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 - 2023-2024

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 – Olexander Yarovyi

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.

Master theses projects – Bert Jan Kooij

http://radar.tudelft.nl/People/bio.php?id=23

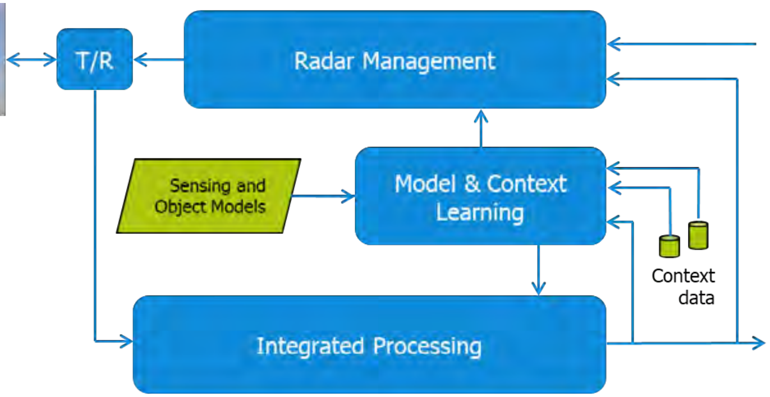
- Imaging techniques that are an extension of the classical radar technique and are able to reconstruct not only the location of the reflection, but go beyond that location of the reflection. Some of these techniques are able to reconstruct the permittivity and conductivity of a scattering object. The 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

Master projects – Hans Driessen

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



Context of the topics

- 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

Just a few example topics

- 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

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

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

- What applications could you 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) ...

- 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; programming MATLAB-Python.

A few project descriptions follow, also in later slides by PhD students. The projects can be shorter Extra Projects and/or expanded into a full MSc Thesis. If interested, please get in touch for a first discussion!

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Master theses projects – Francesco

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

1) Radar signal processing & ML pipeline for observing multiple people

WHAT. One of the most interesting challenges when observing people with radar systems is monitoring the dynamics of groups, i.e., when two or more individuals are close to each other and do things together. The examples are countless: friends or couples walking together, parents and child(ren), people queuing in public spaces and so on. Even if modern mm-wave radars have good resolutions in range thanks to their wide bandwidth, the angular resolution remains largely insufficient to distinguish multiple people and their body parts, and the resulting point clouds are ‘flickering’ even with small changes in aspect angles.

In this project you are asked to develop a signal processing pipeline to separate the signature of multiple people moving as a group. Specifically, you can combine both elements of *‘conventional’ signal processing* (e.g., super-resolution techniques or multiple target trackers) and *machine learning blocks* or networks that can replace or complement their functionalities.

A good example is the reference paper [1], which was published by a former MSc student in our group based on his thesis’ work.

Note that this is a rather *open* project, so there are many possible approaches that can be explored.

WHO. For this project you have a good background in radar signal processing and machine learning, and a willingness in engaging with experimental work and data collection. Moreover, you are comfortable coding in Matlab for the signal processing part and in Python/Matlab for the neural network part.

[1] L. Ren, A. G. Yarovoy and F. Fioranelli, "Grouped People Counting Using mm-Wave FMCW MIMO Radar," in IEEE Internet of Things Journal, vol. 10, no. 22, pp. 20107-20119, 15 Nov.15, 2023, doi: 10.1109/JIOT.2023.3282797.

[2] Y. Xu, W. Li, Y. Yang, H. Ji and Y. Lang, "Superimposed Mask-Guided Contrastive Regularization for Multiple Targets Echo Separation on Range–Doppler Maps," in IEEE Transactions on Instrumentation and Measurement, vol. 72, pp. 1-12, 2023, Art no. 5028712, doi: 10.1109/TIM.2023.3320761.

[3] Y. Xu, W. Li, Y. Yang, H. Ji, B. Li and Y. Lang, "Multiple Targets Echo Separation on Radar Range–Doppler Maps via Dual Decoupling Perception," in IEEE Sensors Journal, vol. 22, no. 21, pp. 20797-20804, 1 Nov.1, 2022, doi: 10.1109/JSEN.2022.3206592.

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2) Vehicle Ego-Motion Estimation using Radar Sensor Network

WHAT. Accurate estimation of vehicle ego-motion is crucial for the effectiveness of advanced driver assistance systems (ADAS) and has a significant impact on various downstream applications. While conventional odometry sensors can be employed for estimating vehicle motion, their reliability is not always guaranteed. As a result, it becomes imperative to explore additional sensor modalities.

In this project, the focus will be on leveraging a radar sensor network for the estimation of vehicle ego-motion.

Several studies in the literature have explored radar-based ego-motion estimation. However, some approaches are poorly adapted from Lidar sensor-based methods, some have poor robustness against complex real-world radar data, and some can only provide partial ego-motion information.

To address these shortcomings, this project aims to delve into the utilization of multiple automotive radars, i.e., a radar sensor network, for ego-motion estimation. For this, you will develop pipelines that combines signal processing and deep learning tools on automotive radar data.

An illustrative example is provided in reference [1]. Additionally, propelled by advancements in deep learning (DL) techniques, this exploration is not confined to model-driven approaches, but extends to data-driven methods, as exemplified by [2], a piece of work developed by our group.

WHO. For this project, you will need to have some background in FMCW/mm-wave radar, i.e. how it works, what type of data it produces, and some background knowledge in radar signal processing to manipulate the data. Finally, you will need strong programming skills such as MATLAB or Python to develop your own methods.

If interested or have any question, you can contact Dr Francesco Fioranelli (f.fioranelli@tudelft.nl) or PhD candidate Simin Zhu (s.zhu-2@tudelft.nl).

[1]-Kellner, Dominik, et al. "Instantaneous ego-motion estimation using multiple Doppler radars." 2014 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2014.
[2]-Zhu, Simin, Alexander Yarovoy, and Francesco Fioranelli. "DeepEgo: Deep Instantaneous Ego-motion Estimation using Automotive Radar." IEEE Transactions on Radar Systems (2023).

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3) Cognitive Radar: Semidefinite Programming Waveform Generation using Neural Networks.

WHAT. Semidefinite programming (SDP) is a subset of convex optimization problems that can be applied to many radar problems. However, they are slow to solve, but in many cases fast solvers are needed for pseudo-real-time applications. Some studies use neural networks as surrogate models to solve an arbitrary SDP problem, but the connection with radar application has not been investigated in the literature.

In this MSc thesis, the use of neural networks to solve SDPs for radar waveform design is studied. Specifically, we want to design radar waveforms that can operate well in a congested electromagnetic environment where other emitters are operating (e.g., radio communications or mobile phones), without mutual destructive interference. This project is in collaboration with the group of Prof A. De Maio at the University Federico II of Naples, one of the world-leading groups in radar signal processing.

As a starting point, you should understand and implement the generic framework explained in [1] and then adapt it to solve the SDP described in [2]. The goal is to use the neural network to generate the baseband IQ samples of the desired waveform, placing notches at those frequency bands where interference is detected. First, the problem will be solved with simulated data, generating in MATLAB the interference signal and evaluating the performance in terms of radar detection capabilities. Then, once a neural network is trained, the system will be tested with data using the PARSAX radar on the roof of our faculty building.

WHO. For this project you have some background in radar signal processing and machine learning, and preferably in optimization approaches. Moreover, you are comfortable coding in Matlab for the signal processing part and in Python/Matlab for the neural network part. Since this is a really hot topic in the research community, this work can potentially lead to a publication in a conference or journal.

