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TU Delft

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 - 2018

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!

THALES

www.thalesgroup.com

MSc thesis project at Thales Nederland B.V.

LOCATION *DELFT*

Thales Nederland is active in the Defense and Security sectors and is, with more than 2000 employees, a top provider of high-tech jobs. Product innovation and swift anticipation of the newest technological possibilities are the mainsprings of our business. Examples are radar, communication and command & control systems for naval ships and communication, security and payment systems for trade and industry.
Thales Nederland is part of the Thales Group, which has a workforce of over 68.000 in more than 50 countries making it one of Europe's largest electronics companies.
Thales Delft is a small R&D site of Thales Nederland close to TU Delft, and it offers a limited number of MSc thesis projects focusing on radar. The thesis assignments are formulated in detail together with the student and his/her university mentors.

THEME 1: Radar Classification using Machine/Deep Learning

Deep Learning (DL) is a type of machine learning that attempts to model high level abstractions in data. In recent years, remarkable achievements using DL architectures have been demonstrated in the fields of speech and image recognition, text analysis, autonomous driving, etc.
DL techniques applied to radar data unlocks new and exciting capabilities, for instance in the field of target classification.

THEME 2: Distributed Radar Networks

Distributed radar networks, and particularly multi-static radar, entails observing an object or volume from different aspect angles simultaneously by using multiple transmitters and/or receivers positioned at different locations. The additional information that is obtained by this setup could be used for e.g. classification purposes.

THEME 3: Information-based Processing in Radar: Compressive Sensing and Information Geometry

Compressive Sensing (CS) is a recent paradigm in sensing that works with a reduced number of measurements for a comparable sensing result. Promising benefits of CS in radar are improved resolution and multi-target analysis.
Information geometry (IG) is an approach to stochastic signal processing whose structures can be treated as structures in differential geometry. Most promising benefits of IG have been found in resolution analysis and parameter estimation.
Both fields stress the importance of information in measurements as the useful dimension of signals is much smaller than the data dimensionality. Accordingly, conventional processing can be improved if the demands of data acquisition and signal processing are optimized to the information content. Tools from CS and IG can also be used in development of deep learning in order to improve the stochastic analysis of the underlying processing layers.

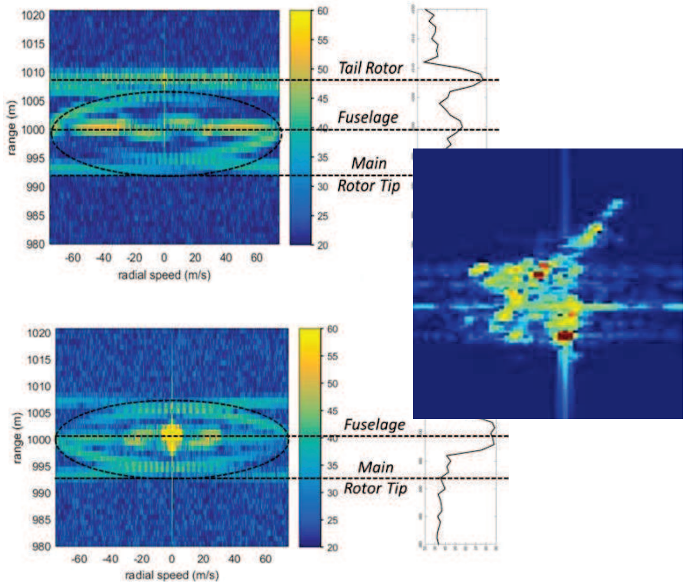
To apply for an internship, please contact:
denis.riedijk@nl.thalesgroup.com

Radar Features for Classification of Aircraft

Surveillance radar plays an important role in Air Traffic Control. The primary task for an Air Traffic Control surveillance radar is detection and tracking of aircraft. However, radar measurements can also be exploited to extract specific characteristics of an aircraft, for instance, the its length or wingspan. These characteristics can be used for classification, which provides additional information about the aircraft class or type. In some situations, the availability of extra information about the aircraft class may improve air traffic safety.

Different aircraft classes, such as light aircraft, business jets or airliners exhibit different characteristics (e.g., they differ in size, engine type and materials). If such distinguishing characteristics or *features* can be extracted from radar measurements, they can be used for classification. What features are of interest depends on the classes to be separated.

In general there is an interaction between the radar waveform and the features that can be extracted. A specific radar frequency or a specific polarisation, for instance, may enhance object features suitable for classification.

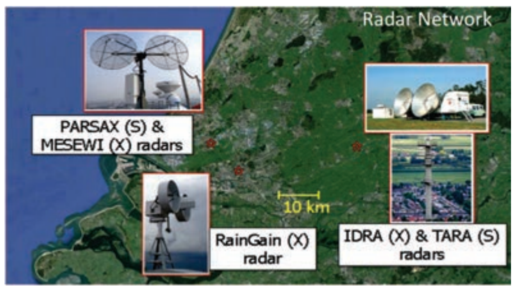


Aim of the Project

The aim of the project is the exploration of suitable features that can be exploited to classify aircraft based on radar measurements. The MS3 group has a distributed radar system that can be used for measurements of aircraft.

Research topics of interest are:

- multifrequency measurements and features
- polarimetric measurements and features
- range-Doppler measurements and features
- multistatic measurements



TNO innovation for life

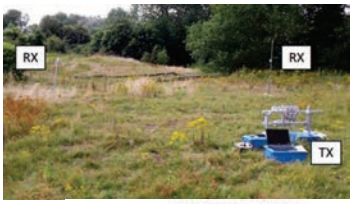
Contact: Jacco de Wit
TNO Department of Radar Technology

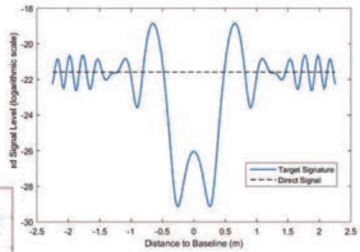
Radar Techniques for Persistent Urban Surveillance

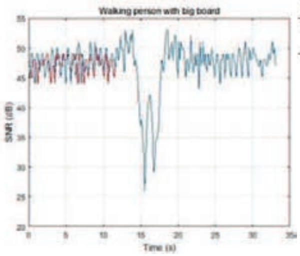
Radar is a strong asset for surveillance tasks; it is capable of quickly scanning large areas. However, in a crowded urban environment radar is hampered by buildings, fences, cars and other obstacles. Due to these obstacles a large part of the surveillance area may be shielded from the radar and many multipath reflections may occur. Multipath reflections are reflections from (moving) objects of interest, that do not arrive at the radar directly, but via additional reflection off obstacles in the surroundings. Without precautions, multipath reflections may be interpreted as additional objects.

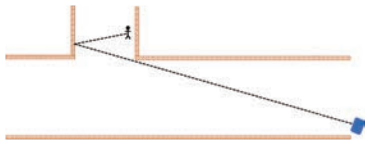
Multipath reflections do contain information that can be exploited to better locate moving objects or map the surroundings. Depending on the environment, multipath reflections may even enable detection of objects in areas where there is no direct radar line-of-sight!

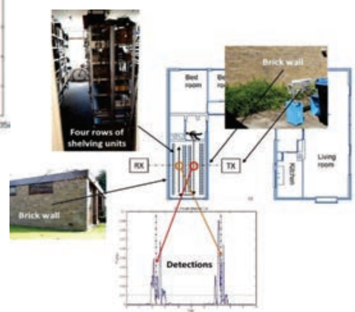
In a dynamic environment where goods are delivered and moved, vehicles drive and park, or fences are opened and closed, multipath conditions are variable. In this case, multipath reflections carry information about changes in the environment, which may be exploited to maintain a current map of the surroundings.

