Thesis subject – Academic Year 2023-2024

Design of advanced beam-forming techniques for simultaneous scanning & communication operating modes antennas for 5G/6G OpenRAN

Laboratory: Lab-STICC UMR 6285 – www.labsticc.fr

Financial support: Project PIEEC 5G – DGE / BPI France

PhD Supervision:
Prof. Christian Person, Lab-STICC/ IMT Atlantique, CS 83818, 29238 Brest cedex 03, France

email : christian.person@imt-atlantique.fr

Keywords: Design and synthesis of multi-beam antennas, active antenna, 3D integration technologies, electromagnetic modeling, integrated antennas, electromagnetic coupling, radome, meta-surfaces, beamformer

1. Context

This project is part of the PIEEC European initiative “Microelectronics and Communications” (Important Project of Common European Interest - PIEEC) carried by the Telco operator Orange. It aims to develop concrete solutions for the next digital decade of Europe by creating and deploying secure and sustainable digital infrastructures through “5G everywhere”. The solutions will contribute to the digital transformation of businesses through vehicular infrastructure and services (vehicle-to-X) as well as private 5G networks. Collaboration with the microelectronics sector will enable alignment of research throughout the digital value chain.

The main challenge of the project as a whole is to allow the entire territory to benefit from new 5G services. This necessarily requires effective and economical solutions for radio access to ensure total coverage of France.

2. Ambitions – Objectives of the thesis

IMT Atlantique and the laboratory Lab-STICC (www.labsticc.fr) contribute to this ambitious project, by developing specific research building blocks or components. As part of this thesis, we are working on the implementation of “Plug-in” solutions for Radio access interface components for the so-called OpenRAN (Open Radio Access Network) access network, providing new functionalities for antenna systems. This involves developing key hardware technological components, i.e. Radio Units (RUs), making it possible to investigate advanced integration solutions with dynamic reconfigurability capabilities to adapt to network requirements.

For the 5G/6G access network, an OpenRAN approach is promoted, with a mutualization of radio functionalities control operations in the CU (Central Unit), or a distribution in the DU (Distributed Unit) or at the nearby antenna radio front-end in the RU (Radio Unit).

3. Objectives / Expected results & out-comes:

The improvement of 5G communication networks performances brings strong constraints on the implementation of MIMO systems in the RU, with enhanced capabilities in terms of multi-beam operating modes that can be dynamically changed depending on expected data rates and environmental impact. The ability to scan and to optimize communication links, with the ambition of reducing power consumption and ensuring interoperability and multimodal connections are addressed by this thesis.

As part of this proposal, we are working on the development of “Plug-in” solutions for radio access interface components at the OpenRAN (Open Radio Access Network) layer, focusing on antenna systems to provide new features.

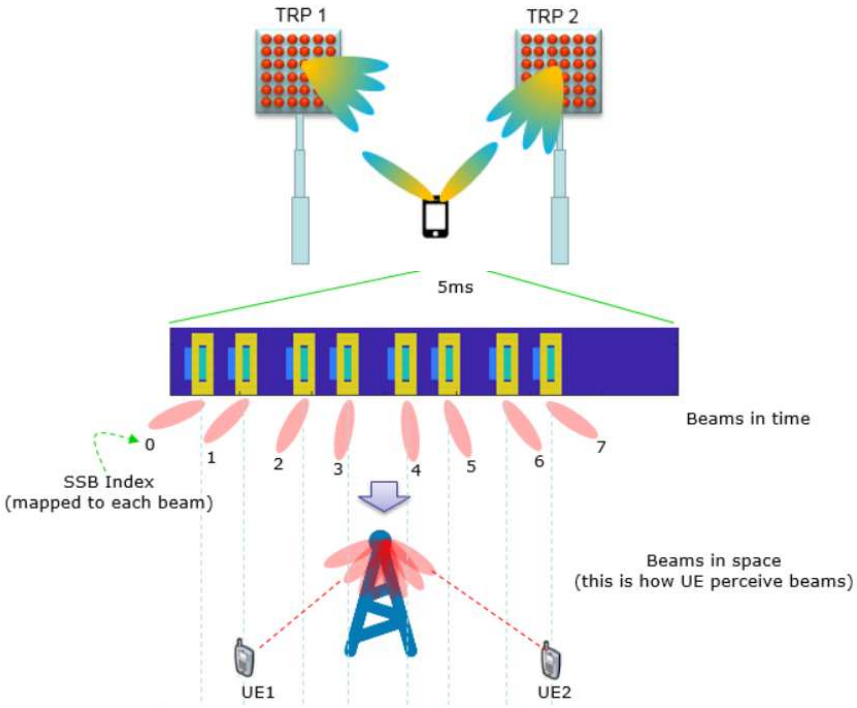

Illustration of reconfigurability for Radio Units in the 5G NR (New Radio) context [1]

4. Work organization:

Task 1: New beam-forming concepts – State of the art: Analysis and Specifications

Based on the analysis of the limitations of “off-the-shelf” solutions, the first part of the thesis aims to identify concepts of antenna networks currently used for 5G/6G Radio Units, including in particular reconfigurability radiation properties. This involves firstly analyzing the capabilities and performances of currently available solutions, by identifying the limitations (level of reconfigurability (spacial diversity, frequency, polarization, simultaneous multi-channels), control constraints (interfaces and dual TX/Rx modes possibilities), dimensions, radiation performances (isolation, gain, ...), etc...).

