UNIVERSITÉ PARIS-EST — ÉCOLE DOCTORALE Mathématiques et STIC

ESYCOM — LABORATOIRE ÉLECTRONIQUE, SYSTÈMES DE COMMUNICATION ET MICROSYSTÈMES

UPEM Université Paris-Est Marne-la-Vallée — le cnam — ESIEE PARIS

PhD position available

« Development of electronic antennas optically controlled through SiGe/Si phototransistors and VCSEL links"

Context

The microwave domain is in today in a great evolution, preparing the further fifth mobile generation (5G) and the related wireless infrastructures (100Gbps wireless link for backhauling), and also preparing future radio band up to the THz for either radio communications or new spectroscopy/imaging applications. Sensor networks also will benefit from this move which enables novel mode of ultra-low consumption communication together with increased cells density and security.

Some directions to accompany these needs cover the development of directive antennas that can be reconfigured or electronically controlled, for point to point links and massive MIMO solutions. Electronically pointing employs beamforming antennas with a large matrix of radiating patterns that need to be controlled in phase. Those antenna become as well more compact as the frequency increases. It can be considered new frequency bands from the 10GHz range up to the THz range, with a particular interest in 10-20GHz, 30-40GHz, 60GHz, 100-140GHz, 240GHz, 300GHz bands.

Development of such directive or electronics antennas put new challenges and opportunities. The opportunities are on the increase of gain thus improvement in sensitivity of the link, on the reduction of dimensions due to the frequency increase thus enabling a more compact subsystem with increased integration capabilities, increase in bandwidth and data rates due to the frequency increase as well. The challenges however are large, both on the cost and performance perspectives. Such antennas require:

- Millimeter-waves and sub-THz high density chip-to-antenna interconnections
- Advanced circuit/device solution to control efficiently the phase and frequency of radiating elements

Objectives

The project here intends to investigate further the opportunities provided by the development of an optical mean of control of those antennas. It has the objective to provide an efficient way of feeding the antenna with either control signals for the reconfigurability or the direct radio signal feeding of the antenna. The standard glass fiber has the advantage as compared to cables or metal interconnects not to perturb the EM behavior of the antenna. It is also possible to use integrated optical waveguides for a greater interconnects density. Furthermore the opto-microwave solution which consists in transmitting radio signal through the fiber enables the transmission of ultra-low phase noise signal in the optical domain. Last the optical domain enables a direct control of the delay when transmitting the signal to the antenna. This has the property to reduce the control complexity of beamforming antennas from a $o(N^2)$ complexity to $o(N)$.

Work plan

The state-of-the-art of optically controlled antenna is furnished with few technical solutions including PiN photodiodes, phototransistors and optical switch to deliver quasi-DC control signals for reconfigurable antennas. Few works also use photodiodes/antennas to deliver the Radio signals to single antennas. Other works also consider photodiode in so called indirect-optically-injected-local-oscillators (IOILO) to feed beamforming antennas sub-tiles. Some works have been done also on direct-OILO (DOILO) using phototransistor to perform the optical detection and mixing at a board level. The literature on using phototransistor is however very scarce and many developments are expected further. None of these works has considered thoroughly the opportunities of further integration of the phototransistor with antenna at the wafer or radiating pattern/chip level, which could provide novel way of feeding the antenna (reconfigurable antenna, standalone antenna or beamforming antenna). That is the purpose of the project to focus on it using a novel SiGe/Si Heterojunction bipolar Photo-Transistor (HPT) technology developed by the laboratory. Few runs are envisaged in a 500GHz SiGe/Si BiCMOS technology from IHP, and the project benefits from already available 80GHz SiGe bipolar HPTs and circuits. The project will focus initially at frequency of few 10GHz and then will investigate the frequency limits and challenges to rise up to 300GHz.

The work plan of the PhD will be as follows:

- **Phase 1: State-of-the-art**
  - Reconfigurable antennas and beamforming control circuits
  - Optically injected oscillators (IOILO and DOILO)
- **Phase 2: Breadboard demonstrators**
  - Demonstration of an optically controlled antenna using HPT (emitting antenna) and VCSEL (receiving antenna): **1/** HPT in optically controlled switch configuration; **2/** HPT as an RF feeder of the antenna; **3/** Dual receiving antenna using VCSELs
  - Demonstration of DOILO using SiGe/Si HPTs
- **Phase 3: Integrated antennas on chip usign SiGe/Si HPT**
  - Demonstration of SiGe HPT in a SiGe130nm BiCMOS technology
  - Investigating differential topologies (HPT, antennas)

Place of Work:

ESYCOM lab, ESIEE Paris, Université Paris-Est Marne-la-Vallée
Noisy-le-Grand, France

Contacts :

Jean-Luc Polleux, jean-luc.polleux@esiee.fr
Jean-Marc Laheurte, Jean-Marc.Laheurte@u-pem.fr