MSc graduation work at IRCTR

And some background on IRCTR

Synopsis

• **IRCTR = fundamental knowledge × cutting edge technology**
  – who we are
  – what we do
  – how we do

• **MSc++: enjoy your work & build-up your career**

• **A selection from the current MSc project offer**
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Who we are
The International Research Centre for Telecommunications and Radar, **IRCTR**

Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS)
Delft University of Technology

**Delft Technical University of Technology**

- oldest and largest technical university of The Netherlands
- around 13,000 students in 8 faculties
- international Master Courses; language: English
- around 5,000 staff members
- extended laboratories and facilities

TU Delft campus area
Overview on European cooperation

IRCTR profile

- Research Centre of Delft University of Technology
- Established for project driven research
- Brings applied pre-competitive research to industries and organizations
- Internationalization
- Supported by Dutch Government
IRCTR - general structure

- Radar
- Ground Penetrating Radar (GPR)
- Antennas/ applied electromagnetics
- Remote Sensing
- Telecommunications - Centre for Wireless Personal Communication
- Radio-navigation
IRCTR – radar/ GPR & antennas

Radar

• Mission statement:

   To understand physical effects (i.e. the propagation and scattering of electromagnetic waves) and the technology required to define, launch, receive, and process waveforms capable of extracting features from the received echoes; the theoretical research is complemented with properly designed experiments, leading to advanced experimental facilities.

• Components:
  
  – study of frequency and/or phase modulated waveforms, e.g. frequency and polarization agility ➔ high spatial resolution + multi-parameter descriptors of objects
  
  – future applications: a radar that operates as a communication device by coding its waveform
IRCTR – radar/ GPR & antennas

Ground penetrating radar (GPR)

• Mission statement:
  The development of Ultra-Wideband (UWB) technology for detection, ranging, positioning and classification of targets

Components:
  – ground penetrating radar: video impulse GPR and a stepped frequency continuous wave (SFCW) radar
  – UWB radar for human beings detection
  – UWB positioning and communications
  – improved GPR-antennas (including adaptive antennas)
  – new methods of subsurface imaging based on interferometry and polarimetry
  – the development of classification algorithms
IRCTR - radar/ GPR & antennas

Antennas/ applied electromagnetics

• Mission statement:

To create a bridge between the people involved in the theoretical investigations and those focusing on experimental validation

Eng goal: to master the complete chain: model ➔ analysis + optimisation ➔ physical implementation ➔ measurement

IRCTR - radar/ GPR & antennas

Antennas/ applied electromagnetics

• Components:
  – development of models (focus on time-domain approaches)
  – identifying the most adequate computational techniques to be employed for the analysis and optimisation of antennas
  – understanding the technological requirement for manufacturing them
  – streamlining the measurement methodologies
IRCTR - remote sensing

Atmospheric radar remote sensing

• Mission statement:

To develop new tools and methodologies for the observation of atmospheric phenomena with the aim to enhance the understanding of meteorological processes and to improve climate predictions

• Components:
  – electromagnetic scattering
  – sensor synergy
  – signal processing
  – radar technology
Radar earth observation

• Mission statement:

The development of new Synthetic Aperture Radar (SAR) technologies, be it for observation from space or the air.

• Components:
  – frequency-modulated, continuous-wave (FM-CW) radar based systems
  – P-band SAR systems
  – enhanced information extraction from radar data, for instance through radar signature studies and simulation
  – new applications in high-resolution and/or polarimetric imaging, moving-target indication and wind vector determination over water surfaces
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IRCTR - research activities

• Strategic research objectives:
  – radar
  – wireless communication

• Work philosophy:
  – large research programmes, often encompassing more specific projects
  – dedicated (smaller scale) projects
  – own initiatives → highly innovative domains
  – participation in wide international consortia
Projects - radar & GPR

Advanced Re-Locatable Multi-Sensor System for Buried Landmine Detection:
- time span: 1999-2006
- result: 2 operational radars
- One impulse radar and one SFCW radar

Projects - radar for atmospheric research

The transportable radar system for atmospheric measurements - TARA:
- based on the FM-CW radar principle
- measures clouds and precipitation as well as clear-air turbulence
- operational since 2001
Projects - agile radar

PARSAX
Polarimetric Agile Radar in S- And X-band

System Design and manufacturing of a Radar Allowing simultaneous BSM estimation of Non-stable Objects
The PARSAX radar developed in the project will be used for testing and validating a new method to separate targets and clutter by using polarimetric properties of backscattered radar signals.