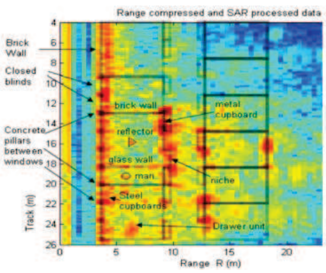










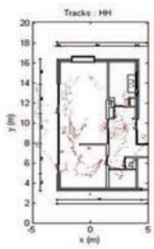


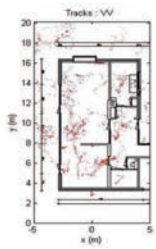
Aim of the Project

Exploitation of multipath reflections is an emerging topic in urban radar surveillance. The project aims at developing new techniques for radar surveillance in an urban environment, based on actual radar measurements.

Possible research topics include:

- multistatic tracking
- “around the corner” radar
- multipath exploitation
- forward scatter radar





innovation for life

Contact: Jacco de Wit
TNO Department of Radar Technology

MASTER MARKET EVENT MS3 GROUP

SECURE CONNECTIONS FOR A SMARTER WORLD

GENERAL INFORMATION

Company Profile:

NXP Semiconductors enables secure connections and infrastructure for a smarter world, advancing solutions that make lives easier, better and safer.

WORLDWIDE #1 position in Identification Industry and Automotive.

Team Profile:

The **Radar Software & Algorithm** team is one of the system R&D teams within **Business Line Infotainment and Driver Assistance (IDA)**, which is part of the **Business Unit Automotive**. The team is responsible for innovative algorithms and future radar system design.

We are looking for:

- Currently studying towards your Master in the Electrical engineering department
- Good knowledge of signal and antenna array processing
- Interest in radar sensors and automotive
- Willing to work on real sensor and perform experiments
- Good knowledge of Matlab
- At least 9 months availability
- Language: Good command of English.

We offer:

- Dynamic organization and informal working environment with a can-do attitude
- Challenging high tech company building the next generation of innovative technologies for the automotive market.
- Monthly allowance
- Relocation allowance (if eligible).

PROJECT LIST:

OBJECT HEIGHT ESTIMATION USING RADAR

Estimation of echoes height is an important feature for collision avoidance system, world mapping and classification applications. Estimation of the height of the object is important to correctly represents the surrounding environment. Different techniques need to be investigated and a proper DSP algorithm needs to be created.

PoC: francesco.laghezza@nxp.com

SUPER RESOLUTION VIA COMPRESSIVE SENSING

To increase the angle resolution keeping constant the number of element in the array, digital signal processing techniques can be successfully used with different tradeoffs. Compressive Sensing (CS) techniques can increase the resolution as the same number of antenna elements can be distributed over a larger aperture. Tradeoffs like sensitivity losses or complexity can also be individuated using this technique.

PoC: venkat.roy@nxp.com

MULTIDIMENSIONAL SPECTRAL PEAK ESTIMATION FOR AUTOMOTIVE RADAR (from august 2018)

Radar sensor play a key role in the realization of autonomous vehicles. At NXP, signal processing software for these radars has been developed assuming one dimensional linear antenna arrays. However, radars are nowadays required to estimate the direction of arrival in two dimensions (horizontal/vertical).It has been found that simple 2D interpolation techniques don't offer the required accuracy in the direction estimation process. build upon an existing solution and propose and investigate several multi-dimensional peak estimation algorithms that can improve the accuracy of the current algorithms.

PoC: feike.jansen@nxp.com

POLAR CODES FOR ULTRA RELIABLE AND ULTRA LOW LATENCY COMMUNICATIONS

Machine-to-machine communication is becoming an essential part of new wireless communication systems due to new emerging applications such as automated driving, Internet-of-Things (IoT). One of the most important breakthroughs in ECC in recent years, is the invention of polar codes included in 5G cellular standard , however, its performance is highly dependent on decoding method.

PoC: nur.engin@nxp.com

Project 1: Object height estimation using radar

Background/Context:

Estimation of echoes height is an important feature for collision avoidance system, world mapping and classification applications.

Estimation of the height of the object is important to correctly represents the surrounding environment.

The main goals of this project will be to:

- Gain a solid understanding of automotive radar systems and digital signal processing.
- Investigate the characteristics of the multipath based height estimation techniques for short and long arrange applications.
- Understand how/when the different techniques can be used and benchmark the performances.
- Desing the proper algorithm and test it with simulated data and real test.

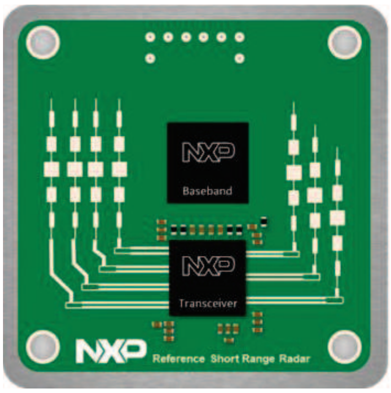
Requested Profile: Background on radar system and signal processing. Matlab simulation experience is required.

Supervisor: Francesco Laghezza (email – francesco.laghezza@nxp.com)

Project 2: Super resolution via compressive sensing

Background/Context:

To increase the angle resolution keeping constant the number of element in the array, digital signal processing techniques can be successfully used with different tradeoffs. Compressive Sensing (CS) techniques can increase the resolution as the same number of antenna elements can be distributed over a larger aperture. Tradeoffs like sensitivity losses or complexity can also be individuated using this technique.



The main goals of this project will be to:

- Gain a solid understanding of the array processing techniques and CS technique.
- Investigate the characteristics of a sparse array (main beam width, sidelobes, dynamic range, etc.) and compare them with classical super-resolution algorithm for the direction of arrival estimation.
- Understand under which condition compressive sensing can be preferable to classical techniques.
- Understand how the sparse array configuration can be shaped to meet specific application requirements.

Requested Profile: Background on radar system, antenna and signal processing. Matlab simulation experience is required.

Supervisor: Venkat Roy (email – venkat.roy@nxp.com)

Project 3: Multidimensional spectral peak estimation for automotive radar

Background/Context:

Radar sensor play a key role in the realization of autonomous vehicles. At NXP, signal processing software for these radars has been developed assuming one dimensional linear antenna arrays. With such a (phased) array a single direction of arrival can be estimated. However, radars are nowadays required to estimate the direction of arrival in two dimensions (horizontal/vertical). A sensor with a 2D antenna array has been made. It has been found that simple 2D interpolation techniques don't offer the required accuracy in the direction estimation process.

The main goals of this project will be to:

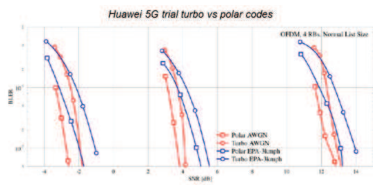
- build upon an existing solution and propose and investigate several multi-dimensional peak estimation algorithms that can improve the accuracy of the current algorithms

Requested Profile: Background on radar system, antenna and signal processing. Matlab simulation experience is required. **Starting date From August 2018**

Supervisor: Feike Jansen (email – feike.jansen@nxp.com)

Project 4: Polar Codes for ultra reliable and ultra low latency communications

Background/Context: Machine-to-machine communication is becoming an essential part of new wireless communication systems due to new emerging applications such as automated driving, Internet-of-Things (IoT), and Industry 4.0 requiring communications of cars/robotics/drones/machines etc. This new type of communication brings new challenges such as ultra high reliability and ultra low latency which can only be achieved with high performance error correction codes (ECC) working efficiently at small packet sizes. One of the most important breakthroughs in ECC in recent years, is the invention of polar codes included in 5G cellular standard , however, its performance is highly dependent on decoding method.

