COLLEGE MATHSTIC
DOCTORAL BRETAGNE
BRETAGNE OCEANE

Fiche sujet pour le recrutement d'un contrat doctoral 2023

Il est impératif que cette fiche ne dépasse pas 5 PAGES

Titre du sujet : Systèmes antennaires Full-Duplex multifonctions à dépointage de faisceau indépendant en émission et réception

Financement demandé :1/2 CDE (Acquis)
Indiquer l'origine du cofinancement (s'il y a lieu) : ½ ARED (Acquis en 2022)

Title	**Multi-function In-Band Full-duplex System with Independent Transmit and Receive Steerable Antennas**
Context	The Full-Duplex (FD or In-Band Full-Duplex (IBFD)) technique that consists of transmitting and receiving at the same time and in the same frequency band, is considered to be one of the most promising ways (e.g. for 5G-Advanced and 6G) in order to double the data rate in terrestrial and space communications, or to optimize the spectral resources. This technique has other potential advantages, such as introducing a first level of security on the physical layer (self-scrambling), the ability to track and transmit simultaneously in the same frequency band (Cognitive Radio), ... Since 2010, a continuous growing number of papers and conference articles (> 8000) on "In-Band-Full-Duplex" or "STAR: Simultaneous Transmit And Receive" has been published among the international microwave scientific community (antennas, RF, Micro/millimeter wave). Special sessions on this topic are regularly organized, in which SITAR members are strongly involved (guest papers, session chairman, TPC, etc.). Moreover, our team has obtained some internationally-recognized relevant results on IBFD techniques at the antenna level, moreover for LEO (CubeSat [1]) and UWB domains [2]-[4] where requirements are particularly stringent. Currently, none of the techniques described in the literature enables to achieve efficient beam steering while keeping the high level of isolation between Tx and Rx required for In-Band Full-Duplex communication mode. Fully digital or hybrid MIMO techniques have recently been put forward, but the most significant contributions in this area together with our own observations from measurements show that a substantial first level of SIC (between 40 minimum and 60 dB) must be obtained at the antenna or analog level in order to i) avoid saturation at the reception level (ADC), or even to protect it from possible degradation and ii) to strive for a total level of self-interference cancellation of at least 110 dB. Some initial work has just been published on an IBFD antenna system with beam-steering capabilities, but the number of radiating elements is restricted to a very low value (4) and the beam-steering functionality is strongly limited.

Objectives	This project targets the realization of an IBFD antenna system with independent TX and RX beam-steering capabilities and whose level of isolation or SIC (Self Interference Cancellation) is at a medium level of 50 dB on the whole band considered and at least better than 40 dB for every steering angle (±35°). Choosing the most suitable SIC topology for a given beam-steering technique will be essential to maintain the targeted SIC level. A combined state-of-the-art study will be conducted and some initial simulations should be done to assess that the SIC technique that we have already identified from our recent works is suitable with this objective. Several milestones are forecast to converge toward a final proof-of-concept system: a 1st IBFD demonstrator with 1D scanning capabilities and a low complexity level (i.e. 1D beam steering and a low number of radiating elements both in TX and TX) will be designed in ISM or C band and experimentally characterized in order to identify the limitation of the proposed approach and the improvements to be done (gain, IC, SLL versus steering angle). Then, one or several 2D beam steering prototypes will be designed and validated experimentally in X- or Ka-Band before achieving a complete system (antenna + digital in a 2nd time) dedicated to the targeted scenarios. Some a priori challenges have already been identified: • Impairments and dispersions in RF front-end component characteristics (e.g. frequency dependence, manufacturing tolerances, PA linearities) can degrade the expected isolation level. So, the selected topology should rely on a symmetrical architecture in order to reduce imbalances in the antenna emitting elements and in the feeding network. For the same reason, we should also minimise the use of commercial components (COTS). • In the context of the targeted application (typically a small embedded platform), the compactness of the system will also be a major criterion.
Novelty of the project	Designing a Full-Duplex antenna system (simultaneous TX and RX on the same frequency band) with independent TX and RX beam-steering/beamforming capabilities is the key feature toward implementing a multifunction FD system. Among the numerous possible configurations, such a multi-function FD front-end could perform simultaneous monitoring-transmission, jamming-simultaneous tracking, and other transmit-receive pairs. To our knowledge, these functionalities have not yet been realized, and furthermore in a single compact packaging.
International collaboration	**None** because this project is indirectly linked to the DGA (AID) and it relies on merging two innovative concepts and the corresponding know-how acquired by the team (from IBFD PhD and AID project APCUSKA-compact and high gain antenna with hybrid beamsteering in Ka band → patent pending) in order to introduce the design of an innovative and multifunctional IBFD system for civil applications.
Expectations	The first proof-of-concept demonstrators will target civilian wireless communication applications (Spatial, drone, 5G-advanced, 6G, …). In the long-term, the design of more advanced demonstrators could be carried out to meet the specifications of military RF front-ends (i.e. instantaneous bandwidth, frequency tunability, power handling, etc.).