- Generate and apply the orthogonal coded signals.
- Research on scattering fundamentals and experimental verifications by realizing a dual-transmit/dual-receive radar.

1. Generation of orthogonal coherent signals with a large BT product and 50MHz spectrum width in the 2 frequency bands: -60dB spurious level. (S-band, 3315+/-25MHz and X-band, [9700~10000]+/-25MHz).
2. Coherent digital processing of the received signals in at least 70dB dynamic range for signal spectrum width > 50MHz.
3. Zoom mode for the X-band extension (300MHz sweep generated for high resolution mode).
Functional diagram of S-(X-)band transmitter

Projects - agile radar

Functional diagram of S-(X-)band receiver
Parameters of PARSAX radar signals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FM signal</th>
<th>FM signal (modulated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency</td>
<td>1200 MHz</td>
<td>1200 MHz</td>
</tr>
<tr>
<td>Peak transmitted power</td>
<td>100 W</td>
<td>100 W</td>
</tr>
<tr>
<td>Signal energy</td>
<td>200 Hz</td>
<td>200 Hz</td>
</tr>
<tr>
<td>Signal type</td>
<td>PCM signal modulated by 8-ary sequence</td>
<td>LFM signal/linear frequency modulation</td>
</tr>
<tr>
<td>Sequence length</td>
<td>20 ns</td>
<td>20 ns</td>
</tr>
<tr>
<td>Doppler frequency</td>
<td>200 Hz</td>
<td>200 Hz</td>
</tr>
<tr>
<td>Signal spectrum width</td>
<td>20 MHz</td>
<td>20 MHz</td>
</tr>
<tr>
<td>Signal duration</td>
<td>100 ns</td>
<td>100 ns</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>200 MHz</td>
<td>200 MHz</td>
</tr>
<tr>
<td>RF product</td>
<td>50 MHz</td>
<td>50 MHz</td>
</tr>
<tr>
<td>Range resolution</td>
<td>3 m</td>
<td>3 m</td>
</tr>
<tr>
<td>Number of integration periods for Doppler processing</td>
<td>512</td>
<td>512</td>
</tr>
<tr>
<td>Doppler velocity resolution</td>
<td>0.07 m/s</td>
<td>0.07 m/s</td>
</tr>
<tr>
<td>Integrated time</td>
<td>0.07 m/s</td>
<td>0.07 m/s</td>
</tr>
</tbody>
</table>

Projects - agile radar

- **Signals generation**
  - Generation of codes sequence (I-Q quadratures) by means of DDS
  - DAC transformation into two analogue signals
  - Generation of modulated oscillators by means of analogue quadrature modulator

- **Algorithm of reception**
  - Transformation of RF oscillation into codes stream as a result of time and amplitude sampling by fast ADC
  - Estimation of the signal complex envelope described by pairs of IQ-components
Projects - agile radar

Airborne Ka-Band FM-CW SAR System:
- low-cost imaging radar systems of high resolution
- operation from very small, possibly even unmanned, airborne platforms
UWB security and communications

Ad hoc networking & Positioning using time difference
Masts calibrate using satellite positioning
Temporary mast mounted UWB radio
Display of personnel locations

Projects - antennas/ applied EM

Antennas
Transmitting Antenna
Pulse Generator Head
Wireless Triggering Line
Antenna Under Test

Antenna Pattern
Personal Computer
Digital Sampling Oven
Projects - antennas/ applied EM

Wide Band Sparse Element Array Antenna (WiSE):
- elementary radiators design
- non-periodic placement + interleaving
- manufacturing
- measurement
Projects – antennas/ applied EM

Time-domain investigation of antenna systems:
- the pulsed-field multiport antenna system reciprocity relation by means of a time-domain approach

Projects – remote sensing

New radar system for the study of light rain:
- system design
- signal processing
- observation strategies
Projects - remote sensing

Radar observation studies:
- data processing
- data analysis
- image processing

Parameter estimation:
- sensor fusion
- retrieval techniques
- application
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The staff

- 3 Professors
- 2 Associate Professors
- 3 Assistant Professors
- 11 supporting/ technical staff
- 17 PhD students

A united, well honed TEAM
Measurement facilities

• Delft University Chamber for Antenna Test (DUCAT)

• Millimetre wave measurement facilities

  Hewlett-Packard network vector analyzer
  up to 110 GHz

  ABmm network vector analyzer
  up to 350 GHz
Software resources

In-house developed software

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The work environment

• IRCTR - a highly international construction:
  – multi-national staff
  – many visiting/ exchange students
  – frequent visits of reputed scientists