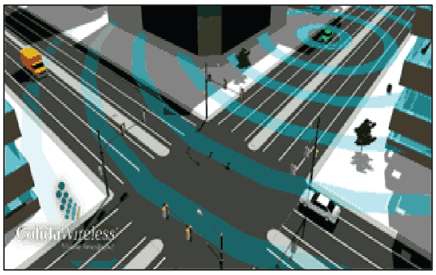


The main goals of this project will be to: This project aims to focus first on comparing the performance of polar codes with the state of the art error correction codes, e.g., Convolutional codes, Reed-Solomon codes, Turbo Codes, LDPC codes at different packet sizes and channel conditions with different decoding techniques. The work involves both theoretical and simulation work. Secondly, new decoding algorithms and architectures for polar codes need to be investigated considering complexity and cost of the receivers. **Requested Profile:** Background on wireless communications and signal processing, and interest in error correction coding and Matlab simulation experience.

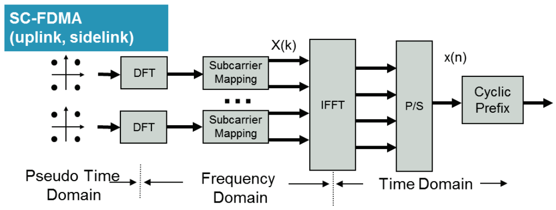
NXP PoC: Nur Engin (nur.engin@nxp.com) & Semih Serbetli (semih.serbetli@nxp.com)

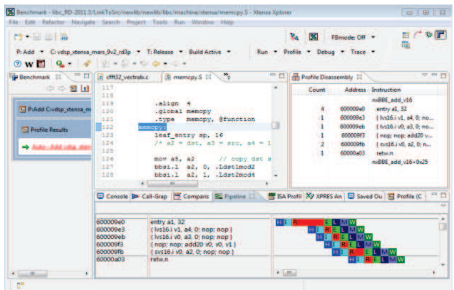
Project 5: Car 2 Car Communication Based on 4G/5G

Creation of an optimized LTE-V2X Radio on NXP Software Defined Radio IC



- Scope:
  - Creation of an LTE-V2X DSP code library
  - Benchmarking (cycles counts, memory, instruction code)
  - Recommendations for LTE-V2X hardware-software architecture for current and/or the next generation NXP devices
- Target Platform:
  - Advanced SDR Platform from NXP based on Tensilica DSP
- Target Application:
  - Advanced algorithms for LTE-V2X release 14, mode 3 and 4
- Skills Required
  - C-programming, Matlab, experience with DSP is appreciated
- Duration: 6-9 months
- Location: NXP Eindhoven
- NXP PoC: Artur Burchard (artur..burchard@nxp.com)



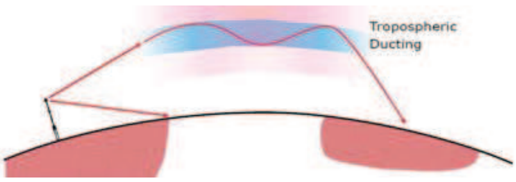


Correlation between trans-horizon propagation measurements and a numerical weather prediction model for potential application in a conditional spectrum usage scenario.

Introduction

As the growth of connected devices continues to increase, the availability of spectrum more-and-more becomes a bottleneck. Therefore, one of the priorities of frequency management policy is to constantly seek opportunities to facilitate more efficient use of the spectrum. This might be enhanced by supporting dynamic shared access of frequency bands by means of a technological solution. The conditions that can apply in such a case might e.g. be driven by constraints of time and location.

Propagation of radio waves used for today's wireless applications is mainly limited by the radio horizon, whereas only a very minor part extends by means of diffraction or tropospheric scattering. This limitation enables frequency planning for confined geographical areas and, consequently, reuse of frequencies in areas with sufficient spatial separation. However, under certain atmospheric conditions, radio waves are able to propagate over distances far beyond the horizon (anomalous propagation, super-refraction or ducting). This is caused by the refractive properties of the transmission path, which is determined by the variation of temperature, pressure and humidity between boundary layers of the atmosphere. Although the latter situation occurs relatively seldom, it might however completely disrupt spatial frequency planning, increasing the probability of distant radio systems to interfere with each other.



Problem definition

To evaluate anomalous propagation of radio waves within the 3.5 GHz band the Radiocommunications Agency of the Netherlands has conducted a measurement campaign that lasted for three consecutive years. Measurements were done using two trans-horizon land cover and mixed land/sea cover trajectories. The primary goal of this campaign was to compare the results with predictions of the commonly used ITU-R P.452 propagation model. In addition, the obtained dataset should be utilized to explore any useful relationship with metrological data. If so, data from a numerical weather prediction model could potentially be used to forecast the conditions for radio propagation within a particular frequency band. Hence, this approach could be used as an instrument for conditional shared access.

Assignment

Comparison of data from the 3.5 GHz propagation measurements with data from a numerical weather prediction model has not yet been done. Initial contacts with the Dutch metrological institute KNMI have learned that both HiRLAM and HARMONIE model data might be candidates for evaluation. If agreement can be found a qualitative and quantitative judgement on the validity of this method should be given. In addition, the usefulness of this method as an instrument for conditional shared access should be discussed and estimated. Finally, guidelines should be given for practical implementation.

MASTER THESIS

ELECTROMAGNETIC ANALYSIS OF SUPERCONDUCTING QUANTUM BITS

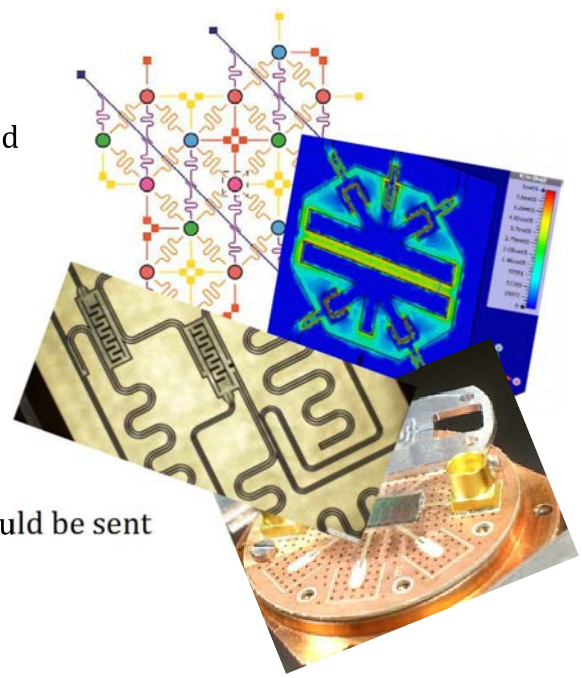
Quantum Technology is a key future emerging technology. QuTech is at the forefront of research and development in quantum technology. QuTech is an organization with depth and breadth of multidisciplinary knowledge where the focus is on smart solutions to complex issues in quantum information platforms. Fifteen 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 for the manufacturability of quantum processors with hundreds or thousands or more qubits.

OBJECTIVE

The purpose of this project is to boost the performance of superconducting quantum bits. Such qubits are vital for superconducting quantum processors. Within this project the focus will be on the development and analysis of novel qubit geometries suitable for 2D surface code. This requires qubits with large number of connectivity, adequate qubit lifetime, tunable transition frequency and specific coupling coefficients to its nearest-neighbors. During the course of this project you will work to establish a good understanding of the dielectric loss mechanisms limiting the lifetime of qubit, investigate computational approach able to accurately simulate these losses and finally design qubit geometries with high quality factor.

