SMILE 2015

Seminar on Microwave Imaging at Limoges

Xlim institut de recherche

June, 23-24 2015

Keywords : **Microwave imaging, Inverse problems, Compressive sensing, Imaging algorithm**

Microwave imaging is receiving substantial attention thanks to the development of new techniques and hardware promising for the large scale implementation of high resolution imaging systems. This seminar is organized to gather the researchers working on these new techniques, involving passive imaging by noise correlation, compressive sensing, innovative devices and signal processing, able to overcome the limitations of the existing solutions.

Participants:

- **CEA, France:**
  Thomas Benoubida, Jean-Christophe Joly, and Pierre Minvielle
- **Delft University, Netherlands:**
  Alexander Yarovoy
- **Duke University, USA:**
  Jonah Gollub, Stéphane Larouche, and David R. Smith
- **ESPCI ParisTech, France:**
  Julien de Rosny and Geoffroy Lerosey
- **IEMN-MC2 Technologies, France:**
  Christophe Gaquiere and Nicolas Vellas
- **Microwave Vision Group, France:**
  Luc Duchesne and Damien Rialet
- **University of Limoges, France:**
  David Carsenat, Cyril Decroze, Thomas Fromenteze, and Ettien Kpré
- **University of Hyogo, Japan:**
  Takuya Sakamoto
- **University Paris Diderot, France:**
  Josselin Garnier

45' Presentations

(including discussions)

Open application

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DE LA RECHERCHE À L'INDUSTRIE cea

Seminar on Microwave Imaging at Limoges - ***SMILE 2015***

Programme

	Tuesday 23^{rd}	**Wednesday** 24^{th}
9:00 - 9:30	Introduction of SMILE 2015	
9:30-10:15	**Takuya Sakamoto** Frequency-domain Kirchhoff migration for high-resolution imaging	**Josselin Garnier** Correlation-based imaging using ambient noise signals
10:15-10:45	Coffee break & Poster session	Coffee break & Poster session
10:45-11:30	**Alexander Yarovoy** MIMO radar for UWB imaging	**Julien De Rosny** Greens function retrieval from electromagnetic noise
11:30-12:15	**Luc Duschene and Damien Rialet** Centimeter wave security scanner for airports	**Nicolas Vellas** Radiometric imaging system for security applications
12:15-14:15	Lunch	Lunch
14:15-15:00	**Thomas Fromenteze** Passive compression for a simplification of the microwave imaging systems	Visit of the technological resource center of Xlim
15:00-15:45	**David R. Smith** Metamaterial aperture for computational imaging	
15:45-16:15	Coffee break & Poster session	
16:15-17:00	**Goeffroy Lerosey** Locally resonant metamaterials beyond homogenization: subwavelength molding of waves, slow waves and negative index media	

Xlim Institut de recherche — cea GRAMAT — cnrs — Université de Limoges — Région LIMOUSIN

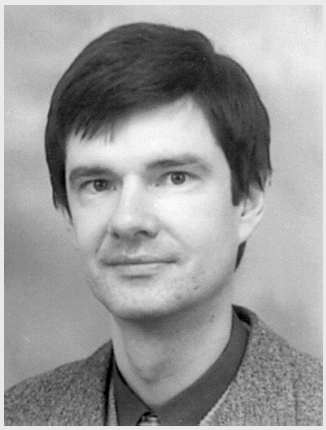
Presenters

Takuya Sakamoto
University of Hyogo

Frequency-domain Kirchhoff migration for high-resolution imaging

In this talk, we present a fast and high-resolution radar imaging algorithm that is a combination of Kirchhoff migration and F-K migration. We use scanning antennas to transmit and receive ultra-wideband signals. To apply conventional F-K migration to such signals, the target location must first be accurately estimated. We use two tools, the texture angle and inverse boundary scattering transform, to estimate the target locations for each delay time and antenna position. Using the estimated locations, radar signals are modified according to the Kirchhoff integral. F-K migration is then applied to the modified signals to obtain a high-resolution radar image. To demonstrate the performance of the proposed method, conventional methods and the proposed method are applied to a measurement dataset.