[1] Kriváchy, T., Cai, Y., Bowles, J., Cavalcanti, D., & Brunner, N. (2020). Fast semidefinite programming with feedforward neural networks. 1–10.
[2] Aubry, A., Carotenuto, V., & Maio, A. De. (2016). Forcing multiple spectral compatibility constraints in radar waveforms. IEEE Signal Processing Letters, 23(4), 483–487.

Master theses projects – Francesco

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

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4) 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.

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.

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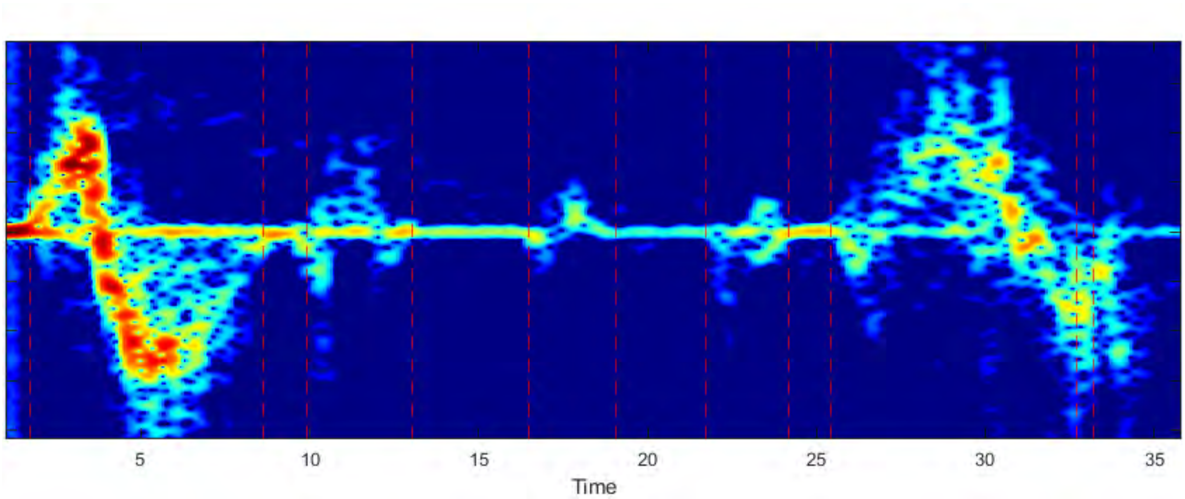
Automating Human Activity Labelling

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.

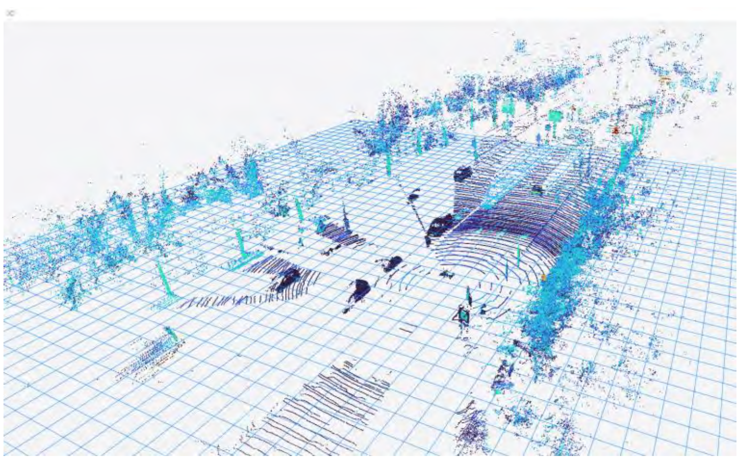
Contact: N.C.Kruse@tudelft.nl (*Nicolas Kruse, PhD candidate*)

EXTRA PROJECT + THESIS PROJECT – *Automotive radar dataset*

A novel automotive dataset has been collected using a high-resolution automotive radar and other sensors such as Lidar, cameras, and GPS. Different projects can be done using this dataset, depending on your background and interests.

- *Signal Processing projects:*
  The data has been collected using a 2D sparse array, which uses a Minimum Redundancy Array (MRA) in the z-direction. Different Direction of Arrival (DoA) algorithms can be developed either using Compressive Sensing (CS) or classical estimation techniques, and their performance can be compared using other sensors as ground truth.

- *Machine Learning projects:*
  With the large amount of data collected, training Machine Learning (ML) to perform some tasks is possible. For example, labels provided from camera data can be used as ground truth for classifying objects (pedestrians, vehicles) in radar data.



In general, you preferably have some background in radar signal processing and/or machine learning. Either MATLAB or Python skills are needed. Since this is a really hot topic, it can potentially lead to a publication in a conference or journal.

<u>Contact</u>: Ignacio Roldan, PhD Student (i.roldanmontero@tudelft.nl).

Master Thesis 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 radar); ...
- 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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Master Thesis Projects – Oleg Krasnov

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

Accuracy of the Radar Doppler Polarimetry

The progress in modern radar technology provides the ability to use sensing waveforms with dual orthogonality to measure all elements of the target's polarization scattering matrix completely instantly or quasi-simultaneously (with time interval between matrix' column measurement better than signal repetition interval). Such waveforms improve the Doppler velocity ambiguity and demonstrate the high efficiency for targets detection and classification using the radar polarimetry in Doppler domain. Still open research questions that are addressed within this project include the general study of the influence of target motion during the coherent integration time (effects of target range migration, cross-channel phase shifts, etc.) on the accuracy of polarimetric features estimation and development approaches for these errors compensation and results validation/calibration.

For this project you have some background in radar polarimetry, FMCW Doppler radar theory and signal processing, and, preferably, in optimal estimation theory. Moreover, you have to be comfortable with the coding in Matlab for the signal processing and simulation. Since this is a really hot topic in the research community, this work can potentially lead to a publication in a conference or journal.

Master Thesis Projects – Oleg Krasnov

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TNO innovation for life

In collaboration with
Miguel Caro Cuenca (miguel.carocuenca@tno.nl)

PARSAX Radar for Space Monitoring

PARSAX is a modern and highly reconfigurable radar created by TU Delft and 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: in 2021, 1778 satellites were orbited, compared to 955 in the previous year. Therefore, the space domain is becoming more crowded by the day and needs to be efficiently monitored.

This project includes the assessment of the PARSAX performance (power budget) for satellite detection and tracking, the design of FMCW waveforms (e.g., bandwidth and repetition frequency) and their processing algorithms that can be applied to PARSAX for satellite detection, development of tracking algorithms for satellites/sun/moon observation that are based on known orbit characteristics and radar's antenna steering limitations. The proposed waveform and designs of the measurements will be validated experimentally.

For this project, you need some background in the FMCW Doppler radar theory and signal processing, and an interest in space object dynamics. Moreover, you have to be comfortable with the coding in Matlab for signal processing and simulation. Since this is an interesting topic for the research community, this work can potentially lead to a publication in a conference or journal.

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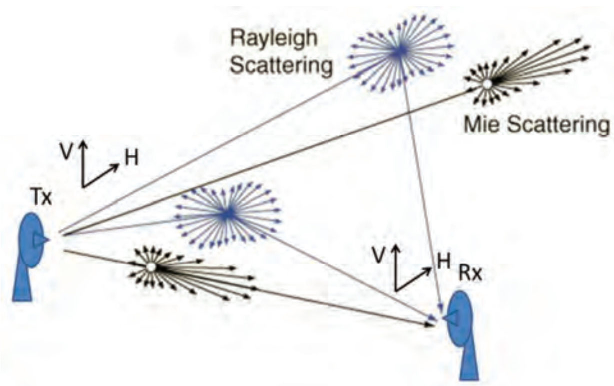
Potential benefits of polarimetric Doppler weather radars with the bi-static configuration

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.

