beamforming? What are the system performance differences of such hybrid beamforming technique in the case of having pure LoS communication, LoS+NLoS propagation and pure NLoS?

Main project activities

The following tasks are included in the project:

Task 1 – Review and understand the relevant literature, methods/tools on hybrid beamforming and on 5G system modeling/propagation.
Task 2 – Develop a 5G multi-user communication system model with flexibility in the propagation environment, beamforming strategy and user positions.
Task 3 – Simulate the performance of a 2D digital beamforming array as a benchmark.
Task 4 – Replace the 2D digital beamforming with 1D digital beamforming in azimuth and fixed analog beam (e.g. cosecant-square shaped) in elevation, evaluate and compare the performance with the benchmark under various propagation and user distribution scenarios.
Task 5 – Based on the model, investigate the future applicability of using environment-specific pattern shapes.

Requirements

For this project, an interest for and knowledge of the following are expected:

(a) Telecommunications and signal processing,
(b) Antenna systems,
(c) Matlab coding

The student will benefit from the previous relevant work and antennas/beamforming expertise of the MS3 and the wireless system characterization and modeling expertise of the NAS group.

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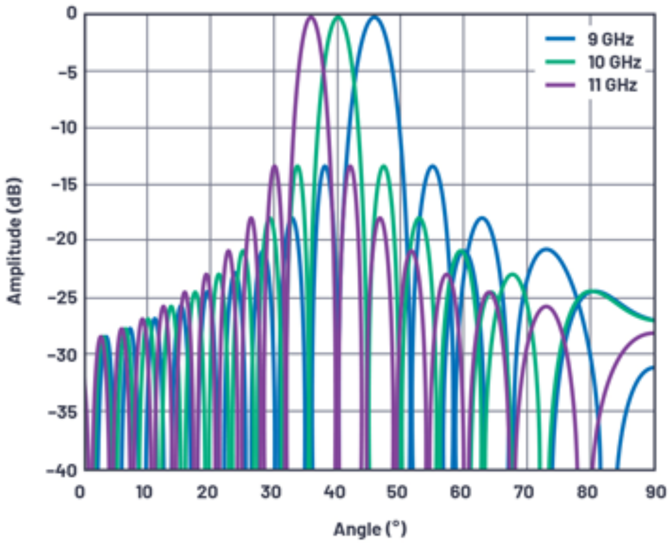
Dr. Remco Litjens – NAS, TNO (remco.litjens@tno.nl)

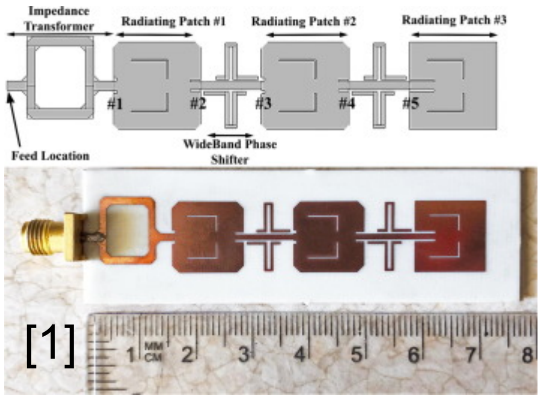
Design of series fed antenna array with reduced beam squint

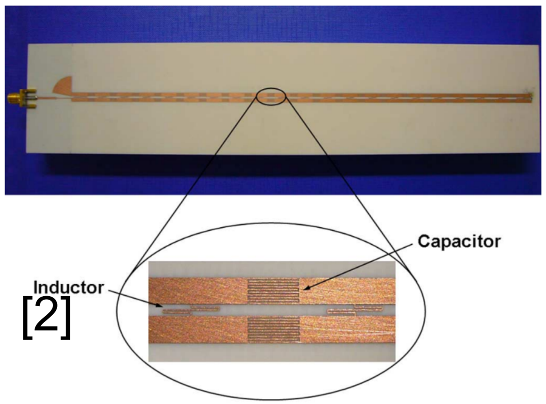
- The usage of series fed antenna in phased antenna has wide range of applications where scanning only in plane is needed such as an automotive, satellite, communication etc. Advantage of such phased arrays is in simplicity and low cost. Disadvantage of such arrays is beam squint.

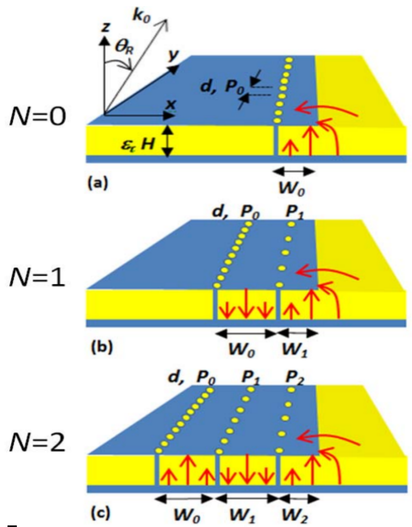
- Beam squint is the change of the beam direction as a function of operating frequency. It is an important parameter that can limit the bandwidth in phased array antenna systems. For this reason, the antenna community has put interest to new configurations/technologies which reduce the unwanted frequency beam squint.