Presenters



Alexander Yarovoy
Delft University

MIMO radar for UWB imaging

Array-based ultra-wideband microwave imaging system is becoming an important tool in various short-range applications, such as ground penetrating radar (GPR), airport security, through wall or rubble imaging and rescue, and in the near future medical diagnosis. Such systems have the potential to deliver high-resolution three-dimensional (3-D) images and offers scanning time in the order of dozens of milliseconds. The main challenge of such systems is finding an optimum between system complexity and resulting image resolution.

One of the ways to resolve this challenge is utilization of multi-static imaging using MIMO antenna arrays. This approach gives the flexibility to define separate transmit and receive sub-arrays and reduces the total number of antenna elements within the array from N to $2\sqrt{N}$ while keeping the same array patterns as the full array. This significant reduction of the density of antenna elements within the physical aperture leads to mutual coupling reduction, simplifies RF front end, and reduces costs and weight of a whole imaging system. The principals of MIMO radar as well as some applications will be discussed in the talk.

Presenters

Luc Duschene
Damien Rialet
Microwave Vision

Centimeter wave security scanner for airports

Recent events have shown that a determined terrorist could be able to board in a plane with explosive materials to blow up the plane during the flight. A project partially financed by ANR (Agence Nationale de la Recherche) and managed by Satimo has been performed to design and validate the feasibility of a new type of security scanner based on centimeter wave imaging. This article describes the main technical activities and results of the SAMOSA project (ScAnner Micro-Onde pour la Sécurisation des Aéroports) in terms of prototypes realized and results of imagery obtained.

Presenters

Thomas Fromenteze
University of Limoges

Passive compression for a simplification of the microwave imaging systems

We present a compression technique for reducing the hardware complexity of high resolution microwave imaging systems, notably used for medical diagnosis applications and concealed objects detection. Based on a compressed sensing approach achieved in the physical layer, this technique allows for the reconstruction of a scene with the measurement of a unique signal. The theoretical principle and the associated signal processing will be discussed in this presentation. Several prototypes and experimental results will be presented.

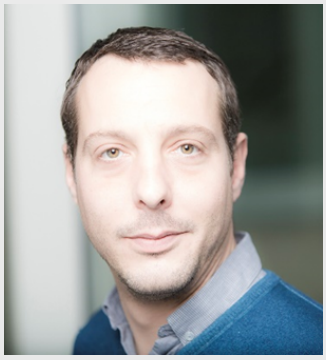
Presenters

David R. Smith
Duke University

Metamaterial aperture for computational imaging

We discuss the design and implementation of a microwave imaging system based on a frequency-dispersive, metamaterial aperture. The metamaterial aperture consists of a parallel-plate waveguide in which is launched a cylindrical wave that excites an array of patterned, resonant, complementary metamaterial elements in the upper plate. The structure radiates a set of complex field patterns whose spatial patterns throughout the scene vary as a function of frequency. With a simple frequency sweep, a three-dimensional image of the scene can be reconstructed using standard computational imaging approaches. We present a complete metamaterial imager system capable of resolving human-sized targets, including the metamaterial aperture, standalone transceiver and reconstruction software. We show the metamaterial imaging system is capable of diffraction-limited resolution, and discuss the performance tradeoffs.

Presenters



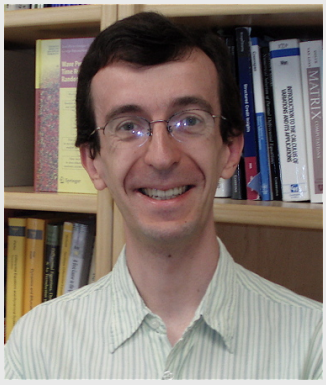
Goeffroy Lerosey
ESPCI ParisTech

Locally resonant metamaterials beyond homogenization: subwavelength molding of waves, slow waves and negative index media

In this talk we will show how going beyond the homogenization paradigm usually introduced in the context of locally resonant metamaterials permits to enrich the physics associated with them in a drastic way. We will first show, using a microscopic approach based on the transfer matrix, that the properties of many metamaterials made out of resonant unit cells are strictly governed by interferences and propagation effects [1]. We will demonstrate how this observation allows one to tailor this kind of composite media at the scale of the unit cell, hence going much further than in the homogenization approximation. We will show how this allows to design various components such as cavities, waveguides, filters, that present deep subwavelength dimensions, much smaller than that of their phononic crystal counterparts [1]. Then, we will demonstrate the possibility to slow down microwaves drastically using this kind of components, while keeping reasonable bandwidths, hence achieving delay bandwidth products 10 times higher than the state of the art in photonics [2]. We will finally explain briefly how a single negative metamaterial can turn double negative simply thanks to multiple scattering, provided that it is judiciously structured [3].

