Application for EDITE Scholarship: Physical layer-based geocasting using multidimensional modulations and antenna arrays

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June 08, 2018

Outline

Academic Career (1)

General Overview:

High School: 2007-2013 (18yo)

- At *Athénée Royale d'Uccle 1*, Bruxelles
- Orientation Mathematics (8hrs/week) and Sciences (7hrs/week)
- Grade: $16^{+}/20$

Bachelor: 2013-2016 (21yo)

- At *Université Libre de Bruxelles*
- 2 days entrance exam (4x4hrs)
- Bachelor of engineering focus **electronics and information technologies**
- Mention: Distinction $14^{+}/20$

Master: 2016-June 2018 (23yo)

- *Bruface* program
- Double Degree
- Master of Science in Electrical Engineering focus **electronics and information technologies**

Academic Career (2)

Bruface Master's program description:

- Bruface stands for **Br**ussels **Fac**ulty of **E**ngineering
- **Double Master Degree** between the *Université Libre de Bruxelles (ULB)* and the *Vrij Universiteit of Brussel (VUB)*
- Fully taught **in English**
- **Worldwide** recognized: ESN, T.I.M.E, UNICA networks
- Particularity: lot of team projects:
  - Conception of the DVB-S2 communication chain using **Matlab**
  - Design of a classification-based CNN for automatic image colorization using **Python**
  - Conception of a complete SIMO OFDM tranceiver chain using **Matlab**

Teaching activities: 2015-ongoing

- Assistant during summer exams at *Passe La Première*
- Mathematics for L1 and L2 students
- Fluid Mechanics and Transfer Processes for L3 students

Academic Career (3)

Belgian System

- Possibility to do an Internship at the beginning of MA2 (not mandatory)
- Master Thesis at the end of MA2 (mandatory)

$\Rightarrow$ I opted for a 3-month Internship followed by a Master Thesis treating the same subject: the development of the Spatial Data Focusing theory

- Longer study of the problematic
- Preamble for the PhD

$\Rightarrow$ Need to introduce the Spatial Data Focusing theory

Goal: Wireless broadcasting of geolocalized data

- Data sent whether the user is there or not
- System does not know users location:
  - User privacy respected
  - Less data traffic
  - Ideal in indoor environments
- Many real-life applications:
  - Interactive contents in museums
  - Danger areas indication for visual impaired persons (zebra crossings)
  - Alert people within an area of sudden emergency

Figure: Example of beamforming

Spatial Data Focusing (2)

Solution

Spatial Data Focusing is a new promising theory (2016) introduced by Prof. Julien Sarrazin, Sorbonne Universités, Paris

- Original technique: **Focusing of data** instead of power focusing (beamforming) towards specific spatial locations
- Main idea: Mapping symbol stream into N-dimensional space. Each dimension is sent by 1 antenna (use of antenna array)
- If the user is not in the predefined direction $\Rightarrow$ **Space orthogonality** is lost

Figure: Beamforming (left), Spatial Data Focusing (right)

Spatial Data Focusing vs Beamforming

- Narrower beam-width (region of correct data detection) obtained with Spatial Data Focusing
- Lighter infrastructure with Spatial Data Focusing