- In the literature, there are some techniques to compensate the beam squint:
  - Wide-band phase-shifting network [1]
  - Metamaterials [2], [3]
  - Metasubstrates [4]
  - Active non-Foster circuits [5]
  - Multi coupled-cavity substrate integrated waveguide [6]







[6]

- The aims of this M.Sc. project are:

1) Investigate the techniques which are used to compensate the beam squint in series fed antenna arrays.

2) Compare two feedings options of leaky wave (series fed) antennas in terms of beam squint

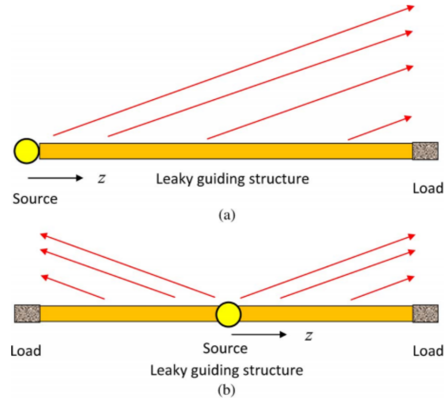


Fig. 1. ***(a) Illustration of different modes of operation for an LWA. (a) Unidirectional case. (b) Bidirectional case.***

3) Proposed and design the suitable basic antenna element for series fed antenna arrays

4) Based on the proposed beam squint compensation technique, feeding position and antenna element, design series antenna arrays with reduced beam squint.

Contact: Dr. Yanki Aslan (Y.Aslan@tudelft.nl)

MS³
Microwave Sensing
Signals & Systems

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TUDelft

Master thesis / extra project

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CC: Nicolas Kruse
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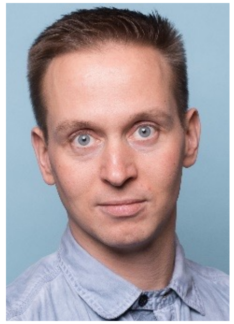


<u>Topic</u>: Radar data domain optimization for distributed sensor networks

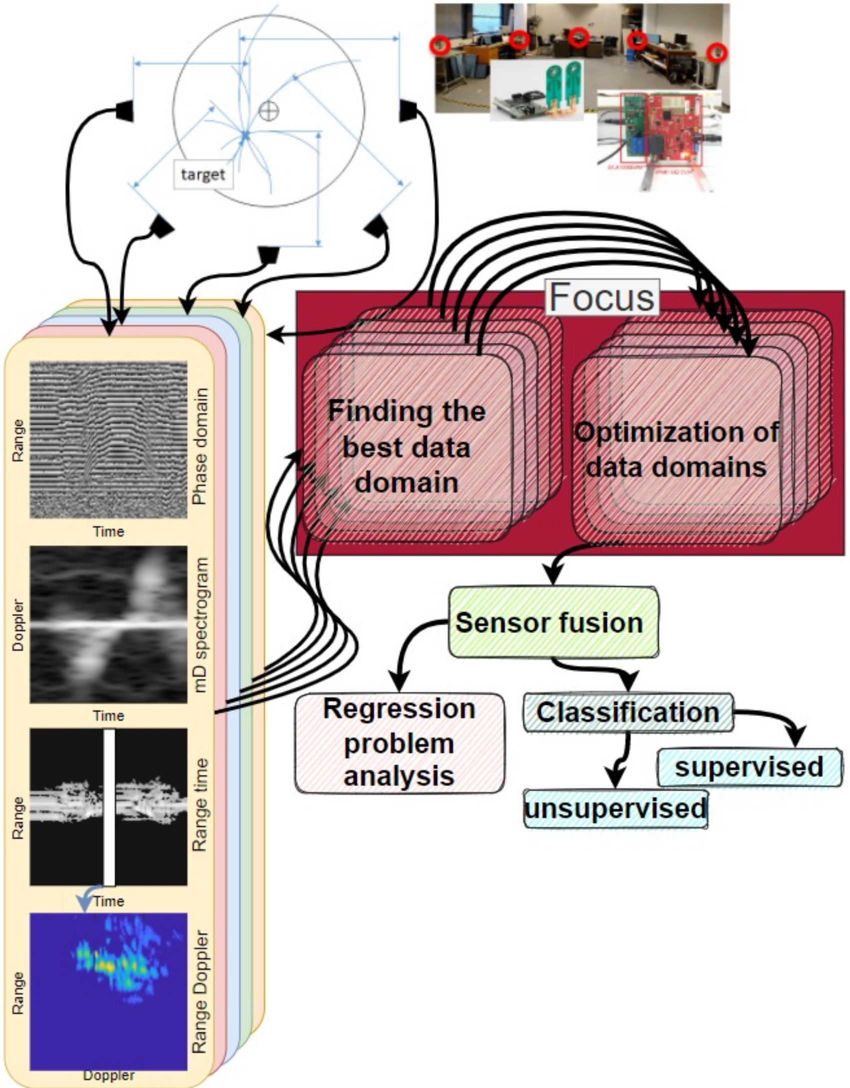
Machine learning	Signal Processing	Data fusion
Radar system		

