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 - 2017

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 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, and it offers a limited number of on-site MSc thesis projects focusing on radar. The thesis assignments are formulated in detail, in accordance with TU Delft rules, only after an interview with the student.

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: **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

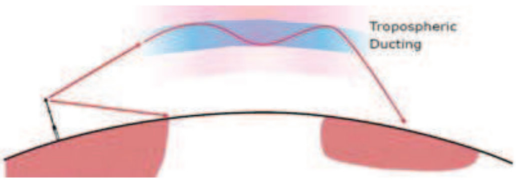
OPEN

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

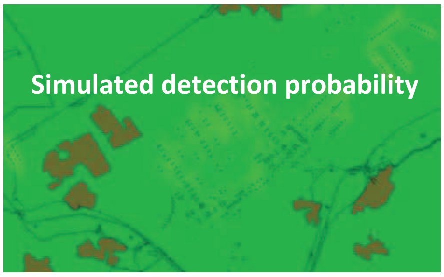
Comparison of data from the 3.5 GHz propagation measurements with data from a numerical weather prediction model has not yet been done. Initial contacts with the Dutch metrological institute KNMI have learned that both HiRLAM and HARMONIE model data might be candidates for evaluation. If agreement can 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.

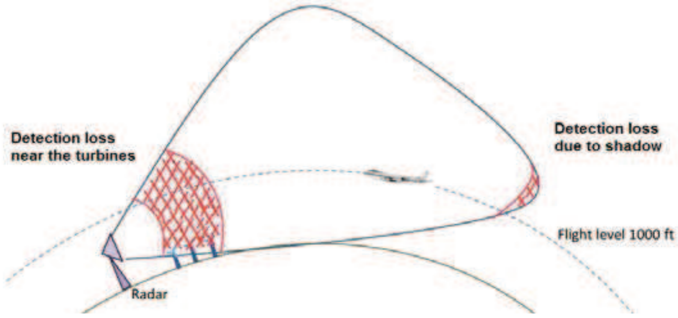
Radar Distortion due to Wind Turbines

Master thesis Electrical Engineering or Physics

Introduction

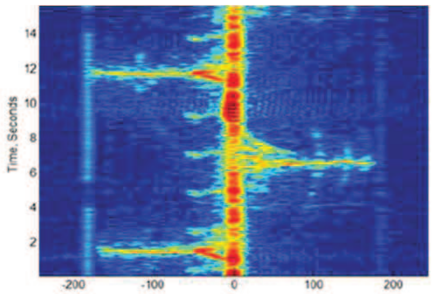
Radar systems are used for applications such as weather prediction, coastal security and air traffic control. Wind turbines can interfere with such radars. This research focusses on primary radars for air traffic control. This radar emits a signal that reflects on airplanes and is then received again by the radar. Wind turbines can distort air traffic control radars roughly through two mechanisms. Firstly by decreasing transmission between radar and target (shadow). And secondly by reflecting the radar signals of the radar (backscatter). The backscatter is a big problem as the rotating wind turbine blades reflect the radar signal with Doppler shifts, which currently cannot be discriminated from flying airplanes.





Problem definition

TNO uses a model (PERSEUS) to predict the distortion of primary radars due to wind turbines. This model includes both effects of transmission loss and reflection. For this thesis we intent to validate the backscatter part of the model. The backscatter of wind turbines has been by the TUDelft (using the PARSAX radar). The measured PARSAX data has to be modelled and compared with the PERSEUS model results. The outcome of the model is a single scan detection probability of an airplane, so a smart comparison with the raw measured data is needed.



← **measured backscatter data**

Goal

The main goal is to correlate measured wind turbine backscatter data with the simulation model. You therefore need to model the PARSAX radar and the measured wind turbines for the simulation. The simulation results then need to be compared to the measured data. The PERSEUS model preferably needs to be validated for several wind turbine types, environments and weather conditions. Possibly more measurements should be done. It is possible to suggest improvements to the model based on the measured data.

Contact

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TNO innovation for life

TU Delft

Calibration targets for automotive radar diagnostics in real time

PhD candidate: Rossiza Gourova **Daily supervisor: dr. Oleg Krasnov**

Motivation

The main drive behind automated driving is to decrease the number of accidents on the road as more than 90% of them involve human errors. This has triggered the development of active safety systems involving different types of sensors. In order to assure human safety, the sensors on the vehicle need to be fault proof. To accomplish that, there need to be means to test the sensors on the go. One possible solution to monitor the state of the radar is to use stable targets present on the road.