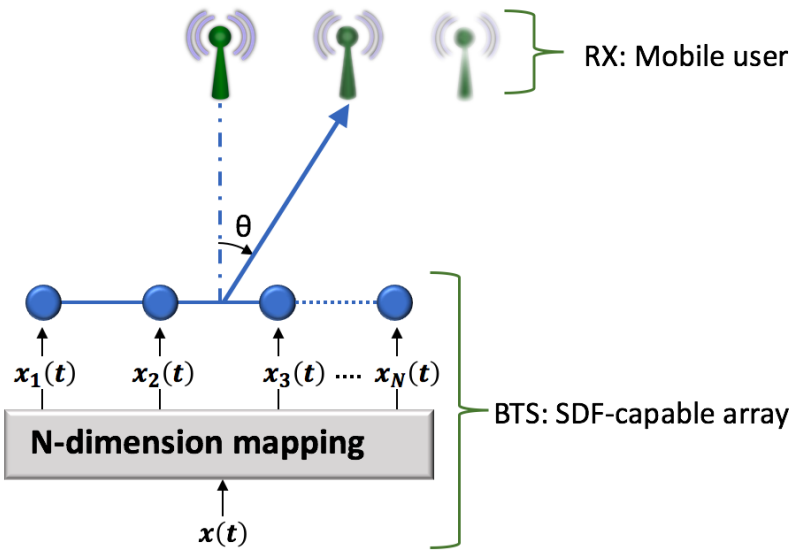

Figure: Architecture of ND TSDF

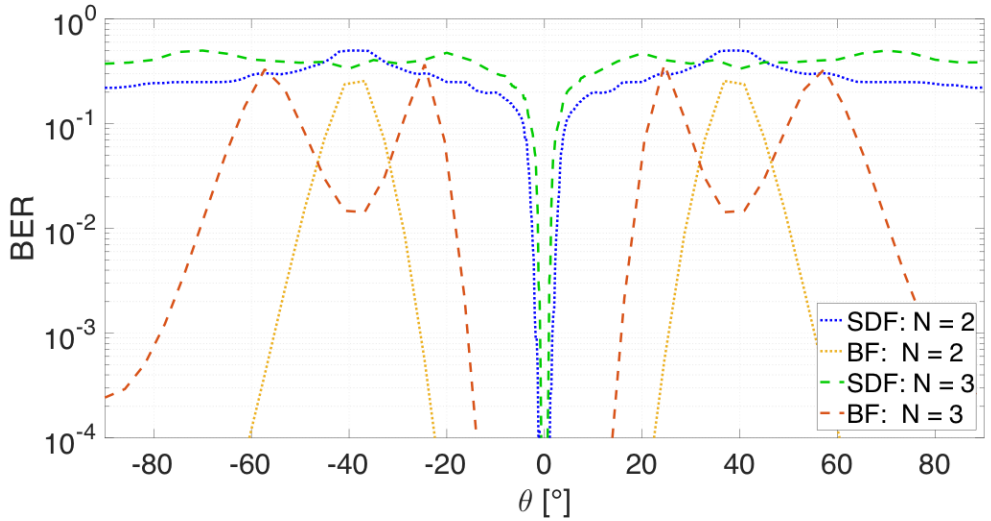

Figure: BER-θ

	Beamforming	SDF
N=2	$\Delta\theta = 51°$	$\Delta\theta = 3.3°$
N=3	$\Delta\theta = 31°$	$\Delta\theta = 1.8°$

Internship at the *Laboratoire d'Electronique et Electromagnétisme* (L2E) from the Sorbonne Universités, in summer 2017

- Experimental validation of SDF ⇒ Conception of a test-bench using Software Defined Radio in order to test focusing algorithms