• Interested in placements abroad? Make use of our international network of collaborations

• Direct access to measurement facilities

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The Pulsed-Field Multiport Antenna System
Reciprocity Relation – A Time-Domain Approach

Adriaan T. de Hoop, Member, IEEE, Valerio Tomazzetti, and Leon Van Bladel

Abstract—A direct time-domain approach to the derivation of
the pulsed electromagnetic field multiport antenna system reciprocity theorem is presented. The theorem introduces the field and system properties in two states: the transmitting state and the receiving state. Two types of antenna systems are discussed: the Kirchhoff circuit one whose local properties are described in terms of multipole Kirchhoff circuits and the waveguide one whose ports consist of multipole guiding waveguide sections.

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Keywords—Antenna theory, reciprocity relation, time domain, equivalent circuit.

Scientific publications in high standard journals:

– MSc student on a Socrates exchange programme obtained MSc degree with highest honours
– manuscript submitted to IEEE Transactions on Antennas and Propagation

Manuscript received: 12 January 2021
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Conference proceeding publications:
- accepted full paper at the 1st European Conference on Antennas and Propagation, EuCAP 2006, Nice

- accepted full paper
- presentation at the 3rd European Radar Conference, EuRAD 2006, Manchester
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MSc projects - radar

- **Title of the project:** New waveforms for Radar -1
- **Subtitle:** Digital matched filtering of the FMCW signals
  - an FPGA based approach
- **Tutor:** Dr O. Krasnov
- **Professor:** Prof. P. van Genderen
- **Description of the project:**
  To develop, model and optimize the FPGA based implementation of the real time algorithm for the polarimetric FMCW radar
MSc projects - radar

• **Title of the project:** New waveforms for Radar -2
• **Subtitle:** Optimal orthogonal PCM codes for the PARSAX polarimetric radar
• **Tutor:** Dr O. Krasnov
• **Professor:** Prof. P. van Genderen
• **Description of the project:**
  The modelling, analysis and selection of the pairs of codes with a given length, which are optimal for the best orthogonality in the whole predefined range of time delays

MSc projects - radar

• **Title of the project:** Design of the hardware circuits for the real-time calibration of the polarimetric PARSAX radar
• **Tutor:** Dr O. Krasnov
• **Professor:** Prof. P. van Genderen
• **Description of the project:**
  To develop, model and analyse the interchannel transmitter synchroniser and calibration circuits
MSc projects - antennas/ applied EM

- **Title of the project:** Pulsed electromagnetic wave propagation along a closed waveguide – A pulse distortion analysis
- **Supervisor:** Dr.ing. I. E. Lager
- **Scientific advisor:** Prof. Dr. Ir. A.T. de Hoop (emeritus professor, Lorentz chair)
- **Description of the project:**
  The explored topic is highly innovative; the contents is primarily theoretic, but has a large applicative potential

MSc projects - antennas/ applied EM

- **Title of the project:** Pulsed-field smart antenna systems analysis
- **Supervisor:** Dr.ing. I. E. Lager
- **Scientific advisor:** Prof. Dr. Ir. A.T. de Hoop (emeritus professor, Lorentz chair)
- **Description of the project:**
  The explored topic is highly innovative; the investigations focus on the development of theoretical models; the application area can be found in the impulse radio (an extremely hot topic in communications)
MSc projects - antennas/ applied EM

• Title of the project: Electromagnetic detection and ablation of female breast cancer
• Supervisor: Dr.Ir. B. J. Kooij
• Scientific advisor: Dr.ing. I. E. Lager
• Description of the project:
The explored topic has a very high societal impact; the project concerns a feasibility study, and assumes a numerical analysis of a highly inhomogeneous domain; the project is part of a cooperation with the Universitair Medisch Centrum Utrecht

MSc projects - remote sensing

• Title of the project: Signal processing for a turbulence radar
• Supervisor: Dr H. Russchenberg
• Scientific/technical advisor: C. Unal
• Description of the project:
IRCTR is developing a new technique to routinely measure turbulence in the atmosphere; the information can be applied in aviation safety, and more generally: in atmospheric sciences
MSc projects - remote sensing

• Title of the project: Space-based radar observations of clouds
• Supervisor: Dr. H. Russchenberg
• Scientific/ technical advisor: Dr. O. Krasnov
• Description of the project:
  Clouds are very important regulators of radiation in the atmospheres; however, their role in the climate systems is far from understood; in fact, it is the most unsure element in climate predictions.