EXPECTED PRIOR KNOWLEDGE / INTEREST

- Knowledge of electromagnetic fundamentals and microwave theory
- Understanding of circuit analysis
- Experience with commercial EM solvers (e.g. CST, FEKO, HFSS) is an advantage but not a must



START: with immediate effect

We are looking forward to your application which should be sent to nadia.haider@tno.nl , A.Yarovoy@tudelft.nl and L.DiCarlo@tudelft.nl

QUTech TUDelft TNO

Classification of radar targets using the PARSAX system

Supervisors: dr. Oleg Krasnov & Prof. Alexander Yarovoy

Motivation

In many practical applications it is of interest to classify observed objects of interest, also called targets, using features that are measured via a sensor. A typical example is the classification of ships using radar measurements. The measured features are compared to features of targets from a database and a decision is made about the class of the observed target.

The MS3 group has a reconfigurable radar, PARSAX, that can observe ships and aircrafts using different sensing modes dynamically. The group is interested in advancing the state of the art in automatic target classification by exploiting sensor management algorithms for selecting the best sensing parameters for observing and classifying targets.

I. Problem

For one selected specific class of targets (sea ships, aircraft, cars on highway) define subclasses with specific differences (e.g. type, size, operational characteristics) and develop algorithm(s) of radar data processing for reliable classification observed target into one of this subclasses.

II. Project goal

The goal of the project is to identify which target attributes can contribute to its classification and which radar parameters can be controlled in order to achieve better classification results.

III. Approach

When classification of targets is of interest, it is possible to compare the measured features to features reported via automated systems such as the Automatic Identification System (AIS) for ships and the Automatic Dependent Surveillance-Broadcast (ADS-B) system for aircrafts.

This project involves both experimental (and/or simulations) and theoretical aspects. Important aspects of this project are:

- A literature survey on target classification that describes classification algorithms, target features that can be used and how these features are related to radar parameters that can be controlled;
- An interface between MATLAB and a website with AIS data or an ADS-B receiver in order to automatically import relevant information about features of the observed targets to MATLAB;
- Implementation of the most promising classification algorithm.
- (optional) Experimental verification of the proposed algorithm.
- Report your findings in a MSc thesis

IV. Example literature

- Kouemou, G. "Radar Target Classification Technologies", in *Radar Technology*, INTECH, 2009, pp. 410. ISBN 978-953-307-029-2
- Copeland, J. R. "Radar Target Classification by Polarization Properties," in *Proceedings of the IRE*, vol. 48, no. 7, pp. 1290-1296, July 1960.

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Project:
PARSAX radar system

GPS-based target detection and imaging

Supervisors: dr. Oleg Krasnov & Prof. Alexander Yarovoy

I. Problem and Motivation

In many practical applications it is of interest to detect and image of observed objects of interest, also called targets, using signals of opportunity such as e.g. GPS signals. In the latter case a transmitter mounted on a satellite of GPS and a receiver located on the Earth's surface form together so-called Forward Scattering Radar.

The Forward Scattering Radar (FSR) is a special type of bistatic radar when the bistatic angle is near 180 degrees, and the target is located near the transmitter-receiver baseline. In FSR, the Babinet's principle is exploited to form the forward scatter signature of a target, and the drastic enhancement in scattering is created due to the forward scattering phenomenon, when the presence of a target blocks the signal wave front from the transmitter. According to the EM field theory, when there is an absolutely black body that is placed in the path of wave propagation and the dimensions of this body are large compared with the wavelength, then a scattered field exists behind the body (a 'shadow' field). This target shadow is an EM field, which is scattered by the target. When bistatic angle approaches 180, the level of the signal reflected from the target is maximal, and the target can be characterized by a forward scattering cross-section that depends on the target shadow silhouette area.

II. Project goal

The goal of the project is to analyses capabilities of GPS signals within FSR scheme to perform detection and imaging of the objects.

III. Approach

This project involves both experimental (and/or simulations) and theoretical aspects. Important aspects of this project are:

- A literature survey on FSR and GPS signal properties;
- Implementation of digital receiver of GPS signals based on real-time sampling scope;
- Implementation of coherent FSR radar with GPS signals from low-elevation satellites by comparing the direct path signal and the signal scattered from a target;
- Implementation of the most promising imaging algorithm.
- Experimental verification of the proposed algorithm.

IV. Example literature

- Chernyak, V., "*Fundamentals of Multisite Radar Systems*", Gordon and Breach Science Publishers, 1998, pp. 41.
- Cherniakov M. et al. "Automatic ground target classification using forward scattering radar", *IEE Proc.- Radar Sonar Navig*., Vol. 153, No. 5, October 2006, pp. 427 – 437.
- Kabakchiev C. et al. "Signal Processing of GPS Radio Shadows Formed by Moving Targets", *Proc. of SPS'2015*, Debe, Poland, 2015.
- Kabakchiev C. et al. "Detection and Classification of Objects from Their Radio Shadows of GPS Signals", *Proc. of IRS'2015*, Dresden, Germany, 2015, pp. 906-911. .

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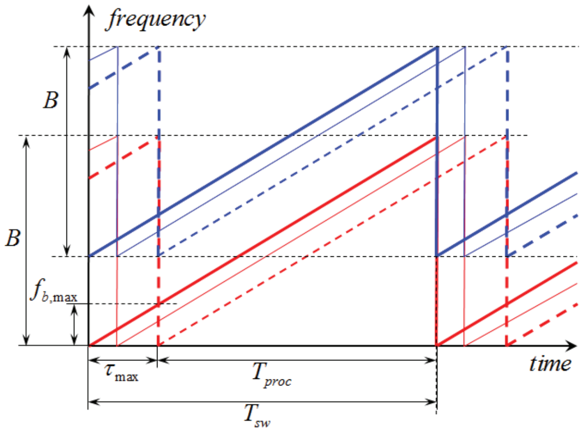
Research themes:
Radar technology
Distributed sensor systems

ORTHOGONAL FREQUENCY-SHIFTED LFM WAVEFORMS FOR MOVING TARGETS CHARACTERIZATION IN POLARIMETRIC/MIMO RADARS

Orthogonal waveforms becomes a hot topic in modern radar development as soon as they provide a unique possibility to operate multiple polarimetric or MIMO radar channels in parallel, simultaneously. It is quite important for many applications, from weather to automotive radars, that are interested to detect targets, estimate their motion and physical parameters as fast as possible. Such signals also increase an ambiguity interval for Doppler velocity measurements.



One of possible types of such orthogonal waveforms includes a pair of the same linearly frequency modulated continuous waves (LFM CW) that are shifted in frequency wider than some predefined by the radar construction value. Such waves within matched radar receiver channels do not create any destructive cross-channels interferences.

At the same time, the detection and measurements of radar targets in such parallel channels take place on different frequencies. Even keeping in mind that such a difference if frequencies is quite small, the resulting targets parameters can be quite different, especially in case of fast moving and/or extended targets. **The goal of this project** is to study this frequency difference for different types of targets and scenarios quantitatively, define limitations for waveforms parameters selection for specific scenario, to analyse/develop possible techniques for compensation.

The study will start with intensive research and study existing references about frequency dependence of targets radar characteristics and methods of their modelling. The main research will be done with development and use of simulation software within Matlab environment. Some concluding results can be validated using experimental dataset measured with the PARSAX radar.

REQUIREMENTS FOR AN APPLICANT TO THIS PROJECT:

- Clear understanding basic radar principles and theory, FMCW radars, Doppler effect, extended target concept (the mark for the ET4169 MRRS course not less than 7.0)
- Basic understanding and knowledge in probability and statistical theory with implementation to data processing
- Skills for scientific literature search, reading and reviewing
- Intensive knowledge of the Matlab programming
- Skills in scientific writing

Contact person: dr. Oleg Krasnov (o.a.krasnov@tudelft.nl), HB 21,280

Research Theme

Next Generation Sensing & Communication

A Fully Flexible Single-Side-Band Radar Deramping Receiver on FPGA

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 are 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.

