Mandatory use of the following format for the title of the file for the web site management.

**PostDoc_ECXX_LABYY_NOMChercheur**

ECXX = ECLI, ECL, ECM, ECN, CS
LABYY = acronyme du laboratoire
NOMChercheur = nom du chercheur émetteur du sujet – futur directeur scientifique
*Un seul sujet par Nom – Un seul nom par sujet*

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**Post Doctorate Proposal 2017**

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<thead>
<tr>
<th>School:</th>
<th>CentraleSupélec (CS)</th>
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<tr>
<td>Laboratory:</td>
<td>Laboratoire des Signaux et Systèmes (L2S)</td>
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<td>Expected duration (&lt; 24 M):</td>
<td>18 months</td>
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<td>Location:</td>
<td>Gif-sur-Yvette</td>
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**Title:** Early Breast Abnormalities Detection via Electromagnetic and Ultrasonic Joint Modalities

**Scientific field:** Electrical Engineering, Electronics, Waves and Photonics Engineering

**Key words:** multiphysics, ultrasound and microwave imaging, biomedical applications, breast cancer early detection, computational modeling, data fusion, Bayesian inference
**Details for the subject**

**• Context-Background.** In the context of early detection of breast cancer and generally speaking of abnormalities by non-invasive/non-ionizing methods intended to work on an uncompressed breast, we wish to design/study algorithms of fusion/inversion of joint data. Electromagnetic and ultrasound modalities are easily deployed indeed in similar conditions (so-called free breast in coupling medium), and are complementary in terms of information, meaning local resolution and sensitivity to contrasts, and more generally about constituent media and distributions thereof. The objective is to model/characterize by simulation the potential performance of this bi-modal examination.

Long-term aim is to propose a clinical system to detect early breast cancer. At this stage (proof-of-concept) we intend to use new methodologies of data fusion to design new multi-modality systems.

**• Start point.** Detection of breast cancer so far is mostly via mammography, which suffers from compressed breasts (i.e., discomfort/pain), ionizing radiation deposited, not enabling to get the 3D structure, low contrast of tumors in mammograms, so small ones are not detected at early stage [Nga15].

The initial idea was then to profit from strong electromagnetic contrasts of tumors [Lazebnik07], e.g., a microwave breast imaging system has been built [Klemm10] without clinical exploitation attainable.

Tridimensional microwave tomography involves illumination at different incidences & frequencies, and fields collected outside. From those, we can in principle retrieve within each 3-D voxel a complex-valued contrast [MiMed], yet that suffers from reduced resolution if low frequencies, and if higher ones, from strong attenuations as waves penetrate farther and farther.

Worst is that inversion here is non-linear, and even if using re-parameterization, we can make the problem multi-linear [Ammar17], matrices involved upon discretization are not hollow, which in particular limits the number of voxels that can be retrieved.

Also, now in non-destructive testing framework, artificial objects to image often are involving a small number of materials (say, 2 to 4). Therein, tools address lack of high-frequency information using priors of images made of a small number of materials leading to constant piecewise ones [Dorn06, Irishina10, Benedetti10, Dorn11]. But breast structures in fine are too complex to use those, though works exist favoring constant images by optimization so that computing time fits clinical use [Zaeytijd15, Bai16].

**• Proposed approach.** Its originality is in using two modalities: microwave and ultrasound. Simply said, the first yields low spatial frequencies of breasts and contrast in terms of tumors, the second yields higher frequencies and highly-resolved images. Now, to exploit at best the information from the two modalities, several conditions must be met as sketched below.

First, measures in both –ultrasound is already used [Wiskina12, Ozmen15]– must be almost simultaneous. Breasts are soft organs that deform in non-rigid manner between different examinations; in [Fang09] fusion between optical images and mammography where the breast is constrained is proposed, but strong hypotheses are on internal structure deformation, and fusion merely determines the area within the unconstrained breast of what detected in mammography. Microwave and ultrasound modalities can cohabit in the same system without excessive interference. I.e., it appears enough to use a fluid enabling breast-sensor contact with good impedance properties (mechanical and electromagnetic).

The second condition is of a parameterization enabling a relationship between the two modalities. To do so, we will consider that the images of the two modalities share same contours, this aspect being tackled via so-called line variables as in the princeps contribution [Geman90].

Finally, an information fusion methodology must be used which is coherent with an inverse problem solution method, and a Bayesian methodology [Demoment89, Rodet15] will well fit therein. Let us emphasize that we have already investigated already that type of fusion approach, in either X-ray [Cai11] or in fusion between x-ray (tomosynthesis) and microwave (typical radar approach) [Tivnan15].

To avoid the limitation of resolution in microwave imaging caused by the relatively small number of illuminations that can be introduced because of the complexity of the direct model, we will use an adaptive grid of quadtree type, so that in particular homogeneous zones are modeled by a small number of voxels focusing onto the boundaries of objects (information that we will get from ultrasound data), this modeling being done thanks to the available expertise at the laboratory and partners.

**• To recap.** The project will lead to the development of a new multi-modality data fusion algorithm (microwave & ultrasound), which to best of our knowledge has not been conducted before. The performance of the approach will be evaluated on realistic numerical simulation data. The work is expected to render possible to get real gains in terms of resolution and contrast, noticing also that in the case of tumors of small sizes the bad resolution indeed reduces the contrast due to the partial volume effect (the volume of the tumor is embedded within the volume of the voxel, which is too large).
• Post-doc & beyond. The post-doc will be about developing data fusion algorithms for breast imaging. Then, if confirmed, a broader project with partners in Europe and China will follow, beyond proven cooperation on data fusion, model choice, and Bayesian methodologies between L2S (under D. Lesselier, as proponent) and SATIE (partnering here, under T. Rodet) [Cai16, Cai17]. Since the present work has strong methodological emphasis, progress in other fields, esp. non-destructive electromagnetic and ultrasonic testing, particularly in the case of composite laminar structures, is expected as a consequence.

• Prerequisite. Good balance of knowledge in electromagnetics, ultrasound, computational modeling, wave-field imaging/inversion, data fusion or fusion of information will much benefit to the applicant.

• References