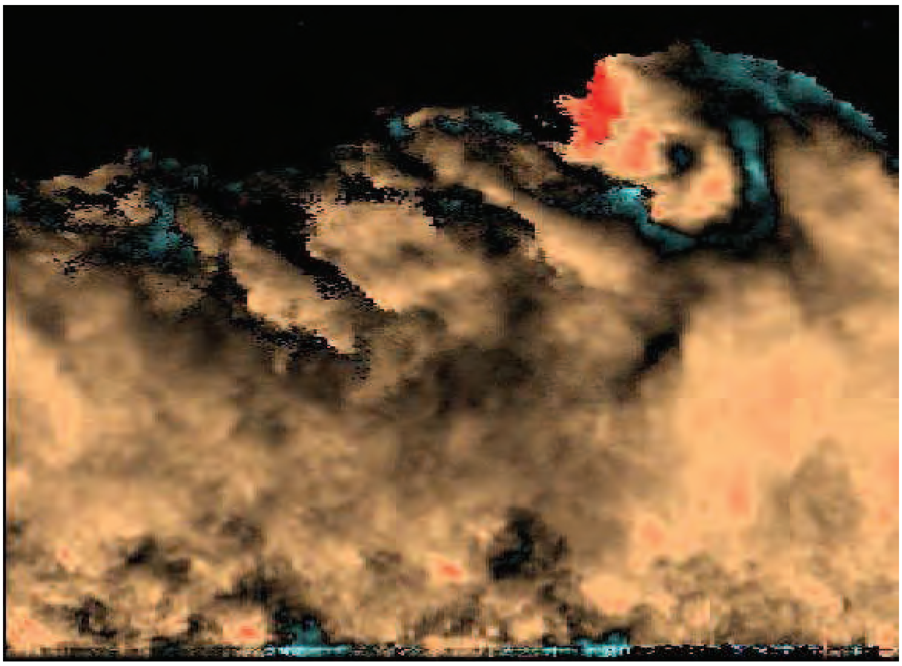


From technological and signal processing point of view it is clear that such radar network can produce much more data if radars will be used in bi-static or even multi-static configurations like distributed MIMO sensing system. At the same time it is still not well studied what additional information 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

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/).

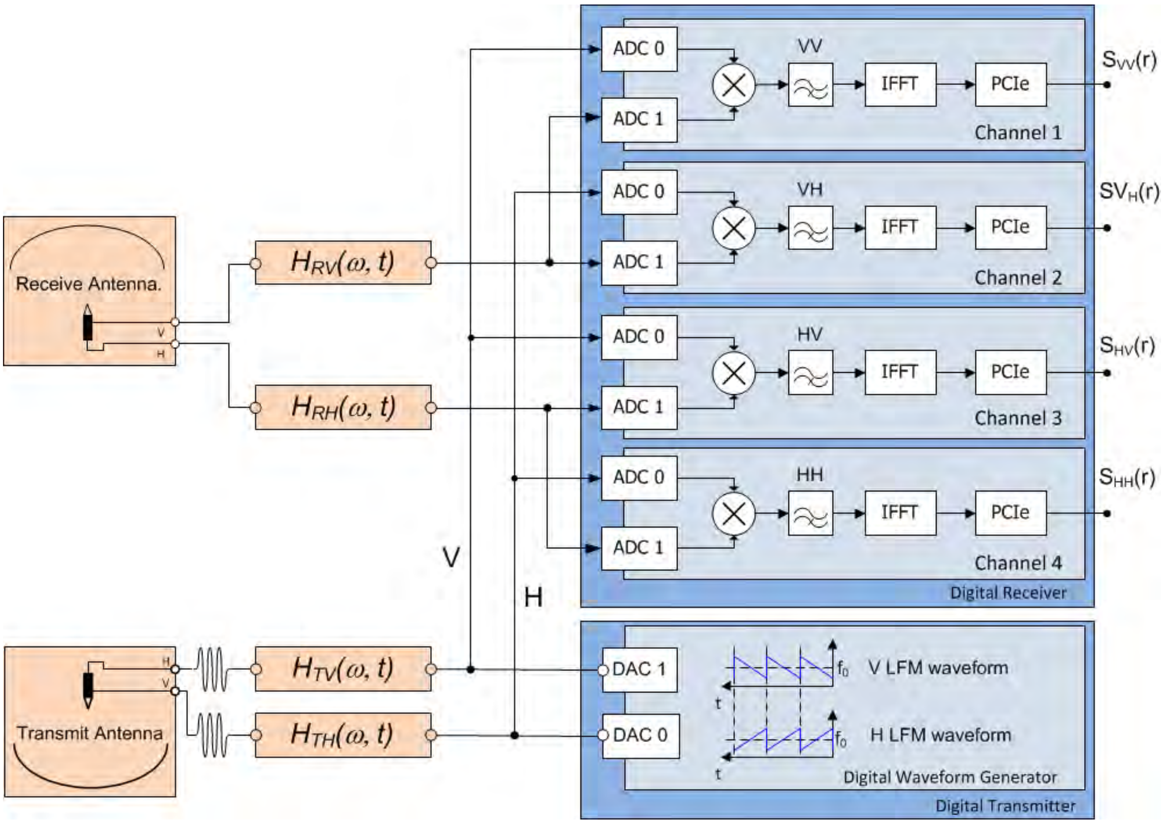
Otto Koedijk, TU Delft/Rijkswaterstaat, 19-08-2022.

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.

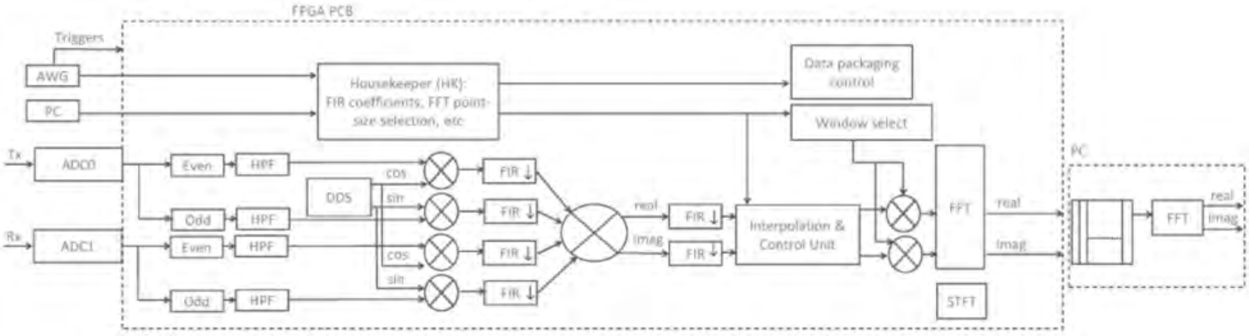
Contact: Dr. Oleg Krasnov, Assistant Prof (o.a.krasnov@tudelft.nl).

