PHD OPPORTUNITIES ON RECONFIGURABLE DIRECTIVE ANTENNAS, FRANCE, 2023

General context

Since decades, mechanical-based solutions as reflectors are widely used for reconfigurable directive antennas. Such solutions, although effective, are bulky and present limitation in terms of agility, tome of reconfiguration and diversity for multiple-beam generation. In order to integrate the antennas in smaller footprints, phased arrays are also an established technology to provide fast beamforming or beam-shaping capabilities. However, phased arrays are limited by their cost, efficiency and thermal management.

In the framework of a national project on reconfigurable directive antennas, key academic French Research laboratories (CEA LETI, ICMCB, IETR, Telecom Paris and XLIM) are joining forces to propose innovative architectures for reconfigurable low-profile and highly directive antennas to go beyond the current state of the art. In this framework, three PhD positions are proposed to tackle next generation challenges for highly directive antennas in a very unique collaborative environment.

The PhD position will start in October 2023 and will be guested by CEA LETI (Grenoble), IETR (Rennes), Telecom Paris (Palaiseau) and XLIM (Limoges). Mobility among laboratories is also foreseen for some PhDs. **Notice that European citizenship is required** due to the defense context of the applications.

PHD 1 : WIDE ANGLE SELF-COMPLEMENTARY ANTENNA ARRAY

Background

Different topologies of broadband directional antennas can be found in the literature. They can be grouped into the following four topologies: Capacitively end-loaded dipoles [1], Long slot array [2], Fragmented antenna [3] and Self complementary array [4].
The current limitations of these solutions are of several kinds. First of all, the frequency band(s) to be covered while maintaining the performances in terms of matching and radiation represent a first latch. For a part of these solutions, the performances in terms of wide-angle beam scanning and active VSWR are often limited to a 60° or smaller elevation. Finally, obtaining an array with many modules and a complex control architecture is a drastic constraint to be minimized to reduce the overall cost of the radiating panel.

Objectives

The work proposed in this PhD focuses on self-complementary antenna arrays. Previous work from TelecomParis has shown that it is possible to design a metamaterial antenna with a thickness lower than $\lambda/4$ at the lowest operating frequency and with a fractionnal frequency bandwidth ratio of 6:1 up to 45° and 5:1 up to 60° for the two main polarizations.

To further improve the performances of this architecture, the research work proposes to address the following issues:

- Derive the antenna design to the frequency band chosen for the study (X and Ku) using an egg-crate structure [5] as a host environment for the feeding system.
- Evaluate the possibility of reducing the number of controls of the developed array, with the ultimate goal of reducing the cost while maintaining the required efficiency,
- Optimize a Wide Angle Impedance-Matching (WAIM) superstrate to increase the beam scanning capabilities beyond 60°,
- Optimize the system performances in terms of Radar Cross Section (RCS) reduction.

PhD profile

The recruited PhD student should have a Master 2 degree (or an engineering degree) with a specialization in Electromagnetism, Antennas, Microwaves, High Frequency Electronics. Strong knowledge in antenna design, electromagnetism, circuit theory, as well as in the use of commercial electromagnetic software will be required. A good level of spoken and written English is required.

Supervision and contacts to apply

PhD Director: Xavier Begaud, xavier.begaud@telecom-paris.fr
PhD Co-Director: Cyrille Menudier, cyrille.menudier@xlim.fr
Co-supervisors: Anne-Claire Lepage, anne-claire.lepage@telecom-paris.fr
Co-supervisors: Marc Thevenot, marc.thevenot@xlim.fr

Candidates should send a CV, their academic transcripts, and the contacts of two referees.

Main location: Telecom Paris (Palaiseau)

References

[1] R.C. Taylor,"Wideband Phased Array Antenna and Associated Methods", US Patent n° 6,512,487 B1, Jan. 28, 2003.
[2] S.W. Livingston et al., "Antenna Arrays Using Long Slot Apertures and Balanced Feeds", Patent n° US 7,315,288 B2, Jan. 1, 2008.
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[4] S. Varault, M. Soiron, A. Barka, A-C. Lepage, X. Begaud, RCS reduction with a Dual Polarized Self-Complementary Connected Array Antenna, IEEE Transactions on Antennas and Propagation, vol. 65, no. 2, pp. 567-575, Dec. 2016.
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PHD 2 : WIDE-ANGLE AND WIDE-BANDWIDTH SLOT CONNECTED ARRAYS

Background

Connected slot and dipole arrays are broadband, wide-angle beamsteering antenna solutions [1]-[3]. The principle of operation is to create a continuous current distribution over the radiating aperture, to avoid resonances and to reduce the active impedance variations of the array elements over a wide band and a wide-angle beamsteering. A ground plane behind the array is necessary to make the radiation unidirectional with an impact on the thickness and RF performances. The stacking of these arrays may require several metal layers [4] or very bulky

feed circuits with the possible excitation of common modes at the expense of polarization purity [5]. However, these arrays achieve great performances, with bandwidths of 5:1 over fields of view up to ±70° in elevation [5]. The bandwidth and scan angle can be improved by replacing the ground plane with multiple Frequency Selective Surfaces [6] or by using Wide Angle Impedance-Matching (WAIM) [7], [8]. However, the design and manufacture of these arrays with standard technologies, e.g. PCB (Printed Circuit Board), as well as the large number of active elements needed for their feeding are major obstacles for the deployment of this antenna technology

Objectives

This work will overcome the limitations of current state-of-the-art solutions in terms of the complexity of the unit cell of the array (number of dielectric and metallic layers of the stack) and the feeding network. In particular, the main objectives (OB) to be achieved are the following:

- Research on an elementary cell design in dual-polarization suited to PCB fabrication and with a thickness compatible with such fabrication. In particular, we aim to reduce the distance between the ground plane and the radiating aperture as well as the thickness of the WAIM without impacting the radiation bandwidth and beam scanning of the array ;
- Reduction of the number of feeding points of the array elements either by optimization of the lattice or excitation weightings, or by feeding via quasi-optical beamformers ;
- Design of a compact, low-profile connected array capable of meeting the expressed needs in terms of bandwidth (>50% relative band) and beamsteering (>70° in elevation).