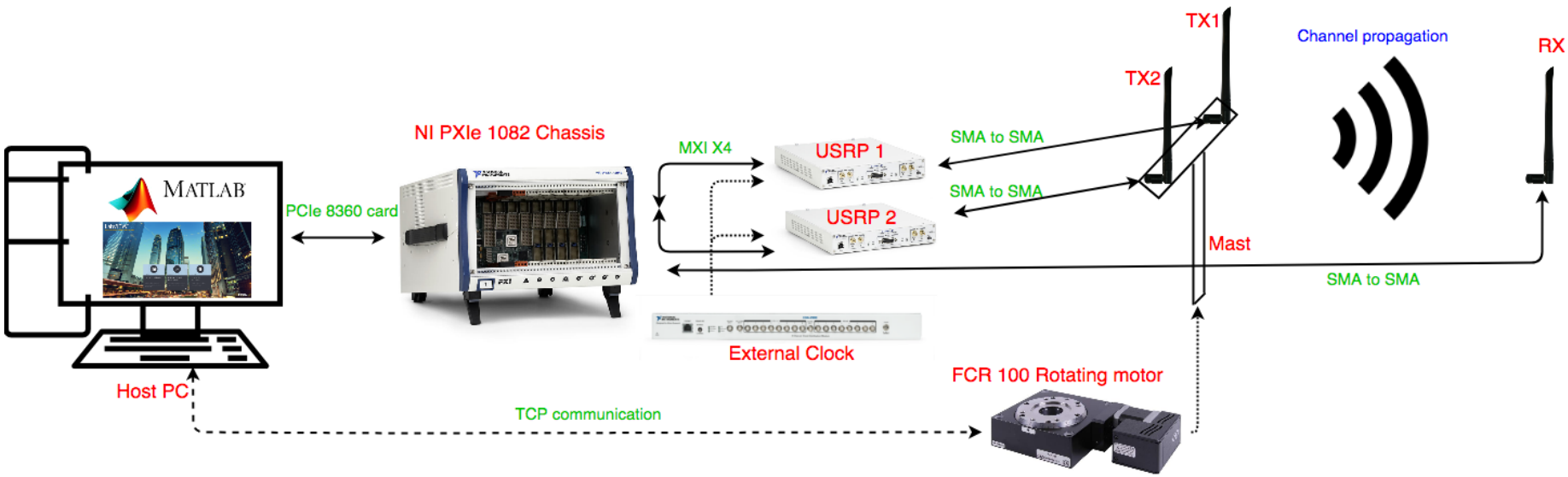

Figure: Test-bench setup

Master Thesis (November 2017-June 2018)

Hyper Resolution Spatial Data Focusing: A time Approach

Presentation of the work:

- Consequent work: 24 ECTS, 8 months, 80 pages, in English
- In close collaboration between ULB and Sorbonnes Universités

Physical comprehension of the Spatial Data Focusing Theory:

- Theoretical Development of 2D/ND time domain approach of the theory:
  - Maximal level of noise allowed to reach the desired BER in the desired direction
  - Establishment of the relationship between the beam-width and the communication parameters
- Validation of the derivation in the anechoic chamber, in April 2018
- Contribution to a publication: J. Sarrazin, M. Odhiambo, S. Golstein, P. De Doncker, F. Horlin, "*Spatial Data Focusing: an alternative to Beamforming for geocasting scenarios*"
  - **IEEE Antennas and Propagation Symposium (APS)**, Boston (USA), Jul. 2018
  - **IRACON COST 7th Meeting 2018**, Cartagena (Spain), May 2018
  - **AREMIF day**, Paris (France), June 2018

PhD thesis in cotutelle between L2E (Sorbonne Universités) and Opera Service (Université Libre de Bruxelles)

- **Supervision** of the PhD by Pr. Dr. Ir. Julien Sarrazin from the **Sorbonne Universités** (multi-antenna and measurement specialist)
- **Co-supervision** of Pr. Dr. Ir. Philippe De Doncker from **ULB** (channel propagation specialist)
- **Involvement** of Pr. Dr. Ir. François Horlin from **ULB** (synchronization and digital communication specialist)

$\Rightarrow$ Reinforcement of the International Relations between the Sorbonne Universités and the Université Libre de Bruxelles

Spatial Data Focusing is a new promising theory ⇒ A lot to investigate

Goal: Develop a suitable technique to perform data focusing toward a given geographical area

- Theoretical aspects:
  - Establish the fundamental Data focusing limitation
  - Find suitable degrees of freedom to achieve beam width of any size
  - 2D focusing aspects
- Experimental aspects:
  - Massive MIMO test-bench to increase the number of antennas (limited to 3 antennas today)
  - Test Spatial Data Focusing in outdoor environments ⇒ Conception of a new test-bench
  - Real-time demonstrator if time allows

⇒ **New scientific topic but in the continuity of the work I have conducted for last one year**

Presentation of the PhD (3)

Estimated planning of the 3-year PhD