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 thesis projects – Yanki Aslan

- **System-based** design approach for array synthesis and beamforming

✓ Electromagnetics	✓ Antenna design	✓ Signal processing
✓ Circuit design	✓ Cooling	✓ Medium access control

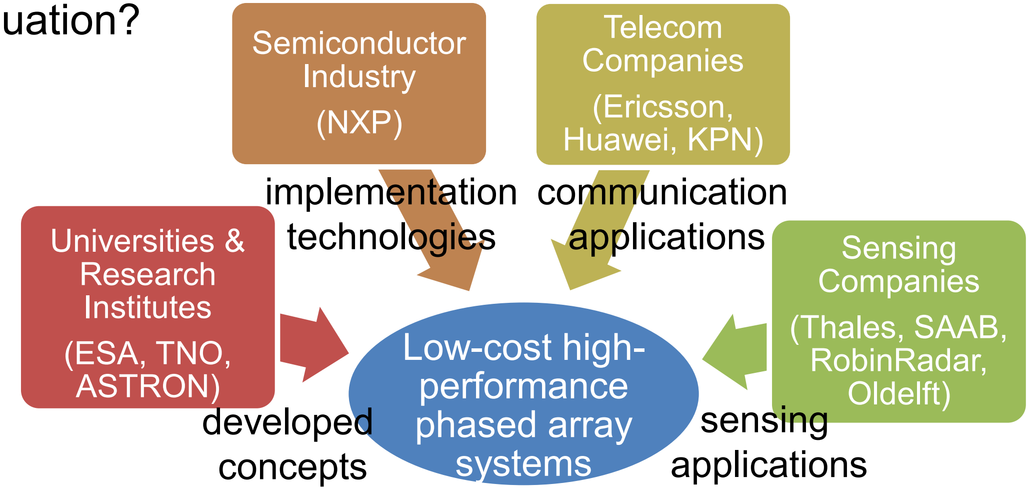
- What you can work on:

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

How? theory, simulation, experiments

Why? to address the **cost and complexity** issues in cellular & satellite communications, radioastronomy, civilian radars and healthcare.

- After graduation?



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Thesis topics – Yanki Aslan

- Please send me an email at Y.Aslan@tudelft.nl if you are interested!
- It is possible to start with an internship! (ET4399 – Extra Project)

Array signal processing and optimization oriented projects:

- 6G beam focusing in radiative near field with very large arrays
- Antenna array optimization strategies for JCAS - joint communication and sensing
- Machine learning assisted calibration of active phased arrays (with NXP)
- Array topology optimization for automotive MIMO radars (with NXP)
- Quantum computing for ultra-low-latency array optimization
- Optimal ultrasound phased arrays for focused brain stimulation

Antenna and beamformer design oriented projects:

- Reconfigurable beam forming network design for satellite antennas (with ESA)
- Dual-polarized series-fed shaped beam antenna arrays
- Sensing through biodegradable implants for biomedical applications (with ECTM)
- Antenna as a heatsink: design and multiphysics simulations

Communication system oriented projects:

- Amplifier-antenna impedance matching effects in 6G antenna arrays (with NXP)
- Optimal use of mixed low & high quality hardware in mm-wave RF front-ends
- Electromagnetic field exposure due to multibeam base station antenna arrays

TU Delft

Master Extra Project Proposal (15ECTS)

Author: Tworit Kumar Dash

Objective :

1. Develop MATLAB functions for Doppler velocity estimation in time domain.
    a. Pulse-Pair method
    b. Poly-Pulse-pair method
    c. First order auto-regressive model
2. Do a performance analysis of all the above mentioned methods with SNR and spectral width and compare the performance with a classical DFT approach.
3. Study convergence criteria for all the above mentioned techniques.
4. Use the same approaches for a azimuth scanning radar.
5. (Optional) If time permits, validate the results with real data from Max3D/MESEWI.

Literature for reference:

1. Mahapatra, P. R., & Zrnić, D. S. (1983). Practical Algorithms for Mean Velocity Estimation in Pulse Doppler Weather Radars Using a Small Number of Samples. *IEEE Transactions on Geoscience and Remote Sensing*, *GE-21*(4), 491–501. https://doi.org/10.1109/TGRS.1983.350512
2. Pinsky, M., Figueras i Ventura, J., Otto, T., Sterkin, A., Khain, A., & Russchenberg, H. W. J. (2011). Application of a Simple Adaptive Estimator for an Atmospheric Doppler Radar. *IEEE Transactions on Geoscience and Remote Sensing*, *49*(1). https://doi.org/10.1109/TGRS.2010.2052055

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.

MASTER THESIS

DESIGN AND ANALYSIS OF SUPERCONDUCTING QUANTUM BITS AND SENSORS

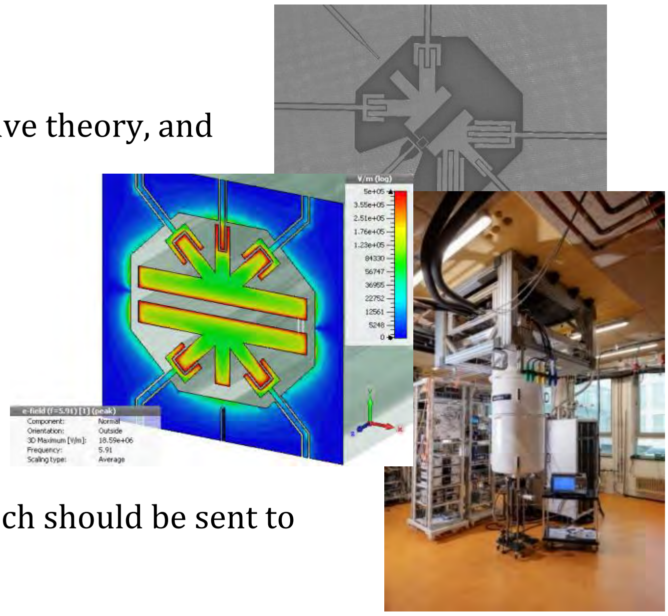
Quantum Technology is a key emerging technology. TU Delft is at the forefront of research and development in quantum technology. QuTech, a collaboration of TU Delft and TNO, is an organization with a depth and breadth of multidisciplinary knowledge where the focus is on smart solutions to complex issues in quantum information platforms. Twenty years ago, the quantum world was limited to the realm of atoms. Since then, quantum behavior has been achieved with solid-state systems at the micro- and millimeter scale. Several solid-state systems show promise of quantum processors with hundreds or more qubits, and quantum sensors with unprecedented sensitivity have already been commercialized.

OBJECTIVE

The purpose of this project is to enhance the performance of superconducting quantum bits or superconducting quantum sensors, which are crucial for superconducting quantum processors and quantum sensing, respectively. Within this project, the primary focus will be on the design, and microwave and electromagnetic analysis of SQUID (Superconducting Quantum Interference Device)-based components. Throughout this project, you will work to develop a deep understanding of the dielectric loss mechanisms that limit the lifetime and explore computational approaches for accurately adjusting various parameters. Ultimately depending on your personal interest you will either design qubit geometries with a high-quality factor or SQUID-based sensor components for ultra-sensitive electromagnetic detection.

PRIOR KNOWLEDGE / INTEREST

- Knowledge of electromagnetics, microwave theory, and experience with commercial EM solvers (e.g., CST, HFSS) is advantageous but not a requirement



START: with immediate effect

We are looking forward to your application which should be sent to Nadia Haider s.n.haider@tudelft.nl

TU Delft QuTech Creating the quantum future

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

MSc Assignments at the Department of Radar Technology

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 and we will explore the possibilities!

Contact

Jacco de Wit (jacco.dewit@tno.nl)

[1] 〉Careers 〉Vacancies 〉keyword "radar technology"

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

Space-based Transmitters of Opportunity for Passive Radar

Motivation

Passive radars are defined as a technology that uses signals transmitted by other (communication) systems (i.e., transmitters of opportunity), to perform target detection and parameter estimation (e.g., position, velocity, size, etc.) of the target. So far, the main research effort has been focused on the development of passive radar systems based on the use of ground-based illuminators of opportunity (IoO), exploiting typically FM radio, digital radio (DAB), digital television (DVB-T), Wi-Fi, and mobile communication networks such as GSM.

Recently, several companies have deployed broadband low-orbit communication satellite constellations (e.g., Starlink, OneWeb, Kuiper Systems) to provide global internet access services. These emerging constellations are considered promising candidates as space-based transmitters of opportunity for passive radar applications due to their advantageous characteristics in terms of global coverage, high bandwidth, high transmitted power, and network density and robustness. However, one of the main challenges posed for the opportunistic use of their transmissions is the lack of publicly available information about their signal properties.