Human motion activity recognition using

(a) SISO radar S/C-band $(\approx 4GHz)$

(b) MIMO radar V/W-band $(60/77GHz)$

- Analytical study combined with real radar data research
  Keywords: signal processing, ML, AI, sensor fusion, radar systems
- Ideal for extra projects
- Extension into a master thesis
- Crossdisciplinarity area needed, i.e., for:
  indoor monitoring + elderly healthcare
  pedestrian detection (automotive sector)
  security & safety applications
- <u>You have experience in</u>: radar systems, UWB technology, Matlab/Python, ML/AI experience



TUDelft

Master thesis / extra project

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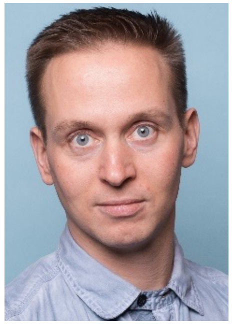

Topic: Distributed radar sensor networks analysis

Target Tracking | Signal Processing | Case study

Radar system

CC: Nicolas Kruse
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Research question(s): Can a network of SISO radars (S/C-band [$\approx 4GHz$]) be replaced by a single MIMO radar (V/W-band [$60/77GHz$])

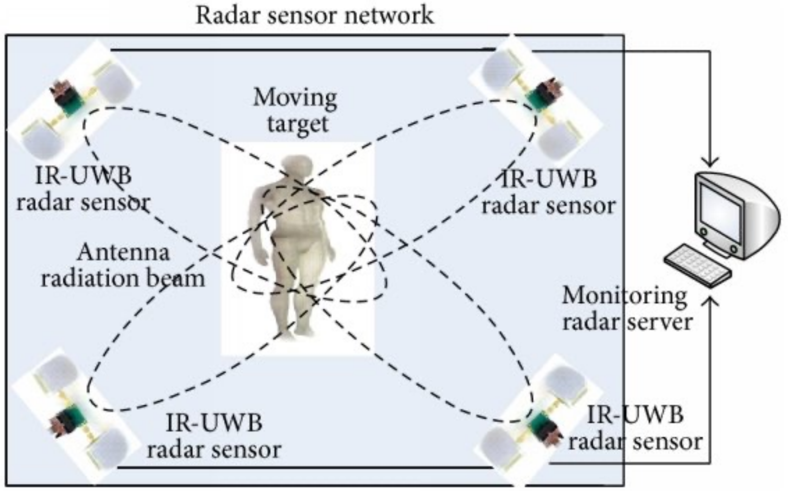
what about: hidden objects, angular resolution, antenna coverage, deployment in the room, can such systems even work together, do I need tracking, …, etc. pp.

Keywords: signal processing, target tracking, optimization

- Theoretical case study which can involve hands on experience
- Ideal for master thesis (can be challenging for an extra project)

- Crossdisciplinarity area needed, i.e., for:
  indoor monitoring + elderly healthcare
  security applications in surveillance areas

- You have: experience with radar systems, a passion for analytical optimization (math), you are communicative and like discussions on a white board, you speak a bit Matlab/Python language, visualization tools are welcome



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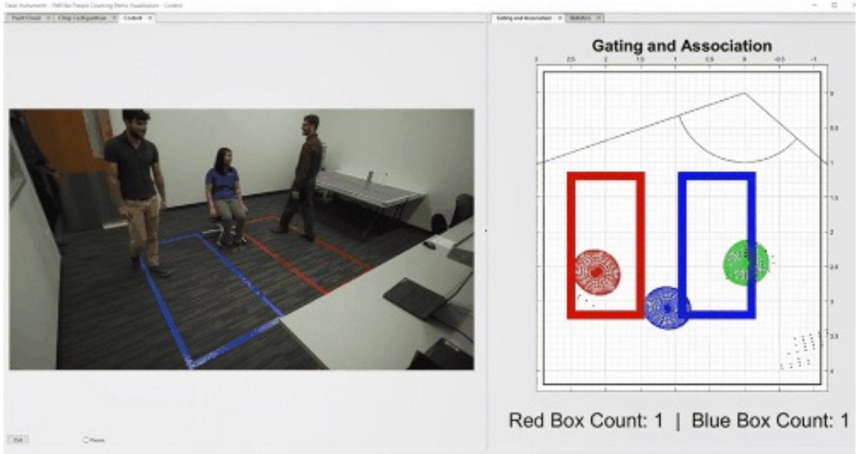


https://e2e.ti.com/blogs_/b/industrial_strength/posts/create-an-intelligent-building-system-use-mmwave-to-count-and-track-people

TU Delft

Polarimetric mm-Wave Radar System for Automotive Applications

Nowadays, more and more cars are equipped with radar systems in order to improve safety and head towards completely autonomous operation. To enable the development of an ever-growing amount of autonomous functions, next generation automotive radar systems need to provide better situational awareness to the vehicle's on board computer. One of the key points in increasing this situational awareness is providing a classification of targets besides just making a detection of said targets.

A key factor to increase classification performance is to provide the classifier with more information about targets so that there are more features to distinguish the classes on. Two of examples of common information sources of information are the radar cross sections of targets and their micro-Doppler signatures.