I. Problem

For automotive radar performance validation in real time, define calibration target selection criteria and propose (analytically defend your reasoning) targets which satisfy those criteria.

II. Project goal

The goal of this project is to analyse existing infrastructure on the road and propose (if needed) alternative solutions for best radar calibration (performance validation) in real time.

III. Approach

This project involves both experimental (and/or simulations) and theoretical aspects. A sample workflow can be:

- Literature review of the measurements of current road infrastructure and of calibration methods used in other radar domains (maritime, airplane radars)
- Define criteria for target selection – e.g. the RCS stability within the family of targets
- Perform a theoretical analysis to determine the most appropriate targets from the existing infrastructure (traffic lights, signs, curbs, shafts, highway fence, etc.). Use simulations to illustrate the validity of the results
- [optional] Validate the results with experiments (NXP Dolphin demonstrator or Continental ARS300 industrial radar)
- If none of the existing infrastructure satisfies completely the defined criteria, propose alternative solutions for target calibration which can be integrated in the current infrastructure
- Report your findings in the MSc thesis

IV. Example literature

- Ioffe, Alexander, et al. "RCS characteristics of street curbs and the applications in automotive radar classification." *Radar Conference. (EuRAD), 2016 European*. IEEE, 2016
- Werber, Klaudius, et al. "How do traffic signs look like in radar?." *Microwave Conference (EuMC), 2014 44th European*. IEEE, 2014.

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For more information about this thesis proposal please contact:
Rossiza Gourova R.Gourova@tudelft.nl **or**
dr. Oleg Krasnov O.A.Krasnov@tudelft.nl

This proposal is related to the currently running project S4DRIVE

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 on 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

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

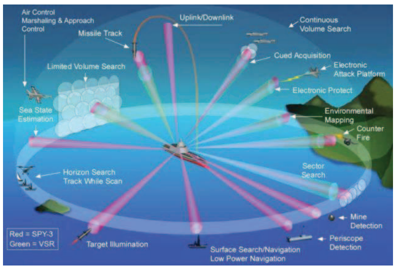
About Cerescon BV

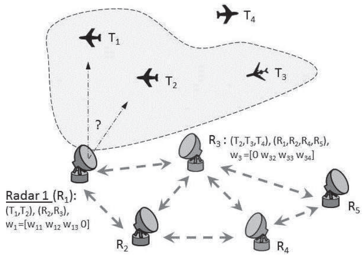
Cerescon is a very young, fast developing high tech startup. Cerescon is aiming at the development, the production and the marketing of an automated selective asparagus harvesting machine.
Asparagus production is up till now a very labour intensive part of horticulture.
The so called "white gold" is 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

The management problem in Multifunction Radar System

Radar networks that employ multiple, distributed stations have attracted a lot of attention due to the improvements in tracking and detection performance they may offer over conventional, standalone radars. Furthermore, recent advances in sensor technologies enabled a large number of controllable degrees of freedom in modern radars, e.g., Multifunction Radar. Thus, these radars are much more flexible than conventional, dedicated radars by being capable of performing multiple functions simultaneously – volume surveillance, fire control, and multiple target tracking.





The aforementioned flexibility introduces a need to effectively manage available radar resources to achieve specified objectives while conforming to operational and technical constraints. Therefore, the radar resource management plays a crucial role in the modern radar systems, and this is the main topic of this thesis.

In this thesis, some of the following radar management topics should be tackled:

- Time budget allocation in multi-target tracking
- Track selection in multi-target tracking and/or surveillance
- Online detailed waveform parameters selection
- Analyzing the existing performance metrics and developing new ones

The above problem(s) may be tacked using the tools related to optimization theory, game theory, partially observable Markov decision processes and/or other relevant approaches.

(Supervisors: Assoc. prof. Hans Driessen and Nikola Bogdanović)

Main literature:

F. Katsilieris, “Sensor management for surveillance and tracking: An operational perspective”, Ph.D. thesis, TU Delft, Delft University of Technology, 2015.

A. Hero et al., “Foundations and Applications of Sensor Management”. New York: Springer, 2008.

N. Bogdanović et al., “Track selection in multifunction radars for multi-target tracking: An anti-coordination game,” in Proc. of ICASSP, March 2016, pp. 3131–3135.