Goal

To analyse and experimentally validate the possibility of using space-based transmitters of opportunity for passive radar applications.

Approach

- Characterize the signals (based on open literature) of several space-based transmitters of opportunity and analyse these in terms of performances for passive radar applications (e.g., detection range, coverage, resolution, etc.).
- Evaluate the signal characterisation of selected transmitters of opportunity by performing real-world measurements of the direct signals (in collaboration with the Radar Technology department of TNO) in terms of performances for passive radar applications (e.g., ambiguity function).
- Design a passive radar system architecture based on space-based transmitters of opportunity.

During the thesis, you can fall back on the expertise in the TNO Radar Department.

Contact

Detmer Bosma (detmer.bosma@tno.nl)

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

Exploiting PARSAX Transmissions for a Bistatic Radar Concept

Motivation

Passive bistatic radars are defined as a technology that uses signals transmitted by other systems (i.e., transmitters of opportunity), to perform target detection and parameter estimation (e.g., position, velocity, size, etc.) of the target. Often the development of passive radar systems is based on the use of ground-based illuminators of opportunity (IoO), exploiting communication signals, such as FM radio, digital radio (DAB), or digital television (DVB-T). The main challenge of such systems is that these signals are not designed for radar applications. Therefore, exploiting the transmission of other radar systems in a bistatic configuration can be beneficial in terms of the bistatic radar performance.

Goal

To implement a signal processing pipeline for bistatic target detection and tracking by a ground-based receiver, exploiting the transmissions of the PARSAX radar, and evaluate the detection and tracking performance by performing measurements.

Approach

- Implement a simulation framework for bistatic target detection and tracking and analyse scenarios for performing bistatic radar measurements with PARSAX as transmitter of opportunity.
- Perform bistatic radar measurements with PARSAX and a receiver (in collaboration with the Radar Technology department of TNO) and evaluate the detection and tracking performance of certain targets (e.g., cars on a highway, aircraft from The Hague-Rotterdam Airport, ships, etc.).
- Compare bistatic detection and tracking performance with monostatic detection performance (i.e., using only PARSAX for transmission and receiving)
- Performing fusion with bistatic and monostatic measurements in order to improve the detection and tracking performance

During the thesis, you can fall back on the expertise in the TNO Radar Department.

Contact

Detmer Bosma (detmer.bosma@tno.nl)

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

Advanced Signal Processing for Radar

Motivation

Can we separate detection of cars and airplanes of Rotterdam airport from clutter as oscillating trees due to wind using advanced processing?

These advanced signal processing techniques for radar systems became an option since extremely high computational power processing platforms recently entered the market.

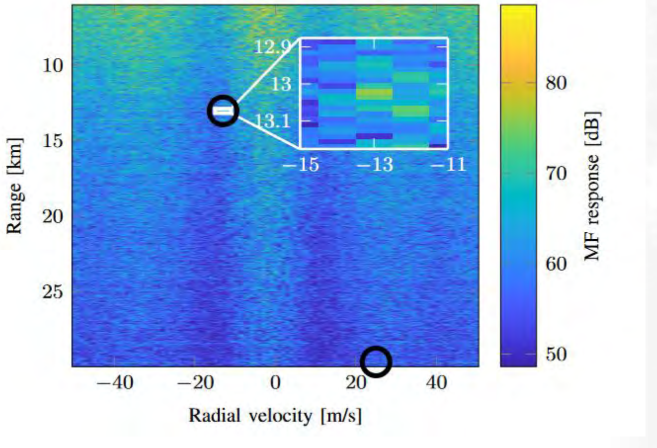


Figure 1. Detecting slow targets in a clutter scene. Could you separate it?

Goal

The goal of this project is to evaluate novel processing algorithms with data measured using the PARSAX radar system. This assignment is in the department of Radar Technology of TNO in the Hague, in collaboration with TU Delft.

Approach

You should combine advanced clutter mitigation techniques with sparse optimization for target detection. In particular, clutter mitigation techniques such as convolutional dictionary learning, kernel design with hyperparameter tuning, etc. could be combined with Bayesian or greedy sparse recovery algorithms. Then, the processing pipeline should be evaluated by doing measurements on the PARSAX radar system.

You will have the freedom to shape your thesis project and to select and develop the processing pipeline of interest. During the thesis, you can fall back on the expertise and cutting-edge techniques recently developed in TNO Radar Department.

Contact

Pepijn Cox (pepijn.cox@tno.nl)

MSc Assignments at TNO

DEPARTMENT OF RADAR TECHNOLOGY

Machine Learning Applied to Radar

Motivation

Machine learning has achieved unparalleled success in many applications. Also various radar applications are expected to benefit from machine learning and deep learning approaches. An example well-documented in scientific literature is radar micro-Doppler classification .

Goal

The goal is to develop and evaluate models for radar applications which are expected to benefit from machine learning approaches. Examples of such radar applications are target detection, tracking and classification, waveform design, antenna and integrated circuits design, radar resource management etc.

Approach

The actual radar application area you would like to work on is open for discussion. Depending on the radar application, measured data or simulations may be available to work with. If appropriate, measurements can be performed with our experimental radar systems to test the concepts you have developed.

In the study, special attention should be given to the peculiarities of the radar domain. For instance, labelled training data are generally scarce in the radar domain. Thus models should be developed which can be trained with less data or with synthetic data. At the same time, the performance of the models must be robust with respect to variations in the environment and 'unseen' events not present in the training set. Robustness, and in relation to that explainability, are very important features for trustworthy machine learning methods.

Contact

Jacco de Wit (jacco.dewit@tno.nl)

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.

Distributed signal processing optimisation

Project overview:

Modern RF systems use multi antenna constellations, e.g., phased arrays. These antenna set-ups are often spatially fixed and optimized for the frequency of interest. However, dynamic and adaptive phased arrays are upcoming. These come in two forms:

1) Based on an Active Electronic Steered Arrays (AESA's), elements can be switched on/off to manipulate the layout of the resulting array. This also allows for reconfiguring the elements in case one fails, known as a soft-failure. In addition, having such a direct and digital control over the array allows the constellation to encounter single antenna failure. Soft-failures may easily be detected and corrected for. In addition, frequency and processing compensation may become interesting features to correct.

2) Based on separate antenna elements fixed to a moving platform, for instance a UAV. Using UAVs requires precise synchronization in time and space but allows for a dynamic layout of the array. The flexibility in gain, beam resolution, and the ability of beam steering by such constellations are significantly improved.

The aim of this MSc project is to gain insights in encountering soft-failures within a phased array constellation by the use of an AI. The project will start by analysing conventional phased array tooling and applying AI to control beam steering and optimizing the array response for various impinging signals. Supplementary, the project will focus on self-healing algorithms towards soft-fails in an AESA. Initially the project will start with the conventional/fixed AESA constellation, and may later move toward a dynamic swarm AESA.

Project goals:

- The research objectives are to outline the various options to encounter soft-fails and to translate these towards a self-healing phased array and/or UAV swarm.
- What number of defect elements affect the array response, what is the turnover point of applying such self-healing algorithms?
- Implementing conventional phased array processing for full AESA understanding and improvements (i.e., complex and real antenna weighting, spatial optimisation of antenna locations).
- Application of Ai within phased array tooling to counter potential hard and soft hardware failures.
- Synthetic analyses of self-healing algorithms on phased array processing for fixed and dynamic array constellations (e.g., requirements of frequency, position and time accuracy).
- Optional; field testing and implementation of algorithms on a research based phased array.