However, there is one property of electromagnetic waves that has not thoroughly been investigated yet for use in classification in the automotive domain. Namely, the polarisation of the backscattered radiation. As scattering of electromagnetic waves depends on wave polarisation and, amongst others, the shape of the target, wave polarisation could provide a rich source of information to enhance classification performance.

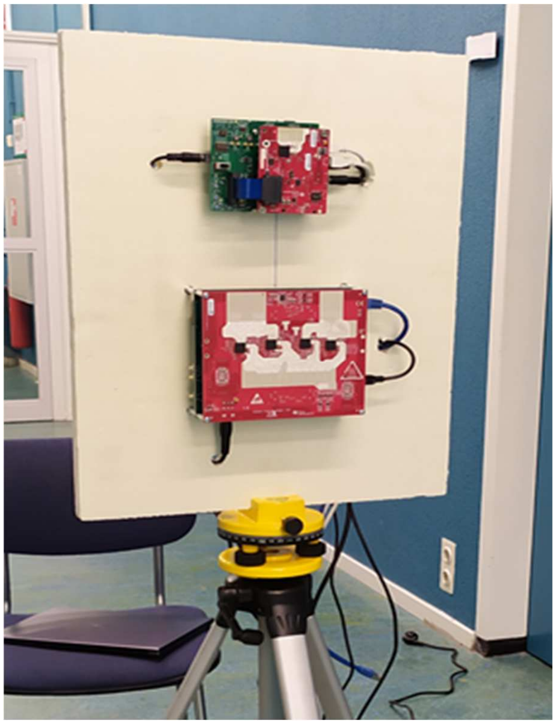


Figure 1: Example of mm-wave radar systems you can use for this project

Goals

As using polarimetry is a very novel subject, all currently available commercially available automotive radar systems use a single polarisation of EM wave to do measurements and thus are not able to perform fully polarimetric measurements.

Your task in this project will be:

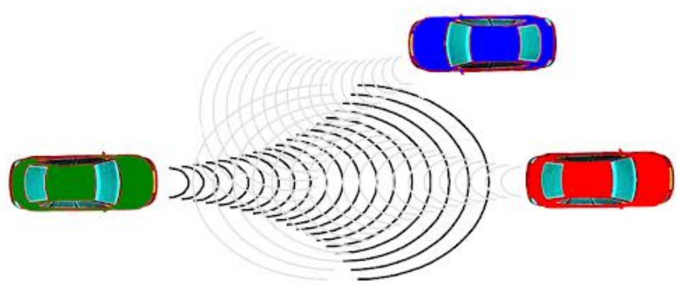
- Creating a radar system comprising of two orthogonally oriented commercially mm-wave radar systems to perform partially polarimetric measurements.
- You will then use this system to perform outdoor measurements of real-world scenarios. For these measurements, scenarios involving vulnerable road users such as pedestrians and cyclists are of importance, as these are especially important to recognise for a car to prevent serious injury or even loss of life. Another main topic of interest is measurements of road surfaces and dangerous road conditions such as puddles of water or patches of ice. Recognising these early can improve performance of road safety systems such as anti-lock braking and electronic stability control.
- Lastly, you will try to implement a classification algorithm to differentiate between the targets you measured.

Are you interested in this project or looking for more information? Please contact Wietse Bouwmeester (w.bouwmeester@tudelft.nl) for a further discussion on this topic.

Automotive Radar Interference Analysis for

Different Radar Waveform Types

Radar has become one of the key sensors in any modern Advanced Driver Assistant System (ADAS) to enhance autonomous driving. However, increasing number of automotive radars leads to spectral congestion and radar sensors suffer from radar-to-radar interference due to sharing limited spectrum. The mutual interference between automotive radars degrades performance of victim radar and increases the chance of miss detection and false detection. Moreover, variety of waveform types are used by automotive radars depending on the application and the structure of the mutual interference varies with the different radar waveform types. Therefore, it is important to analyze different interference scenarios for various radar waveform types. As a preliminary study, the generalized radar-to-radar interference equation is derived to model and simulate interference on the victim radar according to the chosen waveform type. In the framework of this project, the impact of different interferers on target detection will be simulated by using the equation and the detailed analysis of the interference impact on the target detectability will be studied.



The main goals of the project:

- Gaining an understanding of automotive radar systems and various sensing waveform types
- Analytical analysis of different interferers appearance in the range-Doppler plane of the victim radar
- Simulating the synchronized or asynchronized interference on the victim radar in the range-Doppler plane and applying CFAR algorithm for target detection
- Investigating and analyzing the influence of different interference types on the target detectability such as probability of detection and false alarm rate

Requirements

Radar basics (Radar I course), radar signal processing (Estimation and Detection course is minimal requirement; Radar II and Object Classification with Radar are advisable) and MATLAB simulation experience

Contact: Utku Kumbul (u.kumbul@tudelft.nl) Microwave Sensing, Signals and Systems

