Ph.D. thesis in Antenna Engineering

Dual-Band Electronically Reconfigurable Flat Lens Antennas with Ultra-Wide Scan Range

Motivation and state of the art

Novel efficient electronically scanning antennas are essential for future satellite communications (Satcom). The design of antennas for mobile ground terminals, mounted on airplanes or vehicles, pose several challenges. These systems have to track a satellite over a wide field of view, transmitting and receiving in separate frequency bands and polarizations, while complying with strict aerodynamic constraints.
Mature solutions rely on mechanical beam-steering. The antenna is often a bulky reflector with multiple feeds at different frequencies. The use of two separate thinner but electrically large antenna panels with servomotors has been proposed for K/Ka-band applications. On the other hand, standard electronic beam-steering phased arrays are very expensive and often exhibit poor efficiency and high power consumption.

Electronically reconfigurable flat lens antennas, also known as transmitarrays [1]-[5], are a promising alternative to achieve high scanning performance. Each element of the flat lens introduces an optimized phase shift on the impinging wave emitted by a primary source, to steer and shape the radiation pattern. The phase profile over the lens can be dynamically modified by adding reconfigurable devices in the cells, such as switches (e.g. pin diodes) [2], [3] or varactors [4], [5]. Compared to phased arrays, these antennas attain high-gain beam-steering with a significantly lower power consumption and architectural complexity.

However, several research questions and design challenges have to be addressed to enable enhanced functionalities and performance.

(i) No multi-band electronically beam-steering flat lenses have been reported. Only a few dual-band fixed-beam prototypes were presented [6], [6]. They often comprise two interlaced arrays of cells optimized in two separate bands. This approach leads to cells larger than half a wavelength (λ/2), which degrades the scan range and aperture efficiency.

(ii) State-of-the-art reconfigurable flat lenses exhibit high scan losses (>4 dB) for scan angles >45°. The field of view is inherently limited by the relatively directive patterns of the cells.

Objectives and research activities

The Ph.D. work aims to propose and experimentally demonstrate novel concepts and design methods for wideband/multi-band electronically beam-steering flat lens antennas. The main research 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], [7] will be investigated to tailor the angular and frequency response of the cell.
- Novel design solutions to enable 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, bandwidth, power consumption, number of reconfigurable devices and bias lines, will be studied.
- Development of dedicated synthesis procedures to enable the independent control and shaping of the radiation pattern at two or multiple frequencies.
- Experimental demonstration of high-gain dual-band fixed-beam and electronically 2-D beam-steering prototypes achieving extremely wide scan ranges (±60° or greater). The demonstratators will be optimized to work in typical Satcom bands (e.g. around 20 GHz and 30 GHz).

Project framework - The Ph.D. activities are in the framework of a collaborative project among several French research laboratories which aims to develop innovative reconfigurable antenna architectures.

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The candidate will collaborate with the IETR, University of Rennes 1 (www.ietr.fr), which will lead a study on new solutions to excite reconfigurable transmitarrays and reduce their overall thickness. Short-time visits at the IETR can be envisioned.

Candidate profile and skills required

- European nationality required.
- Master Degree or equivalent in Electrical Engineering or Physics.
- Solid background in electromagnetic theory (fundamental theorems, modal expansions, plane waves, transmission lines) and antennas (antenna parameters, aperture antennas, arrays).
- Some experience with one or more electromagnetic simulation software (e.g., HFSS, CST, Feko) and scientific computation software (Matlab, Python).
- Fluent in English, hard-working, passionate about research, able to work both independently and in a multicultural team.
- An experience on lens/reflector antennas or reconfigurable microwave components is a plus.

Host Laboratory

The Ph.D. program lasts 3 years and will be mainly carried out at:
CEA – Leti, *Laboratory of Antennas, Propagation and Inductive Coupling* (LAPCI), Grenoble, France.

CEA–Leti (www.leti-cea.fr/en) is a world-leading research institute, committed to the creation and transfer of novel concepts and technologies in ICT and nano-electronics. It is located on the MINATEC campus, a unique scientific, academic and industrial environment, which hosts 3000 researchers and 1200 students.

Supervision

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Prof. Ronan SAULEAU (IETR, University of Rennes 1, Rennes, France) will externally supervise the research work and follow the candidate during possible research stays at the IETR.

Application – To apply, send your CV, academic transcripts, and the contacts of two referees.

References

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[7] H. Hasani, J. S. Silva, S. Capdevila, M. Garcia-Vigueras, and J. R. Mosig, “Dual-band circularly polarized transmitarray antenna for satellite communications at 20/30 GHz”, *IEEE Trans. Antennas Propag.*, vol. 67, no. 8, pp. 5325 - 5333, 2019.

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