General information

The project will be supervised at the Royal NLR. The student will be hosted by the NLR, location Amsterdam: Anthony Fokkerweg 2, 1059 CM.

TU Delft contact: dr. Yanki Aslan (Y.Aslan@tudelft.nl)

Master Thesis Topics for TU Delft-2023

Detailed Description

NXP Semiconductors, Eindhoven

Contact person at TU Delft: Prof. A.Yarovoy
(a.yarovoy@tudelft.nl)

Please note that the below projects are examples of possible topics. There are many more topics within radar systems algorithm innovation where we can define student projects.

Thesis 1 : Dynamic range improvement for phase-modulated FMCW radar

Description:
In this assignment the student will work on design of polyphase codes with good correlation properties for PM-FMCW and design of zero-correlation zone codes for PM-FMCW, and/or design of receiver that aims at improving the dynamic range considering the hardware limitations

Phase-modulated FMCW (PM-FMCW) waveform has recently attracted some interest due to its ability to combine the benefits of FMCW sensing, such as high range resolution and low-complexity receiver, with the pseudo-random behavior of phase modulated continuous wave, that is beneficial for realization of massive MIMO systems and operation in interfered environment. The state-of the art shows that the main limitation of PM-FMCW is the dynamic range bounded by the code length and thus by the ADC sampling and the system operation cycle. This projects aims at improving the current limitations by designing special codes for PM-FMCW and/or introducing new receiver structures that can improve the current limits.

Organization of the thesis:
The thesis work involves the following steps

• Literature study of existing codes and their properties

• Carry out simulations with suitable codes with good correlation properties for PM-FMCW radar

• Investigate and design polyphase codes with good correlation properties and zero-correlation zone codes for PM-FMCW and/or design of receiver that aims at improving the dynamic range considering the hardware limitations

Requirements:
This project requires a self-motivated candidate with a strong background in optimization, statistical signal processing, understanding of FMCW radars and their properties, estimation theory, and some familiarity with radio frequency (RF) and phase modulated radar concepts. The ideal candidate feels challenged by both theoretical and practical problems. The activities on the project require knowledge of Matlab programming. Through the project, the candidate will have the opportunity to develop industry-relevant signal processing and engineering skills.

What do you get in return?
Through the project, you will be involved in solving practical, cutting-edge signal problems present in modern automotive radars. During this journey, you will not be alone, and you will be supervised by supervisors at the university and experienced engineers from NXP. Therefore you will have the opportunity to use and further develop your signal processing knowledge gained during MSC studies by solving a challenge of practical importance for the next generation of automotive radars. Depending on your results, you will also have the opportunity to write a scientific publication and file a patent.

Thesis 2 : Codesign of 2D antenna array and DOA estimation algorithm for FMCW MIMO automotive radar

Description:
In automotive radar applications, there is a need for high-resolution joint azimuth and elevation (i.e., two-dimensional (2D)) direction-of-arrival (DOA) estimation of the targets. However, typical automotive radar sensors have a limited number of transmit (Tx) and receive (Rx) antennas. Therefore, high-resolution 2D DOA estimation is challenging to achieve. These challenges promoted the use of MIMO radar techniques to increase the degrees of freedom in DOA estimation and, thereby, angular resolution. Still, designing the 2D MIMO antenna array with a limited number of physical Tx and Rx antennas that allows for high-resolution DOA estimation of both azimuth and elevation with reasonable computational load is challenging. For this reason, co-design of the 2D antenna array and the algorithm for DOA estimation is needed.
The previous discussion identified the key challenges when designing a 2D MIMO array and the algorithm for DOA estimation. However, to guarantee the overall performance of the radar in terms of DOA estimation, the array and algorithm should be designed while keeping in mind additional constraints, such as:

- The supported dynamic range of detectable targets with respect to their powers,
- Number of snapshots that are available for DOA processing,
- Physical dimensions of the sensor and area available for antenna placement.

Organization of the thesis:
This thesis is divided into three stages. The first stage is theoretical and involves signal modeling and identification of DOA performance indicator functions that will be used as a cost function for optimization and antenna placement. The second phase of the project involves the implementation of the optimization framework for array design and implementation of algorithms for 2D DOA estimation, as well as their performance benchmarking. In the last stage of the project, if time and hardware implementation of antenna arrays permit, additional real-life experiments will be conducted to evaluate the performance of the array and the algorithms.

Requirements:
This project requires a self-motivated candidate with a strong background in optimization, statistical signal processing, array signal processing, estimation theory, and some familiarity with radio frequency (RF) and radar concepts. The ideal candidate feels challenged by both theoretical and practical problems. The activities on the project require knowledge of Matlab or Python programming and GIT versioning. Through the project, the candidate will have the opportunity to develop industry-relevant signal processing and engineering skills.

What do you get in return?
Through the project, you will be involved in solving practical, cutting-edge signal problems present in modern automotive radars. During this journey, you will not be alone, and you will be supervised by supervisors at the university and experienced engineers from NXP. Therefore you will have the opportunity to use and further develop your signal processing knowledge gained during MSC studies by solving a challenge of practical importance for the next generation of automotive radars. Depending on your results, you will also have the opportunity to write a scientific publication and file a patent.

Thesis 3 : Doppler and DOA estimation for Beamspace DDMA FMCW MIMO radar

Description:
The Frequency-Modulated Continuous Wave (FMCW) waveform with Doppler division multiple access (DDMA) for transmit (Tx) antenna coding (i.e., orthogonalization) is a popular low-complexity approach for implementing MIMO automotive radar. The DDMA MIMO coding enables the separation of Tx antennas at the receiver (Rx) and the creation of a virtual antenna array with an increased number of antenna elements compared to the physical Rx array. However, the DDMA coding of Tx antennas introduces varying mutual phase shifts over the FMCW chirps and thus, at the same time, does beamforming of Tx antennas. The DDMA creates uniform beamforming over the $-90°$ to $90°$ field of view (FOV). However, in practical scenarios, to improve the range and spatially focus Tx power, the Tx array should beamform Tx power in a more narrow FOV (e.g., $-70°$ to $70°$, $-50°$ to $50°$, $-15°$ to $15°$). Therefore, the classical DDMA codes need to be redesigned as well as algorithms related to Doppler and DOA estimation to support simultaneous MIMO coding and flexible Tx beamforming. This comes with tradeoffs related to the orthogonality of Tx antennas and the beamforming of the Tx power, as fully beamformed Tx antennas will not be orthogonal. Therefore, in terms of radar performance parameters, when designing the hybrid MIMO beamformed DDMA FMCW radar, one should pay attention to the tradeoff between angular resolution and the maximum detectable range of the targets related to their radar cross section (RCS).

Organization of the thesis:
This problem will be tackled in three stages. In the first stage, the candidate will derive the signal model that captures both the spatial and Doppler domain of the DDMA MIMO radar. Based on the model, the candidate will (i) propose an approach for designing so-called Beamspace DDMA codes that allow for simultaneous MIMO and Tx beamforming modes of the radar, (ii) define performance metrics (e.g., signal-to-noise (SNR) and signal-to-interference (SINR) ratios) that characterize tradeoffs between MIMO and Tx beamforming modes, and finally (ii) design the algorithm for Doppler estimation that supports new hybrid DDMA beamforming MIMO radar. In the second stage of the project, the candidate will investigate the impact of the Tx beamforming on the direction of arrival (DOA) estimation at the receiver. Then based on the signal model candidate will design Beamspace DOA estimation methods to improve DOA estimation in Beamspace DDMA mode. Finally, in the last stage of the project, if time allows, additional real-life experiments will be conducted to evaluate the performance of the beamspace DDMA.