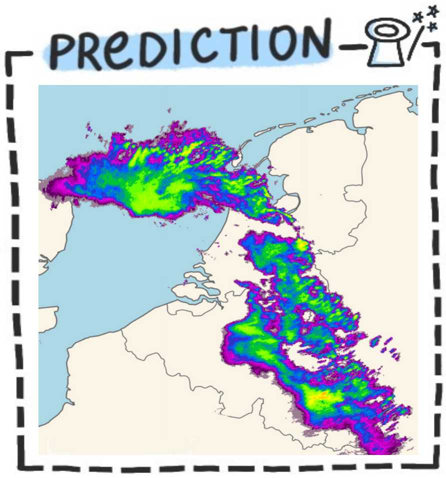
MSc topics 2022-2023

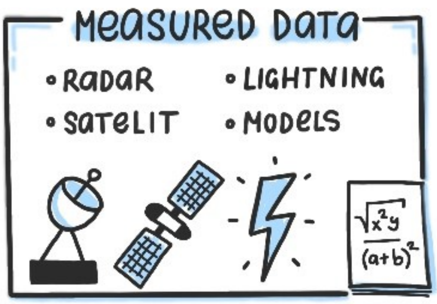
Deep Rain:

Deep learning techniques for rainfall nowcasting

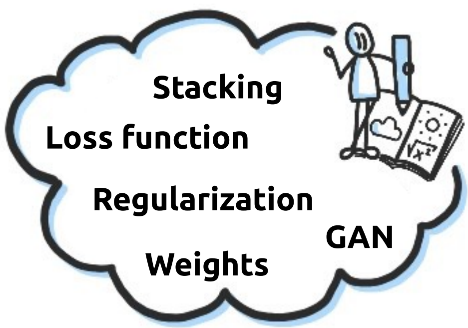
Context: *RainGuRu* (https://rainguru.tudelft.nl/) is a recurrent convolutional neural network for short-term rainfall prediction in the Netherlands based on the Traj-GRU architecture by Shi et al. (2017). The model was developed by TU Delft students Eva van der Kooij (2021) and Diewertje Dekker (2022) within the framework of their MSc theses.

Challenge: RainGuRu already outperforms other nowcasting algorithms. The question is: how can we make it even better? One idea would be to add information about cloud cover, temperature and wind from satellite observations and/or numerical weather models. Another would be to tweak the loss function or consider switching to a GAN model as proposed by Ravuri et al. (2021) of Google's Deep Mind team.





The goal of this project is to develop new, more powerful versions of RainGuRu that look more realistic (i.e., less blurry) and/or are capable of assimilating data from multiple sources, such as satellites, weather prediction models and surface observations.



You will work together with a diverse team of researchers at GRS, Water Management, EEMCS and our partners at HKV to implement the latest advances in deep learning applied to rainfall nowcasting. You will develop new codes, design new learning strategies, and explore new original pathways towards making RainGuRu a better, more reliable and useful tool.

For more information:
Dr. Marc Schleiss
Assistant Professor
Geoscience & Remote Sensing
m.a.schleiss@tudelft.nl

Deze thesis uitvoeren in samenwerking met HKV Lijn in Water?

Dat kan!

Neem contact op voor de mogelijkheden

Mattijn van Hoek
Email: m.vanhoek@hkv.nl
Tel: 06-35119762

HKV LIJN IN WATER

A few more possible topics for the MSc projects (initial directions for detail discussions)

The researchers of the MS3 group are working within the wide area of radar sensors technology, signal and data processing and interpretation for variety of applications. To give you an impression what can be the research topics for your MSc project within the MS3 group, an example of the extendable list of a few hot titles is presented below.

Electromagnetics and Antenna Systems design

- Full-Polarimetric MIMO Antenna Array at 77-81GHz for automotive radar applications
- 10cm*10cm 25GHz Waveguide-slot Array for a Nanosatellites
- The influence of composite paints substances on signals scattering at 77-81GHz automotive radars frequency band.

Technological problems of modern radars

- Multi-static measurements in distributed L-band radar network: handling noise , RF coherency and modulation synchronization of distributed nodes
- Integration and synchronization of the Texas Instrument (TI) and/or NXP automotive MIMO radars with video camera and GPS

Radar Signal and Data Processing

- Ground Penetration Radar (GPR) Imaging of Sewage Pipes Partly Filled with Sand
- Measurements of Moving Targets using multichannel ASTAP MS3/TUD radar system
- Improvement of radars synchronization in distributed network using observations the same moving targets
- Automotive MIMO radars self-diagnostics and instant calibration using statistical processing of targets of opportunity.

If you are interested in one of listed topics or even in some more general or specific research directions, you can contact Prof. DSc. Alexander Yarovoy (a.yarovoy@tudelft.nl, HB21.100) for further discussions.

PARSAX radar for space monitoring

TNO DEPARTMENT OF RADAR TECHNOLOGY

Assignment Description

PARSAX is a modern and highly reconfigurable radar created by TU Delft. PARSAX has already been evaluated for radar applications such as atmospheric studies, and ground- and sea-based targets detection. We are now aiming at testing PARSAX capabilities for space monitoring applications.

In the past years, the number of satellites that are yearly launched is growing exponentially. Only in 2021, 1778 satellites were put into orbit, compared to 955 of the previous year. Therefore, the space domain is becoming more crowded by the day and needs to be efficiently monitored.

Radar systems are commonly used for space monitoring. Furthermore, when applied with optimal techniques, radar can also provide a wealth of information about the observed object. For example, using only the observed radar cross section, satellite parameters such as size, attitude control mode and maneuvers can be estimated.