This state-of-the-art analysis will permit to identify expected developments and performances in terms of sensing and reconfiguration operations for Base station Units.

The study of technical needs for Radio Units will also address the analysis of baseband and fronthaul functions, and especially control interfaces structures supported for the monitoring of multi-sectorial radiations. Algorithm and Analog to Digital/Digital to Analog interfaces /processors commonly used for these functionalities are necessary integrated with other subsets within a Radio Unit. Capabilities and constraints related to such interfaces are to be identified to evaluate limitations and operational configurations of Open RAN compatible with 5G/6G supported standards.

Task 2: A new paradigm for reconfigurable network antenna – Concepts & Advanced designs

We will investigate new approaches, with proofs of concept allowing us to offer new radio sensing and multiple beamforming functionalities. We will contribute to the design and optimization of multi-beam antennas for spatial diversity and multi-band capabilities.

Two research strategies can be studied:
- On the one hand, we will focus our efforts on the design of array antenna systems enabling sub-beam control for multi-beam spatial diversity.
- Secondly, it could be considered to manage frequency sub-bands distinctly in terms of beamforming to provide various coverage scenarios. One issue could be the mitigation of FR1 (Sub-6Ghz) and FR2 (millimeter waves) bands thanks to co-integrated structures.

Task 3: Reconfigurable network antenna solutions offering new hybrid functionalities

The optimization of the radio link toward users must increasingly make it possible to consider simultaneously new performances in terms of electromagnetic footprint of the radio coverage and energy consumption of the network through better exploitation of spectral resources. We propose to investigate radio sensing techniques to better manage this radio link according to user needs and quality of service, with a better consideration of the use of radio, electromagnetic and energy resources.

References

[1] “5G ShareTechnote," https://www.sharetechnote.com/html/5G/5G_Phy_BeamManagement.html

[2] Mustafa Mohsin et al., “On Analyzing Beamforming Implementation in O-RAN 5G”, mdpi Electronics 2021, 10, 2162.

[3] Puglielli et al.: “Design of Energy- and Cost-Efficient Massive MIMO Arrays”, Proceedings of the IEEE Vol. 104, No. 3, March 2016 – p 588- 606

[4] Simonsson, A.; Petersson, S. O.; Widell, G., “Indoor and Mobile Radio Communications, Dual Polarization Beamforming Coverage Demonstrated with 5G NR SSB”, IEEE, IEEE International Symposium on Personal communications, 2021

[5] Y.-N. R. Li et al.: Beam Management in Millimeter-Wave Communications for 5G and Beyond” January 22, 2020., VOLUME 8, 2020 DOI 10.1109/ACCESS.2019.2963514

[6] B. Yang, Z. Yu, J. Lan, R. Zhang, J. Zhou, and W. Hong “Digital Beamforming-Based Massive MIMO Transceiver for 5G Millimeter-Wave Communications”, IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 66, NO. 7, JULY 2018

Candidacy - modalities:

Skills: Electromagnetism, Filters & Antennas – RF Design, High Frequency CAD, 3D Additive Printing Technologies

Theoretical skills: Solid background in one or more of the following domains:

- Theoretical and computational electromagnetics
- Microwave and mm-wave antennas & components
- Technologies for antennas

Technical skills: Experience in one more or more of the following technologies/tools:

CAD Tools (HFSS™, CST™, etc..), Matlab™, Python™

Profile required: Holder of a postgraduate diploma, Master of research or engineer diploma in the domains of physic, Electromagnetisms, Antennas, high frequency components design.

Fluency in English is required, a spirit of collaboration and of initiative in the face of technological challenges.

Intended starting dates: October 2024 or before – Duration 36 months

Modalities / How to apply:

The interested candidates are invited to email (to Christian Person - christian.person@imt-atlantique.fr)

the following elements:

- CV detailing in full your academic background including all modules taken
- Motivation letter
- Academic notes transcript

and optionally, letters of recommendation

Context of the thesis / Location

The research activities will be done thesis is done in the context of the laboratory Lab-STICC – UMR CNRS 6285 at IMT Atlantique (Engineering School).

The selected student will also be associated to other activities of the research group: group meetings, seminars, social events

In detail, the hosting facilities for the thesis is described below:

Establishment: IMT Atlantique Bretagne/Pays de la Loire (Brest campus), a high graduate engineering school (postgraduate): www.imt-atlantique.fr

Laboratory: LabSTICC/DH Team : https://www.labsticc.fr/en/index/

Contact

Prof. Christian PERSON - Director
Lab-STICC / IMT Atlantique
CS 83818
29238 Brest cedex 03, France

Email : christian.person@imt-atlantique.fr