Requirements:
This project requires a self-motivated candidate with a strong background in optimization, statistical signal processing, array signal processing, estimation theory, and some familiarity with radio frequency (RF) and radar concepts. The ideal candidate feels challenged by both theoretical and practical problems. The activities on the project require knowledge of Matlab or Python programming and GIT versioning. Through the project, the candidate will have the opportunity to develop industry-relevant signal processing and engineering skills.

What do you get in return?

Through the project, you will be involved in solving practical, cutting-edge signal problems present in modern automotive radars. During this journey, you will not be alone, and you will be supervised by supervisors at the university and experienced engineers from NXP. Therefore you will have the opportunity to use and further develop your signal processing knowledge gained during MSC studies by solving a challenge of practical importance for the next generation of automotive radars. Depending on your results, you will also have the opportunity to write a scientific publication and file a patent.

Thesis 4 : Fusion of mono-static and bi-static radar response in sparsity based DoA algorithms using Multiple Measurement Vectors technique

Description:
In this assignment the student will work on Direction-of-Arrival estimation techniques that uses measurement data obtained from multiple radars distributed on the car's fascia. Such a system could result in an increased target separation in the direction of arrival dimension whilst keeping the physical dimensions of the individual radars small. For coherent operation synchronization in time, frequency and phase is needed. Quasi-coherent operation doesn't require phase coherency. The measurement data obtained from multiple radars can be grouped in mono-static and bi-static responses. Depending on the system coherency and target coherency this data can be processed in a coherent way, a non-coherent way or a mix of coherent and non-coherent processing. The best target separation is obtained with fully coherent processing. Sparsity based algorithms for DoA estimation, like Sparse Bayesian Learning (SBL) and FOcal Underdetermined System Solve (FOCUSS), are gaining interest. These algorithms assume that the multi-antenna response as measured by the radar is caused by a small number of targets. In an iterative way the measured response is matched with a sparse collection of sources. Multiple Measurement Vectors technique in relation to sparsity based DoA algorithms usually refer to time sequential measurements with an individual radar system. With the distributed radar architecture as mentioned before, the collection of mono-static and bi-static response can be regarded as multiple measurements with slightly different perception on the radar scene. The underlying sparsity of targets for the multiple measurements can have high correlation for a coherent target scene, but for a non-coherent radar scene a target might be not seen by all individual radar sensor

Organization of the thesis:
The thesis work involves the following steps

- After Range Doppler processing extract measurement data for DoA estimation from mono-static and bi-static response. This involves associating data from different range Doppler cells because a target can be experienced at a different distance and with a different velocity by the individual radar sensors.
- Carry out simulations with sparsity based DoA algorithms using multiple measurement vectors
- Quantify the difference in DoA performance between full-coherent and quasi-coherent operation
- Investigate how DoA performance scales with the number of measurements
- DoA performance can be determined in terms of target separation and/or target detection probability. As function of sparsity correlation between measurement vectors, these DoA performance indicators should be investigated

Requirements:
This project requires a self-motivated candidate with a strong background in optimization, statistical signal processing, array signal processing, estimation theory, and some familiarity with radio frequency (RF) and radar concepts. The ideal candidate feels challenged by both theoretical and practical problems. The activities on the project require knowledge of Matlab programming. Through the project, the candidate will have the opportunity to develop industry-relevant signal processing and engineering skills.

What do you get in return?
Through the project, you will be involved in solving practical, cutting-edge signal problems present in modern automotive radars. During this journey, you will not be alone, and you will be supervised by supervisors at the university and experienced engineers from NXP. Therefore you will have the opportunity to use and further develop your signal processing knowledge gained during MSC studies by solving a challenge of practical importance for the next generation of automotive radars. Depending on your results, you will also have the opportunity to write a scientific publication and file a patent.

Thesis 5 : Subspace techniques for DoA estimation with distributed radar

Description:
In this assignment the student will work on Direction-of-Arrival estimation techniques that uses measurement data obtained from multiple radars distributed on the car's fascia. Such a system could result in an increased target separation in the direction of arrival dimension whilst keeping the physical dimensions of the individual radars small. For coherent operation synchronization in time, frequency and phase is needed. Quasi-coherent operation doesn't require phase coherency. The measurement data obtained from multiple radars can be grouped in mono-static and bi-static responses. Depending on the system coherency and target coherency this data can be processed in a coherent way, a non-coherent way or a mix of coherent and non-coherent processing. The best target separation is obtained with fully coherent processing.
Subspace techniques are well-known methods to estimate DoA angles in mono-static radar. These techniques try to decompose the received signal in a signal subspace and a noise subspace. For every target in the measurement data, a dimension in the signal subspace will be present with its corresponding DoA angle. With bi-static radar, a target will be represented with a DoD angle and a DoA angle that via the detected Range and the distance between the 2 radar sensors are geometrically related. The DoD and DoA angles are also the DoA angles of the 2 mono-static radar responses.

Organization of the thesis:
The thesis work involves the following steps

• After Range Doppler processing extract measurement data for DoA estimation from mono-static and bi-static response. This involves associating data from different range Doppler cells because a target can be experienced at a different distance and with a different velocity by the individual radar sensors.

• Carry out simulations with subspace techniques for DoA algorithms using bi-static and mono-static response. Grid-less techniques have preference over grid-based techniques

• Quantify the difference in DoA performance between full-coherent and quasi-coherent operation, where DoA performance is expressed in target separation as function of SNR and dynamic range

Requirements:
This project requires a self-motivated candidate with a strong background in optimization, statistical signal processing, array signal processing, estimation theory, and some familiarity with radio frequency (RF) and radar concepts. The ideal candidate feels challenged by both theoretical and practical problems. The activities on the project require knowledge of Matlab programming. Through the project, the candidate will have the opportunity to develop industry-relevant signal processing and engineering skills.

What do you get in return?
Through the project, you will be involved in solving practical, cutting-edge signal problems present in modern automotive radars. During this journey, you will not be alone, and you will be supervised by supervisors at the university and experienced engineers from NXP. Therefore you will have the opportunity to use and further develop your signal processing knowledge gained during MSC studies by solving a challenge of practical importance for the next generation of automotive radars. Depending on your results, you will also have the opportunity to write a scientific publication and file a patent.

Thesis 6 : Joint Subspace based DoA estimation and calibration of antenna arrays

Description:
In this assignment the student will quantify the impact of antenna imperfections on the performance of subspace techniques for DoA estimation. Subspace techniques that assume shift invariance properties (e.g. ESPRIT) will suffer from antenna imperfections and therefore degrade the DoA estimation algorithm. The student is expected to make a model of antenna imperfections and generate realizations of that model that can be analyzed with a subspace based DoA estimation algorithm. Also investigating low-complexity calibration methods for the antenna imperfections is part of the assignment. The theoretical work is supposed to be verified with experiments in which the antenna imperfections of a radar sensor are measured and DoA estimation algorithms with and without compensation methods are evaluated.

Organization of the thesis:
The thesis work involves the following steps

- Literature study of subspace techniques for DoA estimation including modelling of Antenna imperfections

- Carry out simulations with selected subspace techniques for DoA estimation and realizations of an antenna imperfections model

- Investigate low-complexity compensation methods that reduce impact of antenna imperfections

- Determine antenna imperfections of a radar sensor in an anechoic room. Analyze performance of DoA estimation algorithms, with and without compensation.

Requirements:
This project requires a self-motivated candidate with a strong background in optimization, statistical signal processing, array signal processing, estimation theory, and some familiarity with radio frequency (RF) and radar concepts. The ideal candidate feels challenged by both theoretical and practical problems. The activities on the project require knowledge of Matlab programming. Through the project, the candidate will have the opportunity to develop industry-relevant signal processing and engineering skills.