In this internship you will assess the PARSAX performance for satellite detection and tracking. You will investigate, for example, ideal waveforms (e.g., bandwidth and pulse repetition frequency) that can be applied to PARSAX for satellite detection. Since the current maximum instrumented range is few hundred of km, the signal-to-noise ratio of second time around pulses needs to be assessed too, because expected ranges to satellites are at least 400 km.

TNO Department of Radar Technology

You will perform this assignment in TNO's Department of Radar Technology. We are a passionate and creative group of professionals (60 people) dedicated to the specification, development and evaluation of innovative technology with a focus on high frequency/radar applications. Within our group we thrive on technology advancements in the following topics: high-performance MMICs, miniaturized and integrated RF subsystems, antennas, signal propagations, front-ends, and signal processing algorithms. The department is at the heart of novel, game-changing radar system and signal processing concepts for the military, space and civil domains.

What do we expect from you?

You are in the final stages of your bachelor's or master's degree in physics, electrical engineering or a similar degree and you have a track record in the field of radar technology. Furthermore, you are also familiar with basic radar theory such as the radar equation and system noise sources.

Contact

Miguel Caro Cuenca (miguel.carocuenca@tno.nl)

For this internship vacancy it is required that the AIVD issues a security clearance (VGB) after conducting a security screening.

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

TNO is an independent research organisation whose expertise and research make an important contribution to the competitiveness of companies and organisations, to the economy and to the quality of society as a whole. We develop knowledge not for its own sake but for practical application. To create new products that make life more pleasant and valuable and help companies innovate. To find creative answers to the questions posed by society.

For these assignments you will be working with TNO's Department of Radar Technology. We are a passionate, creative group of professionals dedicated to the specification, development and evaluation of innovative, high-performance MMICs, miniaturised and integrated RF subsystems, antennas and front-ends, and processing algorithms. The department is at the heart of novel, game-changing radar system and signal processing concepts for the military, space and civil domains.

The Department of Radar Technology offers a wide variety of internship assignments, ranging from MMIC and RF-IC design and evaluation, RF front-end development and antenna design and evaluation to novel signal processing algorithms and quantum technology. This leaflet presents only a selection of internship assignments and topics, please visit our website, www.tno.nl[1], for the latest overview of assignments. We are always open for new ideas, so if you do not find a topic of your liking, contact us[2] and we will explore the possibilities!

Radar Waveform Design

Waveform design is one of the critical aspects of radar performance optimisation. Traditionally waveforms designed for signal-to-noise ratio optimisation are applied in radar (based on matched-filter detection). Signal-to-noise ratio optimisation is however only one criterion that can be used for waveform design. Currently there is a growing interest in other criteria for radar waveform design. For detection of targets in clutter, for example, optimisation of the signal-to-clutter ratio may be a more suited criterion. Another objective for radar waveform design may be to highlight specific target features to improve not just target detection, but also target classification. Waveforms designed according to this criterion are so-called *target-matched* waveforms. The research topic of this assignment is the design of radar waveforms given a certain objective. The first step is to define suitable criteria for waveform optimisation given this objective. Then the waveform can be developed and validated. Simulations are an important tool for this assignment, but the performance of the final waveform can be validated with actual radar measurements.

[1] 〉 CAREER 〉 VACANCIES 〉 keyword "radar"
[2] 〉 jacco.dewit@tno.nl

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

Machine Learning Applied to Radar

Deep learning techniques usually thrive when large sets of labelled data are available. In the radar domain, labelled data tend to be scarce depending on the application area. This assignment focuses on achieving robust performance of machine learning methods when only small labelled data sets are available. Potential research topics are Transfer Learning using simulations in addition to actual radar measurements, Informed Machine Learning exploiting expert knowledge to improve the training process and Domain Adaptation Networks enabling the use of radar measurements made in different frequency bands, with diverse polarisations or with varying waveform settings.

Adaptive Radar and Formal Verification

Future radar systems have an increasing level of adaptivity, enabling the systems to adapt to and react on unknown or unforeseen events or operational conditions. This high level of adaptivity can be exploited for real-time waveform optimisation, smart resource allocation and even novel online learning and cognitive radar concepts. Within this framework possible internship assignments may focus on the development of novel concepts for (short-term and long-term) radar performance optimisation including online-learning and cognitive approaches. At the same time, such a high level of adaptivity raises the important challenge to ensure the radar system meets its original requirements. A high degree of adaptivity leads to a multitude of system settings and an accordingly expanded test space, rendering traditional verification techniques impractical. Therefore, other possible internship assignments may focus on applying formal verification techniques to the radar domain. The actual research question can tailored to your specific interests and background.

RF Front-Ends and MMICs

The RF-ICs and MMICs designed for radars are mostly for applications between 3 and 10 GHz. MMICs are, among others, used to generate the high transmit powers needed at each antenna element in a phased array antenna. Stability of the large signal chips and high efficiency are two terrains of continuous research. Examples of interesting internships in this field are the design of a frequency doubler needed to generate signals needed to improve the efficiency of high power amplifiers and stability analysis for high power amplifiers employing poly-harmonic distortion (PHD) modelling (X-parameters). The design of high-purity signal generators and receiver RF-ICs is another terrain of research. Investigation and design of advanced PLL like cascaded or off-set PLLs is a topic for an internship. Or design automation by automated design and optimization of transformers used for on-chip matching networks for receiver RF-ICs if you have the combination of programming and RF design-skills.