[1] F. Lemoult, N. Kaina, M. Fink and G. Lerosey. Nature Physics 9, 55-60 (2013).
[2] N. Kaina, A. Causier, Y. Bourlier, M. Fink, T. Berthelot and G. Lerosey. submitted (2015).
[3] N. Kaina, F. Lemoult, M. Fink and G. Lerosey. submitted (2015).

Presenters



Josselin Garnier
Paris Diderot University

Correlation-based imaging using ambient noise signals

In sensor array imaging one uses waves to probe for information about an unknown medium. These waves can be acoustic, elastic, or electromagnetic. They are generated by an array of transmitters and recorded by an array of receivers (transducers in acoustics, seismographs in geophysics, or antennas in electromagnetics). Recently the possibility to use uncontrolled sources or even ambient noise sources has attracted a lot of attention, in particular is seismology where sources (earthquakes) are rare and uncontrolled. We will explain how passive correlation-based imaging allows to use such signals.

Presenters

Julien de Rosny
ESPCI ParisTech

Green's function retrieval from electromagnetic noise

Experimental demonstration of electromagnetic Green's function retrieval from noise in anechoic and reverberant cavities is presented. Especially, in this talk we show that the Green?s function between two antennas can be extracted by cross-correlating milliseconds of decimeter wavelength thermal noise. The temperature dependence of the cross-correlation amplitude is well predicted by the black body theory in the Rayleigh-Jeans limit. Because thermal noise level is very weak, care is given to identify all the noise sources that contribute to the correlation. The effect of a non-uniform temperature distribution on the cross-correlation time symmetry is also explored. Finally we apply these results to image a metallic scatterer.

Presenters

Nicolas Vellas
Christophe Gaquiere
MC2 technologies
IEMN Lille

Radiometric imaging system for security applications

MC2 technologies will present a millimeter wave radiometric camera for people screening usable in a wide range of applications. The MilliCam technology developed by MC2-Technologies is based on innovative sensors to reach high detection levels. This camera does not emit any radiation and can be deployed very easily for civil or military applications. This product is perfectly adapted for the detection of objects hidden under the clothes of people arriving at a checkpoint. A description of the method used will be described in a first time. In a second time few results will be presented in order to demonstrate the potentialities of this technology.

Poster session

Thomas Benoubida
Pierre Minvielle
CEA CESTA

High resolution radar imaging with variable polarization

A 3-D radar imaging technique is developed for fast and efficient identification and characterization of radar reflectivity components of complex objects, when the collected scattered field is made of polarization-diverse measurements. In this context, all the polarimetric information seems irretrievably mixed. A direct model, derived from a simple but original extension of the widespread "multiple scattering model" leads to a high dimensional linear inverse problem. It is solved by a fast dedicated imaging algorithm that manages to determine at a time three huge 3-D scatterer maps which correspond to HH, VV and HV polarizations at emission and reception. It is applied successfully to various mock-ups and data sets collected from an accurate and dedicated 3D spherical experimental layout that provides concentric polarization-diverse RCS measurements.

Poster session

Ettien L. Kpré
University of Limoges

Orthogonal frequency hopping waveforms design for MIMO Radar Applications

MIMO radars have received increasing attention over the last decade due to their potential compared to conventional radars. The essence of this concept is to probe the channel with M orthogonal signals and record the backscattered signals with N receivers. The beamforming is performed by both transmitters and receivers, adding a new degree of freedom. Consequently, it allows for the reduction of the number of antennas required in conventional radars while keeping the same resolution.

In order to generate orthogonal waveforms, we propose a method to create alternative orthogonal frequency hopping codes based on Linear Feedback Shift Registers. The advantages of the proposed scheme include easy generation, low degree of correlation, constant signals envelop and energy. We also introduce a metric of waveform performances using single value decompositions (SVD). Moreover, a method of signal to noise ratio evalutation is derived.