Future Surveillance Radar

Background

Surveillance radar is being used for monitoring large areas:

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

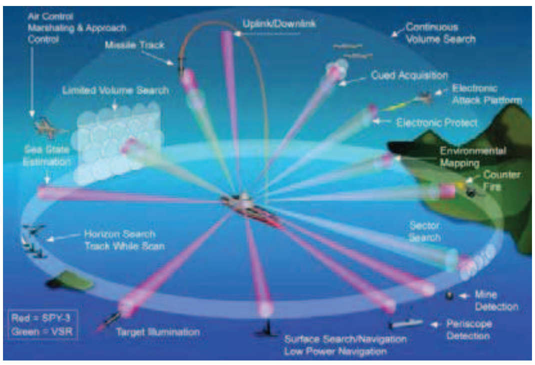
Modern radars have and will have increasingly more capabilities, among which:

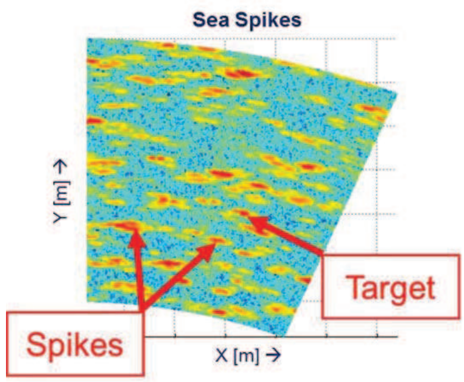
- Distributed transmission of (complex) waveforms;
- Huge processing capacity combined with advanced processing concepts.

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 (<u>see separate poster!</u>).





(Supervisor: Assoc. prof. Hans Driessen)

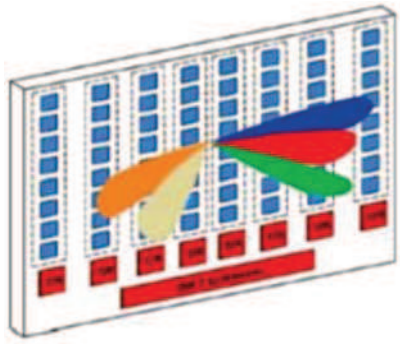
Advanced 5G Solutions

Side-Lobe Reduction in Antenna Arrays for 5G

MSc Yanki Aslan – PhD Candidate

Y.Aslan@tudelft.nl

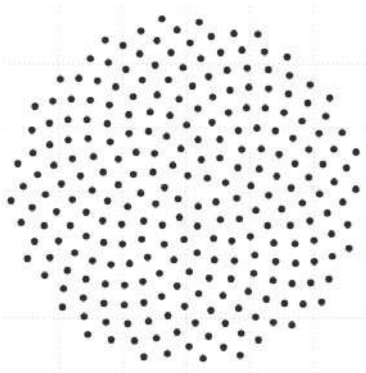
- Using the concept of beam-division multiple access (BDMA), a base station can communicate with a mobile device via a narrow beam. Meanwhile, two mobile devices in different beams can share the same radio resources (time & frequency), thus the capacity of a mobile communication system may increase greatly. Thus, it is beneficial to apply BDMA in the next generation access technology.

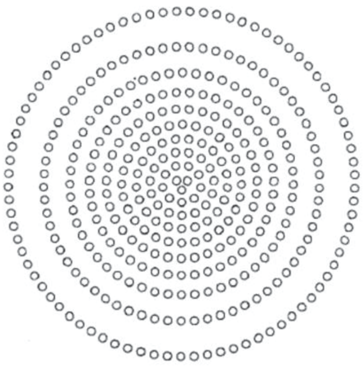


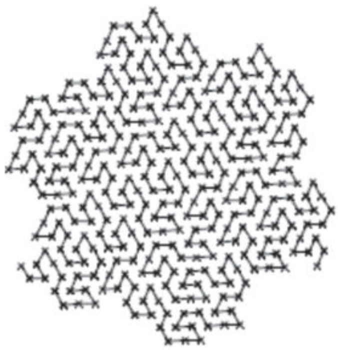
- Simultaneous transmission to a large number of users may cause strong inter-user interference. Therefore, arranging side lobe levels (SLLs) below a certain level is very critical.