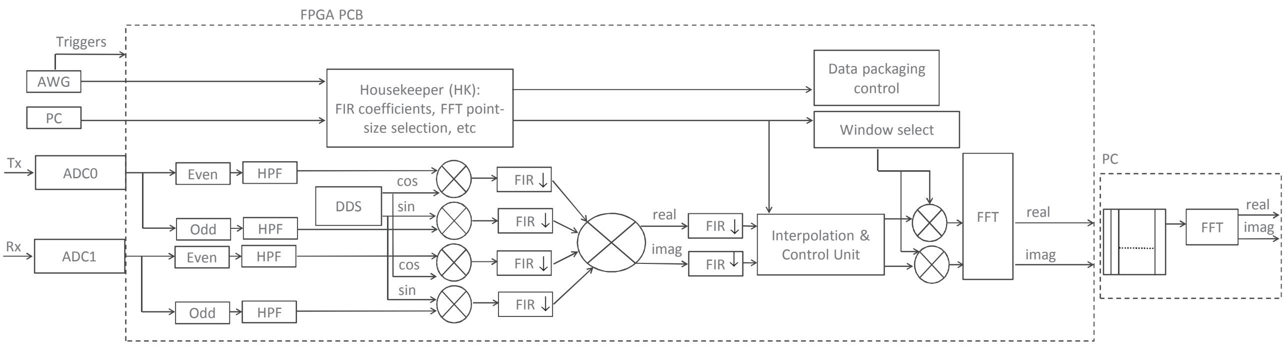
This work focuses on the LFMCW class of radars and their waveforms, where the project addresses:

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

Adaptive Receiver Requirements

- Build interface to Xilinx's online FIR coefficients reload.
- FFT point-size online select.
- Window selection automation. Can be stored on chip/off-chip or calculated online.
- Xilinx Direct Digital Synthesizer (DDS) centre frequency online reconfigure.
- Two-way switchers between PC and FPGA using Digital I/O (DIO).
- Arbitrary Waveform Generator (AWG) to control a few DIOs to indicate a certain functionality/command etc, like a switch of waveform for example. (implementation examples available in the AWG documentation).
- 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 protocol 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). This is discussed in the paper "Waveform and Receiver Parameters Design Choices for a Reconfigurable Digital FMCW Radar" by S. Neemat et al.

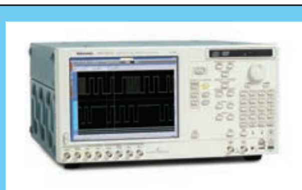


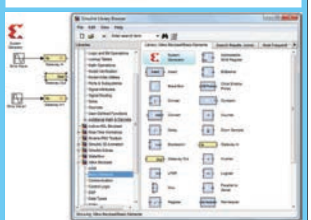
Board & Development Environment

Board:
Innovative Integration (II)
X5-400M.
Development Platforms:
Simulink (Xilinx system generator),
Xilinx ISE.

MATLAB SIMULINK

XILINX ISE DESIGN SUITE





Delft University of Technology, EEMCS, MS3 group, The Netherlands
For more information contact:
S. Neemat (S.A.M.Neemat@tudelft.nl)
O. Krasnov (.a.krasnov@tudelft.nl)
A. Yarovoy (A.Yarovoy@tudelft.nl)

TU Delft
Delft University of Technology

Future Surveillance Radar

Future Surveillance Radar

Background

Surveillance radar is being used for monitoring large areas:

- Maritime monitoring;
- Air traffic control;
- Environmental analysis.

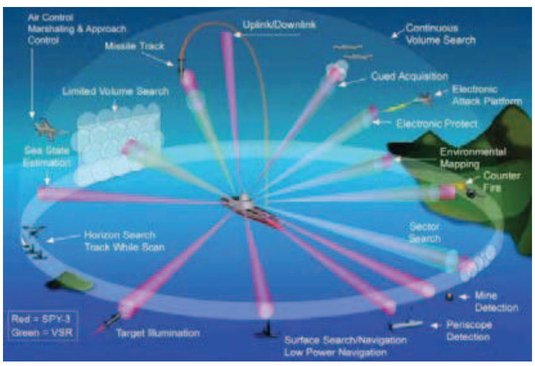
Modern radars have and will have increasingly more capabilities, among which:

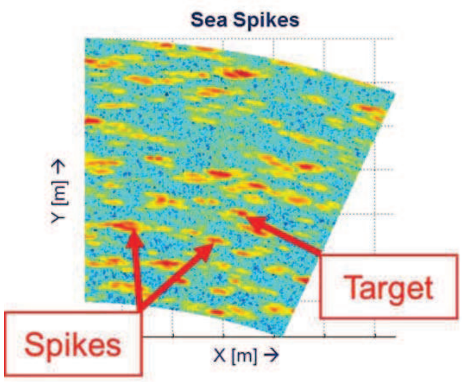
- Distributed transmission of (complex) waveforms;
- Huge processing capacity combined with advanced processing concepts.

Topics in Future Surveillance Radar

Potential topics for a MSc thesis are in the following broad areas:

- Transmission and waveform concepts for improved detection and classification;
- Design and analysis of detailed waveforms;
- Spatio-temporal characterization and processing of sea clutter;
- Characterization and processing of extended objects;
- Parameter estimation / machine learning in stochastic dynamic systems;
- Online management of radar modes and waveform parameters.





(Supervisor: Assoc. prof. Hans Driessen)

A study of extended targets radar detector

Modern wideband radars have enabled a sub-meter range resolution, thus providing additional possibilities for target detection and classification. However, the target detection in such high resolution mode has a few differences w.r.t. the detection in low range resolution mode. Thus, the targets of interest (aircrafts, cars) cannot be considered as point-like anymore; instead, they are spread in a few adjacent range cells. This phenomenon has to be considered to improve radar performance. To address this problem a few techniques of extended target detection have been recently proposed, however, they generally assume target range extent to be known. The aim of this study is to analyse the performance of existing detectors and propose techniques for reliable estimation of the target range extent.

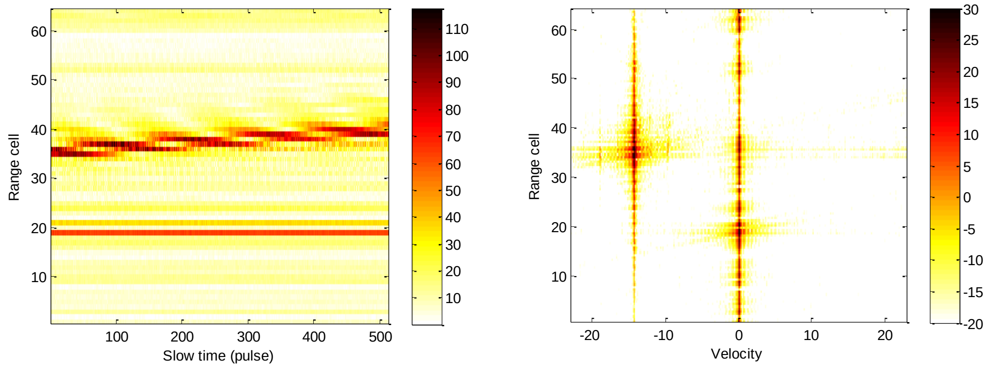


Figure 1. Bus at Mekelweg observed by PARSAX radar

Sub-tasks:

- Overview of signal and clutter models in high resolution radar. Formulation of the appropriate models and their numerical simulation according to defined models [1]. Literature overview about radar CFAR detectors. Analysis of existing extended target detectors and target range extent estimation;
- Formulation of the particular technique for target range extent estimation and its statistical analysis;
- Simulations of existing and proposed techniques [2, 3]; performance assessment by numerical simulations. Semi-experimental data processing from PARSAX radar in its high resolution mode (1.5 m range resolution) [4].

The final report will describe the methodology, description of the proposed/analysed techniques, together with their performance analysis.

