INSTITUT FRESNEL

PhD proposal - 2017

MIMO sensor for near-subsurface imaging

Context

The use of electromagnetic wave in the microwave domain is of particular interest for probing the subsurface in a nondestructive way. Many potential applications exist in various domains as for example humanitary (anti-personnal mines detection), civil engineering (pipe detection), agricultural domain (water resources management, moisture imaging), environmental domain (polluting products detection) (see also the European COST Action TU1208 on Civil Engineering Applications of Ground Penetrating Radar). The microwave imaging technique exploits the induced scattering phenomenon resulting from the interaction of an incident wave with an investigation zone. The measured field is then post-treated with an inversion algorithm to establish a map (complex permittivity distribution) of the probed area [Zhang2011], [Voznyuk2013]. As subsurface imaging is concerned, major difficulties exist related to the limited number of data (aspect-limited configuration), the leak of energy at the air/soil interface and the wave attenuation in the soil (medium with losses). It is thus of great interest to measure as much as possible all available information. The recent research conducted by the HIPE group at Institut Fresnel on Ground Penetrating Radar, with a soil-equivalent medium, allowed us to develop measurement treatment procedures [Eyraud2010] and a calibration process as well as an inversion procedure taking into account the radiation pattern of the antennas [Nounouh2014a] [Nounouh2015b]. These studies have proven that it is possible to image targets even if there are close from the interface [Nounouh2015a].

Work programme (3 years duration)

The objective of this PhD thesis is to achieve a substantial improvement on the imaging instrument design using a multi-sensors system specifically adapted to the studied configuration. To avoid problems linked to the reflected configuration and to the weak intrinsic information content, the work will focus on the improvement of the data acquisition, in particular on the development of a Multi-Input Multi-Output system allowing a better information diversity (spatial information and polarization). The applicant will take part in the necessary steps of the conception of this instrument: MIMO antennas array, onboard acquisition system, ... The measurements will be performed on natural heterogeneous media, first, in "ideal" conditions (anechoic chamber, vectorial network analyzer, ...) and thus, in-situ. The PhD student will also need to adapt and improve the measurements post-treatment procedures in the framework of this new configuration. The goal is to provide maps of the near subsurface which are quantitative and reliable even with difficult measurement conditions (moisture, heterogeneities, ...).

The lab

The Fresnel Institute, UMR 7239, is a French research laboratory where approximately 140 people work in the fields of photonics, electromagnetism, signal and image analysis. The Institute is composed of 11 research teams working on meta-materials, photonic crystals, laser damaging, light scattering, image analysis, statistical optics, bio-photonics, non-linear microscopy, micro-wave imaging, high resolution imagery, optical filtering, multi-layer coatings fabrication technologies, processing of multidimensional signals, biometry...
The majority of its permanent members are associated with institutions of higher education in Marseille (Aix Marseille University, Ecole Centrale, Polytechnique...). The Laboratory also coordinates an Erasmus+ Master and Doctorate program (Europhotonics - POESII).

Applicant profile
The applicant must have good knowledge in electromagnetism as well as in the microwave regime specificities. Skills in hyperfrequency electronics and in antennas design will be appreciated.

Selected references
[Nounouh2015a] S. Nounouh, C. Eyraud, A. Litman, H. Tortel, *Near-subsurface imaging in anabsorbing embedding medium with a multistatic/single frequency scanner*, Near Surface Geophysics, vol. 13, 3, pp. 211 - 218, 2015.
[Nounouh2015b] S. Nounouh, C. Eyraud, A. Litman, H. Tortel, *Quantitative imaging with incident field modelling from multistatic measurements on line segments*, IEEE antennas and wireless propagation letters, 14, pp. 253 -256, 2015.
[Nounouh2014] S. Nounouh, C. Eyraud, H. Tortel, A. Litman, *A. Modeling of the antenna effects and calibration for subsurface probing*, Microwave and Optical Technology Letters, vol. 56, pp. 2516 - 2522, 2014.
[Voznyuk2013] I. Voznyuk, H. Tortel, A. Litman, *Scattered Field Computation with an Extended Feti-Dpem2 Method*, Progress In Electromagnetics Research, 39:247-263, 2013.
[Zhang2011] X. Zhang, H. Tortel, S. Ruy, A. Litman, *Microwave imaging of soil water diffusion using the linear sampling method*, IEEE GRS Letter 8 (3), 2011.
[Eyraud2010] C. Eyraud, J.-M. Geffrin, P. Lewyllie, A. Franchois, A. Dubois, *Target localization and measured scattered field pre-processing using spectral bandwidth minimization for shallowly buried target problems*, Microwave and Optical Technology Letters, 52, 2010.

Keywords
Electromagnetism propagation and scattering phenomena - Microwave measurements - Hyperfrequency - Instrumentation and measurements - Vectorial Network Analyser - Buried targets - Imaging - MIMO systems - Antennas arrays - Near-subsurface - Dispersive medium

Contact
Christelle Eyraud (advisor): christelle.eyraud@fresnel.fr, +33 4 91 28 80 85
Amélie Litman (co-advisor): amelie.litman@fresnel.fr, +33 4 91 28 80 04
Hervé Tortel (co-advisor): herve.tortel@fresnel.fr, +33 4 91 28 80 06
webpage: `http://www.fresnel.fr/spip/spip.php?article1469&lang=en`

Submit CV and cover letter to: christelle.eyraud@fresnel.fr

DGA funding (was acquired) - conditions relating to nationality: applicant must be a citizen of an EU country or Swiss a national.