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

Integrated Filters in Phased Array Environment

Active phased array antennas must comply with stringent requirements in terms of sensitivity to interference caused by other nearby radiating systems, especially in complex platforms, which are populated by an ever-increasing number of sensors and communication systems. Radio frequency (RF) interference can cause a number of issues, e.g., saturation of the array receiver, with consequent loss of sensitivity and missed detections, increased false alarm rates or a reduced channel capacity for telecommunications. This performance degradation can be prevented by implementing frequency selective functions in the antenna panel and RF front-end. For this purpose, filters can be inserted in the transmit/receive module of the individual antenna elements. The main challenge in designing filters for wide scanning phased array resides in a limited available space. Miniaturised filters with low loss and high rejection performance is a challenging research problem. The internship assignment will address the design of integrated filters and frequency selective screens, depending on the specific interest and background of the student.

Dielectric Dome to Enhance the Scanning of Phased Array Antennas

Wide angle scanning phased array antennas are widely applied in radars and communication (SATCOM, 5G, etc.) systems. One of their main design challenge resides in the performance degradation due to two main effects: a reduced aperture projected in the scanning direction and mismatch caused by the dependence of the active input impedance on the scanning angle. A solution to this problem is to combine the phased array with a dielectric lens. The mismatch is solved by operating the array in phasing configurations limited to the cases in which the array is matched. Moreover, the current distribution over lens can be controlled by properly defining the phase distribution over the array, thus allowing to illuminate a wider area and then increase the directivity for wide scanning. The main drawbacks of this solution are the size and weight of the lens which might make it unpractical in several applications where small volumes and low weight are crucial issues. In past few years, several activities have been carried out at TNO with the goal of minimising the lens volume and weight and a few novel lens configurations have arisen as promising solutions.

Several topics for the internship can be defined depending on the interest and background of the candidate: design of wideband matching layers, exploring among others 3D printing technology; designing a low profile radome solution that does not affect the antenna field of view; studying the feasibility of a single dome that works for both the transmit and the receive array antennas.

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

Active Array Antenna

Array antennas are typically designed considering a 50Ω interface with the electronic front-end. This assumption is mostly valid when the transmit and receive functions are implemented in the same antenna aperture, when a switch or circulator separates the antenna from the active controls. In recent years the interest in the application of phased array technology for terrestrial and satellite communication has significantly grown. For such applications separate antenna apertures are typically used for the receive and the transmit function. The antenna is in this case directly connected to the (power or low noise) amplifier and the constraint of 50Ω impedance interface can in principle be released.

In this internship the student will investigate possible benefits of a co-design of an array antenna and an amplifier and compare several configurations. The specific application and antenna technology will be decided together with the student.

Artificial Intelligence Applied to Antenna Array Design

Array antennas are typically designed ad-hoc to provide specific radiation characteristics, e.g. scan range, bandwidth, cross-pol ratio etc. As a result, antenna designers spend significant effort to satisfy the requirements and companies devote important budgets and time on array design. A potentially revolutionary concept is to apply machine learning techniques and train a neural network to “design”. The way ahead, though not unique, would be the use of a bitmap-like approach for the unit cell geometry.

In this internship, the student will familiarize oneself with the use and automation of electromagnetic simulation software, as well as basic antenna concepts. Possibilities other than the bitmap approach will also be investigated for the geometry of the cells. Once the configuration is defined, an extensive set of simulations will be performed and used to train and validate a neural network. *Some Matlab (or Python) programming skills are required. Basic machine learning knowledge is a plus.*

Overview of internship assignments AD/AS

Topics for MSc internships and theses at Thales NL Delft include:

- Micro-Doppler characterization, modelling, classification
- Machine learning for radar tasks such as classification, detection, clutter mitigation, etc.
- Quantum computing for radar processing
- Multi-static operation

First contact points in case of interest:

-Ronny Harmanny (Thales NL)

-Francesco Fioranelli (MS3)

THALES

Smart Vital Signs Monitoring in Wearables

Wearables for vital sign monitoring are becoming ever more pervasive in our day-to-day and bring the promise of Nyquist rate health monitoring. However, for them to become fully autonomous, there is a need to integrate signal processing and machine learning algorithms on-chip capable of extracting useful information from the data. This brings a challenge in terms of the power and area constraints in wearable technology and requires novel algorithm formulations.

Assignment

This project will be carried out in collaboration with NXP in Eindhoven. You will explore signal processing and machine-learning algorithms to analyze data from various NXP sensors for vitals monitoring (e.g., heartbeat, respiration rate, oxygen saturation, skin moisture, etc.). You will implement these algorithms using the NXP eIQ development tool and their optimized microcontrollers for DSP and ML within the constraints of a wearable device. Finally, you will validate the performance through experimental testing and data collection.

Requirements

MSc EE/BME student.

You should be comfortable with signal processing, machine learning, and embedded systems programming. Curiosity, hard work, and creativity are always needed. If interested, contact Dr. Dante Muratore and Dr. Francesco Fioranelli via email with a motivation letter and attached CV (with taken courses and grades).