PhD profile

The recruited PhD student should have a Master 2 degree (or an engineering degree) with a specialization in Electromagnetism, Antennas, Microwaves, High Frequency Electronics. Strong knowledge in antenna design, electromagnetism, circuit theory, as well as in the use of commercial electromagnetic software will be required. A good level of spoken and written English is required.

Supervision and contacts to apply

PhD Director: Ronan Sauleau, ronan.sauleau@univ-rennes.fr
PhD Co-Director: Cyrille Menudier, cyrille.menudier@xlim.fr
Co-supervisor: Mauro Ettorre, mauro.ettorre@univ-rennes.fr
Co-supervisor: Marc Thevenot, marc.thevenot@xlim.fr

Candidates should send a CV, their academic transcripts

Main location: IETR (Rennes)

References

[1] M. H. Novak, F. A. Miranda, and J. L. Volakis, "Ultra-wideband phased array for millimeter-wave ISM and 5G Bands, realized in PCB," IEEE TAP, Vol. 66, No. 12, pp. 6930 - 6938, Dec. 2018.
[2] M. Ettorre, F. Foglia Manzillo, M. Casaletti, R. Sauleau, L. Le Coq, and N. Capet, "Continuous transverse stub array for Ka-band applications," IEEE TAP, Vol. 63, No. 11, pp. 4792 - 4800, Nov. 2015.
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[5] E. Yetisir, N. Ghalichechian, and J. L. Volakis, "Ultra wideband array with 70° scanning using FSS superstrate," IEEE TAP, Vol. 66, No. 10, pp. 4256 - 4265, Oct. 2016.
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PHD 3 : DUAL-BAND ELECTRONICALLY RECONFIGURABLE FLAT LENS ANTENNAS WITH ULTRA-WIDE SCAN RANGE

Background

Antennas on mobile satellite ground terminals have to scan in a wide field of view, transmitting (Tx) and receiving (Rx) in separate frequency bands. Current systems rely on separate Rx and Tx mechanically steered antennas. Their costs and size are unsuited for many applications, often requiring strict aerodynamic constraints.

Reconfigurable flat lens antennas, also known as transmitarrays [1]-[5], are promising candidates for energy-efficient high-performance electronic beam scanning. The flat lens is spatially fed by a primary source. Each unit cell of the lens introduces an optimized phase shift on the incident wave, to steer and shape the radiation pattern. The phase profile over the lens can be dynamically modified using simple reconfigurable devices in each cell, such as switches (e.g. pin diodes) [2], [3] or varactors [4], [5].

However, several design challenges have to be addressed to develop beam-steering flat lenses with enhanced functionalities and performance.

In particular, no multi-band electronically beam-steering flat lenses have been reported. Only a few dual-band fixed-beam prototypes were presented [6], [7]. They often comprise cells larger than half a wavelength, which degrades scan range and aperture efficiency.

Moreover, state-of-the-art single-band beam-steering designs exhibit high scan losses (>4 dB) for scan angles >45°, due to relatively directive patterns of their unit cells.

Objectives

The thesis aims to propose and experimentally demonstrate novel concepts for the design of wideband/multi-band electronically beam-steering flat lens antennas. The main goals are:

- Study of new approaches for designing unit cells with broad radiation patterns, stable performance under oblique incidence and wideband/multiband operation. Electrically thin subwavelength cells and Huygens' radiating elements [5], [8] will be investigated to tailor the angular and frequency response of the cell.

- Study of novel solutions enabling a fine electronic control of the phase shift introduced by the cells. Multilayer cells comprising either pin diodes or varactors, or a combination of both, will be analyzed. The trade-offs between phase resolution, loss, bandwidth, power consumption, number of reconfigurable devices and bias lines, will be considered.
- Development of dedicated synthesis procedures to enable the independent control and shaping of the radiation pattern at two or multiple frequencies.
- Design and experimental demonstration of high-gain dual-band fixed-beam and 2-D electronically beam-steering prototypes with extremely wide scan ranges (±60° or greater). The demonstrators will operate in typical Satcom bands (e.g., K- and Ka-band).

PhD profile

- M.Sc. or equivalent degree in Electrical Engineering or Physics. Solid background in electromagnetic (EM) theory, antennas, microwave circuits and components.
- Some experience with EM simulation (e.g. HFSS, CST) and scientific computation (Matlab, Python) software.
- Fluent in English, able to work both independently and in a multicultural team.
- European nationality is required.

Supervision and contacts to apply

PhD Director: Dr. Antonio Clemente, antonio.clemente@cea.fr
Daily supervisor: Dr. Francesco Foglia Manzillo, francesco.fogliamanzillo@cea.fr
External supervisor: Prof. Ronan Sauleau, ronan.sauleau@univ-rennes1.fr

Ph.D. duration : 3 years. Main location : CEA – Leti (www.leti-cea.com), Grenoble, France.

Candidates should send a CV, their academic transcripts, and the contacts of two referees.

References

[1] J. R. Reis, M. Vala and R. Caldeirinha, “Review paper on transmitarray antennas,” IEEE Access, vol. 7, 2019.
[2] L. Di Palma, *et al.*, "Circularly-polarized reconfigurable transmitarray in Ka-band with beam scanning and polarization switching capabilities", *IEEE Trans. Antennas Propag.*, Feb. 2017.
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