What do you get in return?
Through the project, you will be involved in solving practical, cutting-edge signal problems present in modern automotive radars. During this journey, you will not be alone, and you will be supervised by supervisors at the university and experienced engineers from NXP. Therefore you will have the opportunity to use and further develop your signal processing knowledge gained during MSC studies by solving a challenge of practical importance for the next generation of automotive radars. Depending on your results, you will also have the opportunity to write a scientific publication and file a patent.

Thesis 7 : Array optimization based on side lobe level and DOA estimation performance study for a distributed radar setup

Description:
In this assignment the student will work on design of distributed array setup for the FMCW radar. In a distributed radar setup, multiple radar sensors are distributed on the car's fascia. Such a system could result in an increased target separation in the direction of arrival dimension whilst keeping the physical dimensions of the individual radars small. For coherent operation synchronization in time, frequency and phase is needed. Quasi-coherent operation doesn't require phase coherency. The measurement data obtained from multiple radars can be grouped in mono-static and bi-static responses. Depending on the system coherency and target coherency this data can be processed in a coherent way, a non-coherent way or a mix of coherent and non-coherent processing. The best target separation is obtained with fully coherent processing.

Based on the way the data is processed different antenna elements are combined together. The virtual array that is used for mono-static response can be different from the one that is used for multi static response. Optimizing the array design for achieving best DOA (Direction of Arrival) performance in both mono-static and multi-static performance by optimizing the side lobe level (SLL) of the array is the main research topic.

Organization of the thesis:
The thesis work involves the following steps

- Literature study of existing array optimization techniques
- Understand the distributed radar setup and perform simple simulations to study the DOA performance with different distributed setups
- Investigate and design an optimization technique to optimize the mono-static responses by optimizing the array topology on a single sensor
- Investigate and design an optimization technique to optimize the multi-static responses by optimizing the array topology on multiple sensors that are distributed on the car fascia

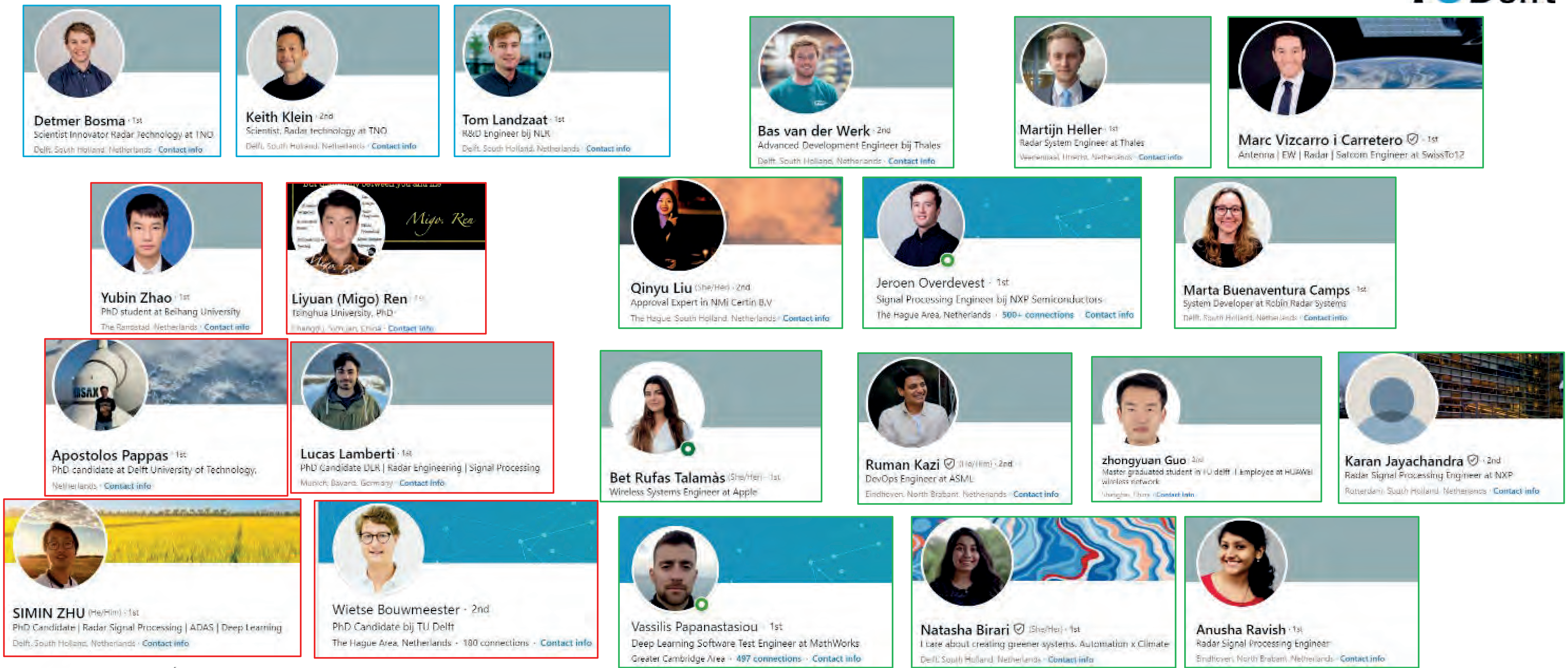
Requirements:
This project requires a self-motivated candidate with a strong background in optimization, statistical signal processing, array signal processing, optimization techniques like convex optimization, estimation theory, and some familiarity with radio frequency (RF) and radar concepts. The ideal candidate feels challenged by both theoretical and practical problems. The activities on the project require knowledge of Matlab programming. Through the project, the candidate will have the opportunity to develop industry-relevant signal processing and engineering skills.

What do you get in return?

Through the project, you will be involved in solving practical, cutting-edge signal problems present in modern automotive radars. During this journey, you will not be alone, and you will be supervised by supervisors at the university and experienced engineers from NXP. Therefore you will have the opportunity to use and further develop your signal processing knowledge gained during MSC studies by solving a challenge of practical importance for the next generation of automotive radars. Depending on your results, you will also have the opportunity to write a scientific publication and file a patent.

What about our graduate alumni?

MS³ Microwave Sensing Signals & Systems
TU Delft



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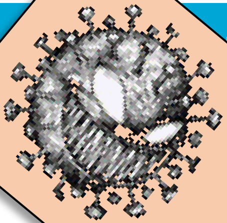
Microwave Sensing, Signals and Systems (MS3) Group

INVITES YOU TO JOIN

THE MS3 MASTER EVENT

Come to learn about our group and current Master Thesis Projects



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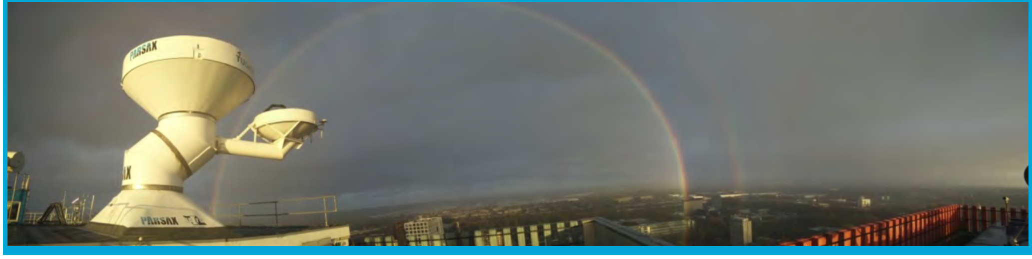
- Short presentation o (NXP, TNO, THALES , etc.)
- Free interactions for Master Project opportunities

18:00 Social Time & Pizza

Wait for announcements!



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