References:

[1] F. Le Chevalier, Principles of Radar and Sonar Signal Processing Norwood: MA: Artech House, 2002.

[2] P. K. Hughes, "A High-Resolution Radar Detection Strategy," Aerospace and Electronic Systems, IEEE Transactions on, vol. AES-19, pp. 663-667, 1983.

[3] A. De Maio and M. Greco., Modern Radar Detection Theory. SciTech Pub., 2016.

[4] http://parsax.weblog.tudelft.nl/

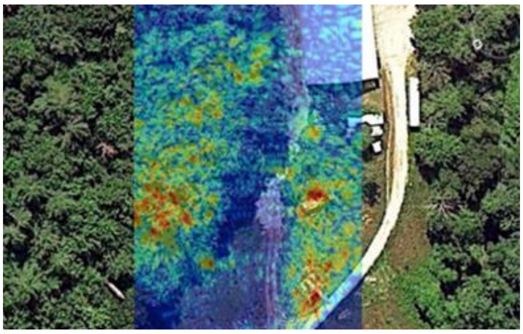
Supervisors: Hans Driessen and Nikita Petrov (till April 2018)

Radar based Road Mapping

Context

High-accuracy localization of moving vehicles at urban environments is crucial for emerging autonomous driving. Current approaches integrate global positioning system (GPS), inertial measurement unit (IMU), wheel odometry, and light detection and ranging (LIDAR) data acquired by an instrumented vehicle, to generate high-resolution environment maps that is used for localization. Unfortunately, not all of the current vehicles equipped with advanced instruments such as LIDARs thus these maps can be achieved through special vehicles which is expansive and time consuming process. Since radar sensors are already available in most of the modern cars, in this master thesis project, we design a method/algorithm that uses radar sensor to create road maps that can be used for localization.

Experimental Automotive Radar



Environment map (SAR Image)

Assignment

The proposed project has the goal to develop, implement and test radar based mapping algorithms. The list underneath provides an overview of the research questions that will to be solved in this project:

- Feasibility of using available radar sensors for road mapping. Is it possible to recreate same map with different passes? Accuracy? Location of radar at car?
- Design and implementation of an algorithm for creating environmental (road) maps that is suitable for automotive radar.
- Feature extraction and registration of maps.
- Fusion of radar based map with available road maps.

Requirements

C, MATLAB and radar basics

Contact: dr. Faruk Uysal, Microwave Sensing, Signals and Systems Group
f.uysal@tudelft.nl

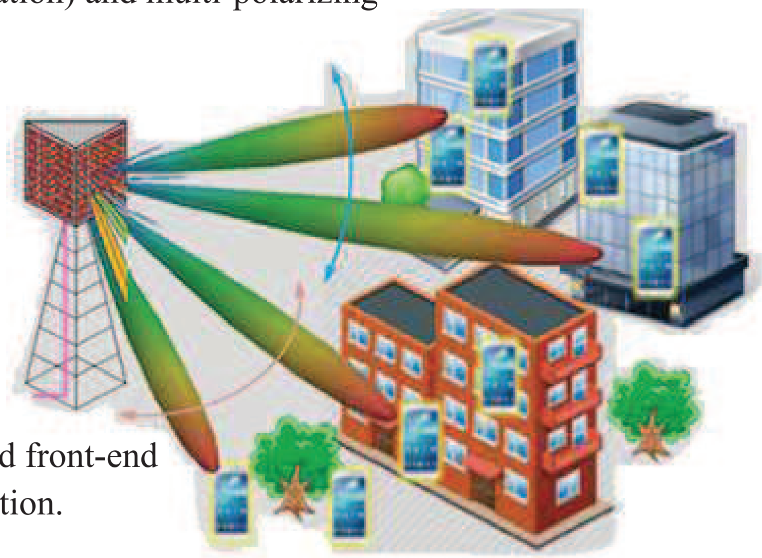
radar.tudelft.nl

Antenna array designs

Motivation

The next generation mobile communication system, 5G, should provide a strongly increased system capacity as well as data rates up to a target of 10Gbps. With these high demands on mobile network, the sophisticated multiple beam active antenna systems operating in higher frequency bands will be the key devices. The benefits provided by using this antenna system include reduced interference by intelligently controlling the beam direction. To reduce fading effects, other antenna requirements such as selectivity in operating frequency (or broadband operation) and multi-polarizing ability are also desirable.

The MS3 group is involved in the project 'Advanced 5G solutions' for research on technological breakthroughs for a broad scope of 5G application areas, especially communication and automotive.



Our group is focussing on development novel solutions in antenna topologies and front-end configurations for multiple beam generation.

The topics

There are three interesting topics in this project :

- **The design of antenna element (small antenna array) with dual polarized capabilities**
- **The design of the "filtenna" array combining the function of filter and antenna**
- **The design of sub-array topologies to provide amplitude taper yielding low natural side lobes**

If you interested any of these topics, you can contact me at J.Puskely-1@tudelft.nl and we can discuss the topics in more detailed.

Additional information

The topics will be supervised by Dr. Jan Puskely/ Prof. Alexander Yarovoy. A PhD student of the group will be assigned as daily advisor.

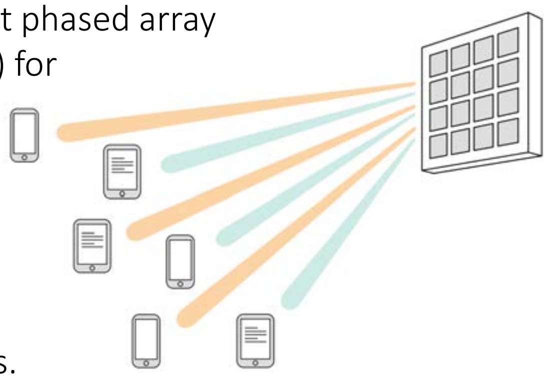
The good background in microwaves and antennas is important. The knowledge of MATLAB and CST MS is beneficial.

Advanced 5G Solutions

Antenna Arrays and Beamforming for 5G

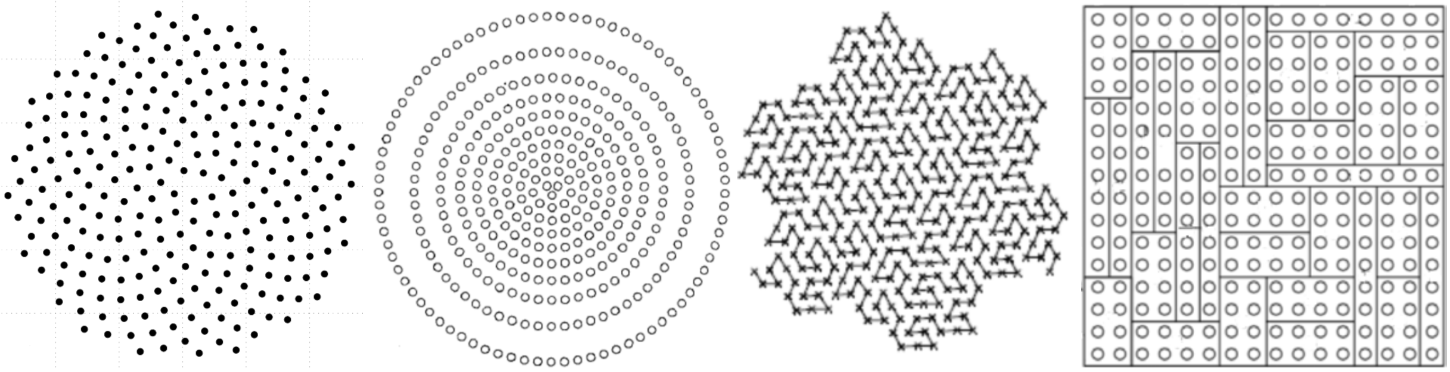
MSc Yanki Aslan – PhD Candidate
Y.Aslan@tudelft.nl

- In "Advanced 5G Solutions", we aim to design low-cost phased array base station antenna systems at mm-waves (~30 GHz) for simultaneous multiple beam forming with enhanced spatial multiplexing, limited interference, acceptable power consumption, suitable processing complexity & speed and passive cooling.
- This challenging task requires innovative approaches in antenna array topologies and array cooling strategies.