Master Thesis - Energy-Based Models

In this document, background, tasks and objective of the Master Thesis on Energy-Based Models are summarized.

Summary

Energy-Based Models (EBMs), are a framework which is increasing in popularity for generative modeling. They are trained utilizing a energy function or measure [2]. The approximation of the energy function, in Deep Learning settings, is usually approached via deep neural networks[6]. Using neural networks, furthermore, enable EBM to be adapted to different input formats as graphs, images, time series, etc.[4]

Within the framework of EBMs, more and more attention has been given to task of Out-Of-Distribution (OOD) Detection, where indeed, data are generated from a different distribution (e.g. different environment and conditions than the training data distribution)[5]. As an example of this, in a task of people counting - recognizing humans and discarding other objects, animals, etc.

Seminal recent work approached the OOD detection by using EBMs, as these contributions [3, 1].

In this Master Thesis at Infineon Technologies AG, we aim to:

- Review the state-of-the-art work on OOD detection with EMBs.
- Implement EMBs which use OOD in visual/radar datasets - in tasks as people counting, and others.
- Explore innovation related to OOD metrics, Energy approximations and EBMs training.

What you should bring:

- You should have a background in radar technology and related signal processing algorithm, as well as some knowledge of machine learning fundamentals and implementations

Contact for questions:

- lorenzo.servadei@infineon.com

References

[1] Sven Elflein, Bertrand Charpentier, Daniel Zügner, and Stephan Günnemann. On out-of-distribution detection with energy-based models. *arXiv preprint arXiv:2107.08785*, 2021.

[2] Yann LeCun, Sumit Chopra, Raia Hadsell, M Ranzato, and F Huang. A tutorial on energy-based learning. *Predicting structured data*, 1(0), 2006.

[3] Weitang Liu, Xiaoyun Wang, John D Owens, and Yixuan Li. Energy-based out-of-distribution detection. *arXiv preprint arXiv:2010.03759*, 2020.

[4] Yang Song and Diederik P Kingma. How to train your energy-based models. *arXiv preprint arXiv:2101.03288*, 2021.

[5] Jingkang Yang, Kaiyang Zhou, Yixuan Li, and Ziwei Liu. Generalized out-of-distribution detection: A survey. *arXiv preprint arXiv:2110.11334*, 2021.

[6] Junbo Zhao, Michael Mathieu, and Yann LeCun. Energy-based generative adversarial network. *arXiv preprint arXiv:1609.03126*, 2016.

The MSc projects topics within the Robin Radar Systems

- ## Optimization of an FMCW radar sweep

  The RR currently uses linear FMCW sweeps in our radars. However, this type of waveforms could be used to track the radar easily and might be even jammable. Also, the RR can't place any radars next to each other without interfering with each other. The project would give recommendations on how to solve these problems. Thinking about non-linear sweeps and their processing architectures or other possible forms of sweeps, how this would influence current radar architectures and processing algorithms, and what else there will be influenced within the RR radars.

- ## Feasibility study on ISAR on a 2D Phased Array radar

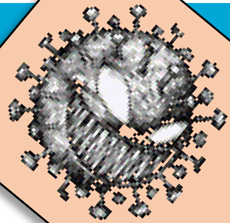
  All of the RR's current radars are rotating and have a short time on target. Current processing algorithms are built on this. In the future, the RR might create a 2D phased array radar that will have the ability to have a much longer time on target. This project is therefore about designing the processing pipeline for an ISAR on a 2D Phased Array radar at Ku-band. It would be about how to design the pipeline, but also about what can be the outcomes from such an ISAR radar. Ideally, how could it help to extract an important information about drones and birds.

Contact: Please contact prof. Olexander Yarovoy (A.Yarovoy@tudelft.nl) if you are interested in these projects or looking for more information.

Microwave Sensing, Signals and Systems (MS3) Group

INVITES YOU TO JOIN
THE MS3 MASTER EVENT

Come to learn about our group and current Master Thesis Projects



Wait for announcements!

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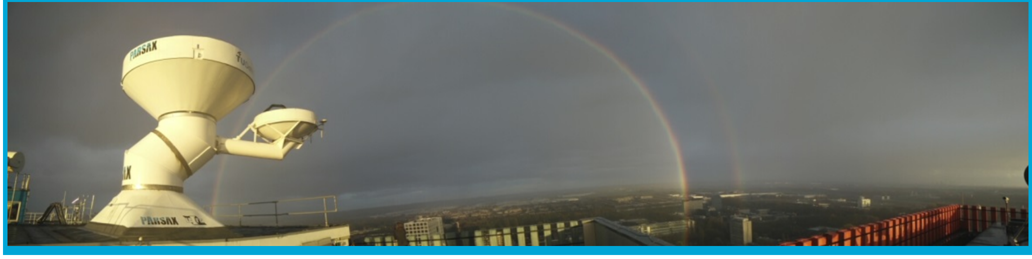
- Start &
  (Snijdersza
- Introduction of t
- Short presentation o
  (NXP, TNO, THALES , etc.)
- Free interactions for Master Project opportunities

18:00 Social Time & Pizza



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