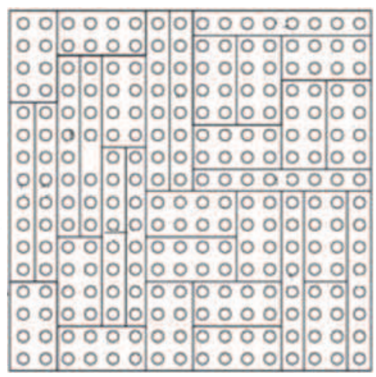
DIFFERENT TILING CONFIGURATIONS AND TECHNIQUES FOR ANTENNA UNITS

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



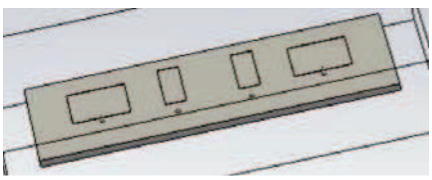


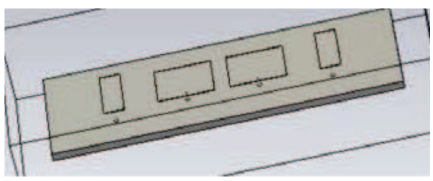


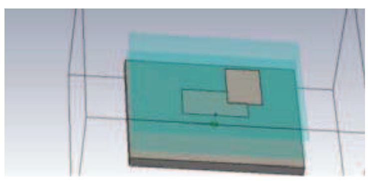


INCLUSION OF DIFFERENT ANTENNA ELEMENT TYPES IN ANTENNA ARRAYS

- Beam-width or directivity tapering & Direction tapering
- Different shapes for the elements, parasitic elements etc.







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

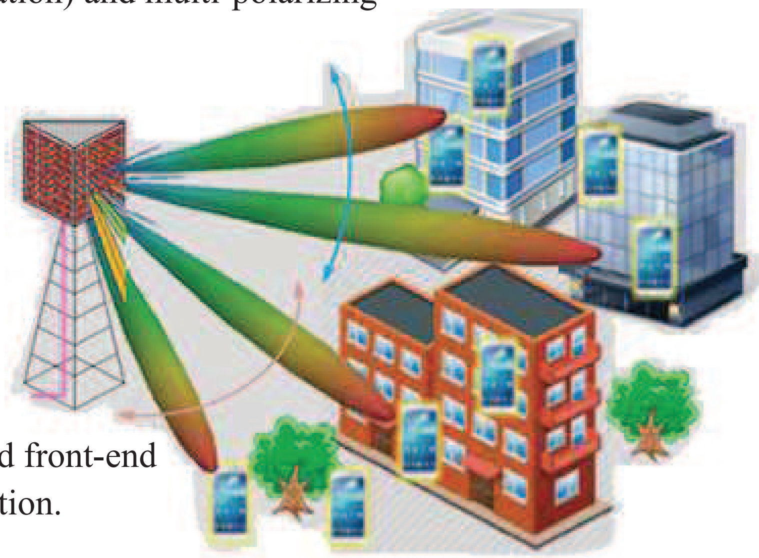
MS3 Master Event

February 13, 2017

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.

Master thesis project

Radar based Road Mapping and Vehicle Localization

Keywords: localization, radar, maps

Highly accurate localization of moving vehicles in urban environments is crucial for emerging autonomous driving. Current approaches integrate global positioning system (GPS), inertial measurement unit (IMU), wheel tick odometry, high-resolution panoramic imagery and light detection and ranging (LIDAR) data acquired by an instrumented vehicle, to generate high-resolution environment maps that is used for localization. Most of these sensors are not yet part of the standard equipment for modern cars. Therefore gathering the data for these maps still requires expensive special vehicles. Due to this, the process of gathering data for map generation is expensive and time consuming.

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.

The proposed project has the goal to develop a prototype demonstrating the feasibility to create a radar map that can be used for localization based on the output (peek-lists) from off-the-shelf radar sensors.
The list underneath provides an overview of the research questions to be answered in this project:

- Are radar measurements of the same sensor under similar circumstances repeatable
- Are radar measurements from different radar sensors repeatable
- Can the aggregated radar measurements be correlated with TomTom's LIDAR point cloud data

Answers to the above questions should provide sufficient basis to draw conclusions about the feasibility to create a radar map layer from LIDAR data.

For further information please contact
Roland van Venrooij, at roland.vanvenrooy@tomtom.com
or
Faruk Uysal, at f.uysal@tudelft.nl (TUD HB.21.280)

Microwave

Sensing, Signals and Systems (MS3) Group

INVITATION

MS3 MASTER EVENT

Come to learn about our group and current Master Thesis Projects

February 13^{th}

Event Program

15:30 Welcome (Snijderszaal)

- Introduction of MS3
- Short Stories from students
- Master Market

16:00 Lab Tours:

- PARSAX (23^{rd} floor)
- DUCAT (22^{nd} floor)

16:45 Reunion at Snijderszaal

- Social Time
- Closing with **Pizza**

Registration

Registration

Don't forget to register before Thursday February 9!

More information @ **radar.tudelft.com**

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