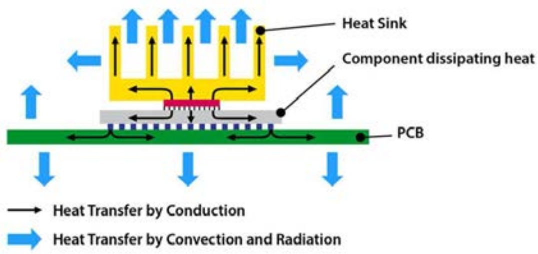
DIFFERENT TILING CONFIGURATIONS AND TECHNIQUES FOR ANTENNA UNITS

- Thinning, random placing, mathematical structures etc.
- Sparse arrays → reduction in power dissipation and passive cooling
- Optimization via tapering functions, genetic algorithm, compressive sensing etc.



THERMAL SIMULATIONS FOR 5G

- Modelling and optimization of the antennas & heat sinks
- Investigation of different boundary conditions & external cooling techniques



Other Contact Persons:

Dr. Jan Puskely – J.Puskely-1@tudelft.nl
Dr. Antoine Roederer – roederer.antoine@gmail.com
Prof. DSc. Alexander Yarovoy – A.Yarovoy@tudelft.nl

MS3 Master Event
January 19, 2018

5G MULTI-BEAM ANTENNA TOPOLOGIES

MASTER THESIS PROPOSAL

5G communication systems are expected to achieve approximately 1000x communication capacity growth and less than 1ms latency in transferred data stream while supporting massive Internet of Things. To achieve the capacity and throughput requirements of 5G technology, a vast amount of spectrum with sufficient frequency re-use is necessary. Therefore, the concept of beam-division multiple access in millimeter-wave systems is being studied at the MS3 group involved in the project 'Advanced 5G solutions' for research on technological breakthroughs for a broad scope of 5G application areas, especially in communication and automotive industry.

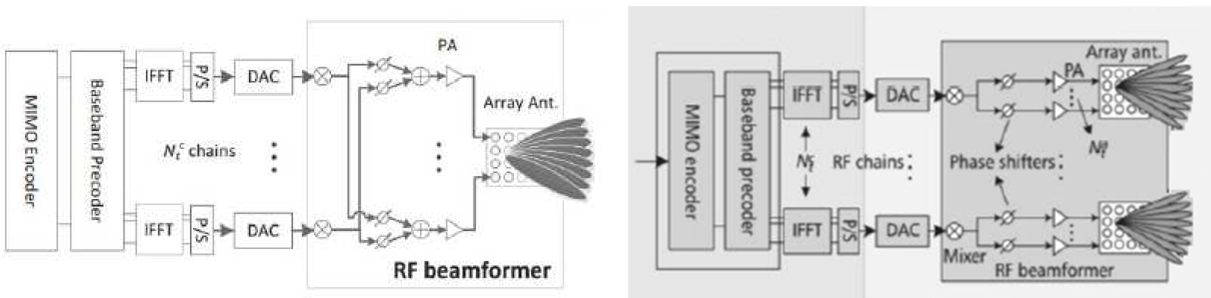
System Behaviour Modelling in 5G

<u>Motivation</u>

In order to understand the feasibility of achieving the desired goals (the number of users that are simultaneously served, data rate per user, maximum distance for reliable communication etc.) with certain limitations (the size of the aperture, number of antenna elements, power amplifier capabilities etc.), it is important to model the behaviour of 5G systems in terms of a link budget. In fact, transmissions in the millimeter-wave bands have significantly less favorable link budgets due to low power amplifier output powers, reduced receiving effective aperture and decreased diffraction and dispersion effects. To mitigate these drawbacks, large scale antenna arrays with tens or hundreds of elements are expected to be deployed in 5G systems. Using a transceiver behind every antenna element will consume unacceptable amounts of power and will likely be cost prohibitive.

To the best of our knowledge, studies on the link budget of 5G networks are still very limited in literature [1, 2] and lack of practical factors that should be considered in the overall design. Therefore, in this master thesis, the aim will be to model and evaluate the performance of 5G systems by taking the following into account:

- Formation of multiple beams at the transmitter by fully digital or hybrid [3-4] beamforming architectures (see Figure 1)
- Maximum power provided by each power amplifier
- Dynamic range of excitations
- Different user positions, antenna polarizations (possibly via Monte Carlo simulations)
- Total cost etc.



(a) Fully-connected type [3]

(b) Multiple array type [4]

Figure 1: Hybrid beamforming architectures

Some examples of 5G link budgets that are available in literature and the references are given in the next page.

MMB link budget analysis	Case 1	Case 2	Case 3	Case 4
TX power (dBm)	35.00	35.00	25.00	25.00
TX antenna gain (dBi)	30.00	30.00	30.00	30.00
Carrier frequency (GHz)	28.00	72.00	28.00	72.00
Distance (km)	1.00	1.00	0.50	0.50
Propagation loss (dB)	121.34	129.55	115.32	123.53
Other losses	20.00	20.00	20.00	20.00
RX antenna gain (dBi)	15.00	15.00	15.00	15.00
Received power (dBm)	–61.34	–69.55	–65.32	–73.53
Bandwidth (GHz)	1.00	1.00	1.00	1.00
Thermal PSD (dBm/Hz)	–174.00	–174.00	–174.00	–174.00
Noise figure (dB)	10.00	10.00	10.00	10.00
Thermal noise (dBm)	–74.00	–74.00	–74.00	–74.00
SNR (dB)	12.66	4.45	8.68	0.47
Implementation loss (dB)	5.00	5.00	5.00	5.00
Data rate (Gb/s)	2.77	0.91	1.74	0.4

Figure 2: Millimeter-wave mobile broadband (MMB) link budget, from [1]

39 GHz mobile network link budget	Downlink cell edge	Uplink cell edge	Downlink cell center	Uplink cell center
PA output power (dBm)	20	18	20	18
Number of PAs	64	16	64	16
Total output power (dBm)	**38**	**30**	**38**	**30**
Number of Tx antenna element	256	16	256	16
Tx antenna element gain (dB)	6	6	6	6
Antenna & feed network loss (dB)	3	5	3	5
Total Tx antenna array gain (dB)	**27**	**13**	**27**	**13**
EIRP (dBm)	**65.14**	**43.08**	**65.14**	**43.08**
Distance (m)	1000.00	1000.00	100.00	100.00
Path loss = 72 + 29.2log10(d) (dB)	**159.60**	**159.60**	**130.40**	**130.40**
Received power (dBm)	-94.46	-116.52	-65.26	-87.32
Bandwidth (MHz)	500.00	500.00	500.00	500.00
Thermal noise (dBm)	-87.01	-87.01	-87.01	-87.01
Noise Figure (dB)	5.00	5.00	5.00	5.00
SNR (dB) per Rx antenna element	-12.45	-34.51	16.75	-5.31
Number of Rx antenna element	16	256	16	256
Rx antenna element gain (dB)	6	6	6	6
Rx antenna feed network loss (dB)	5	3	5	3
Total Rx antenna array gain (dB)	**13**	**27**	**13**	**27**
SNR after beamforming (dB)	**0.60**	**-7.42**	**29.80**	**21.78**
Implementation loss (dB)	3.00	3.00	3.00	3.00
Number of MIMO streams	1	1	8	8
Spectral efficiency (bit/channel use)	0.66	0.13	47.40	27.06
System overhead	40%	40%	40%	40%
Duty cycle	62.50%	37.50%	62.50%	37.50%
Throughput (Mbps)	**122.86**	**14.09**	**8887.91**	**3044.15**

Figure 3: Examples of 39 GHz mobile network link budget, from [2]

References

[1] Z. Pi and F. Khan, "An Introduction to Millimeter-Wave Mobile Broadband Systems," *IEEE Communications Magazine*, vol. 49, no. 6, pp. 101-07, June 2011.

[2] Straight Path Communications Inc., "A Straight Path Towards 5G," *White Paper*, Sept, 2015.

[3] T. Kim, J. Park, J. Seol, S. Jeong, J. Cho and W. Roh, "Tens of Gbps Support with mmWave Beamforming Systems for Next Generation Communications," *IEEE GLOBECOM*, 13, pp. 3790–95, Dec. 2013.

[4] W. Roh, J. Seol, J. Park, B. Lee, J. Lee, Y. Kim, J. Cho and K. Cheun (Samsung), "Millimeter-wave Beamforming as an Enabling Technology for 5G Cellular Communications: Theoretical Feasibility and Prototype Results," *IEEE Communications Magazine*, Feb. 2014.

Graduation assignment/
thesis topic.

Asparagus detection with microwaves

Location: Heeze.
Start: November 2016 (duration approx. 9 months)

Is it your dream to have a challenging internship at a high tech startup? Can you adapt to the speed of a fast growing company? Then this could be the opportunity for a great internship.

Background information on the task

In order to harvest asparagus before the color changes from white to purple, a subsurface detection technique is necessary. For this purpose, microwaves have been investigated. Two methods have been tested to a certain extend: transmission and GPR (Ground Penetrating Radar).
Microwaves with frequencies in the 2 – 3 GHz range have been investigated because these frequencies offer ground penetration capabilities and promise sufficient resolution. Asparagus-soil contrast results from the large gap in dielectric constant. As always with detection problems, success depends on the variability of the background clutter, in this case due to electric and geometric variations of the soil. These variations may even exceed the average asparagus-soil contrast. Clutter suppression is therefore part of the investigation.

Typical dimensions of an asparagus are 1-3 cm diameter and a length of about 35 cm. They grow largely vertically. Typical densities are 1-2 per meter. Sometimes it occurs that two asparagus are only a few centimeters away from each other. They are buried 10-30 cm away from a side of the soil ridge. Roughly speaking, detection should be done at a speed of 0,5 m/s while offering centimeter accuracy of the position in the horizontal plane. An estimation of the 'depth' (the distance to the soil in horizontal and vertical direction), length, and width is desirable.
The detection module moves with 0,5 m/sec speed over the asparagus bed.
Asparagus detection is a challenge for microwave detection.
This is foremost due to

- the small size of the asparagus compared to the wavelength and resolution of microwave instruments and
- the attenuation and variability of the soil.

Nevertheless, it has been demonstrated with a commercial GPR that an asparagus in a test setting could be detected when covered by some decimeters of soil of the kind typically used to grow asparagus in. More extensive transmission measurements with a dedicated robotized setup were less convincing, although cross-polarization measurements still hold some promise. Experimental research supported by simulation models needs to be done.

Literature and knowledge on GPR and transmission related to the asparagus detection problem have been collected and are available for study.

Subscription

Cerescon has different graduation assignments to investigate and develop mentioned methods. Assignments (amongst others):

1. Develop and extend the experimental set up
2. Analyze measuring data
3. Apply the simulation models and develop the modules further.

Measuring equipment and a small (indoor) asparagus test field are in the test hall in Heeze.

Your profile

- Your study is physics or electrical engineering
- You're the type of person that (after some help of a mentor) can work independently
- You have knowledge of RF technology
- You have knowledge of experimental techniques.

We offer

We offer you an educational internship in a challenging high-tech startup where we never have two similar days. As a startup, we face every day and every week new unexpected situations. The culture is very informal, very open and close. The pace is high since we switch quickly and make efficient decisions.

We'll find a suitable mentor from a specialist company for you. If this mentor is not within Cerescon, we'll hire capacity.

You'll get an allowance / graduation fee and travel expenses if you have no free public transport up to a maximum compensation of 40 km one way per day.

I'll take the challenge

Please respond (preferably before mid October) by applying your motivation letter and CV to:
Thérèse van Vinken - therese.vanvinken@cerescon.com
If you have questions regarding the assignment:
Please contact Ad Vermeer- Chief Technology Officer, mobile 06-30614039

About Cerescon BV

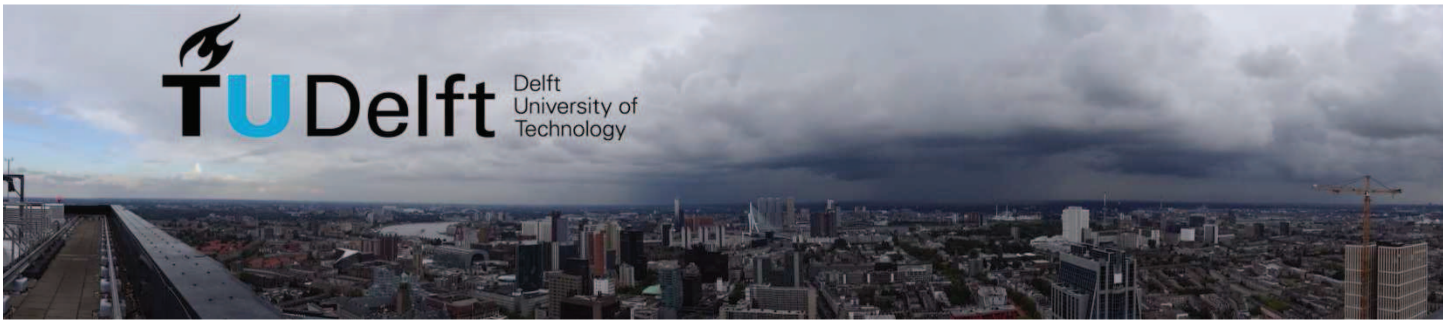
Cerescon is a very young, fast developing high tech startup. Cerescon is aiming at the development, the production and the marketing of an automated selective asparagus harvesting machine.

Asparagus production is up till now a very labour intensive part of horticulture.

The so called "white gold" is up till now harvested manually by thousands of manual workers.

Cerescon is the first company that successfully has proven the feasibility of an automatic asparagus harvesting machine. We now face the challenge to bring this innovation to a successful product and to let Cerescon grow to a successful company. For this, Cerescon needs good employees who can think and act on all levels. Employees with the skills and personality to let Cerescon grow to the organization we want to become: a global player.

Publication date: May-2016



Microwave

Sensing, Signals and Systems (MS3) Group

INVITATION

MS3 MASTER EVENT

Come to learn about our group and current Master Thesis Projects

January 19th

Event Program

15:00 Start & Welcome (Snijderszaal)

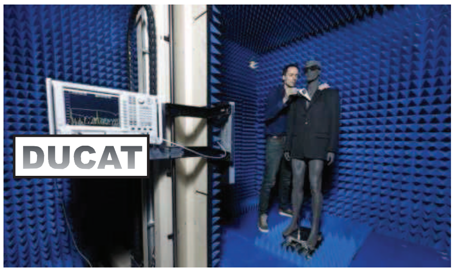
Introduction of MS3

Short presentation of companies (NXP, TNO, THALES and RFx Solutions)

Free interaction for Master project opportunities

17:00 Social Time &

closing with Pizza



Registration is required, don't forget to accept the meeting request **before** Monday January 15!
You can also contact : mrs M. Ramsoekh, email: m.w.s.ramsoekh@tudelft.nl