Master of Science M1, Lyon, France
Laboratory internship, 2023

Project title:
Search for the maximum and minimum sound pressure in an ultrasonic pressure field for the measurement of acoustic safety indices

Number of students: ☒ One ☒ Two

Laboratory: CREATIS
Research team: Imaging platform

Supervisor(s): Adeline Bernard, ingénieur d'études INSERM, adeline.bernard@creatis.insa-lyon.fr

Context and project description:

Context

In recent years, new modes of ultrasound imaging (ultrasound) have been developed and implemented on ultrasound scanners dedicated to research. These systems are called "open" and allow access to settings close to the hardware and raw signals usually not available on clinical ultrasound scanners. These new imaging modes could be useful for a large number of clinical studies (internal and external to the laboratory), whether for cardiac, vascular, cancer or neurological applications.

In order to test the new sequences developed on research ultrasound scanners on healthy volunteers and patients, within the framework of Research Protocols Involving the Human Person (RIPH - Jardé law), it is necessary to provide to the ANSM (National Agency for the Safety of Medicines and Health Products) and the CPP (Committee for the Protection of Persons) with measurements of acoustic safety indices specific to each sequence and each ultrasound probe to certify the absence of risk in their use by comparing them to the thresholds set by the standards.

Thanks to previous projects and internships, a Matlab program has been implemented to drive a three linear axis displacement bench allowing a hydrophone (pressure sensor operating in water) to move along the three spatial axes (x, y and z) to measure the acoustic pressure from ultrasound probes and to realize an acoustic safety index measurement protocol.

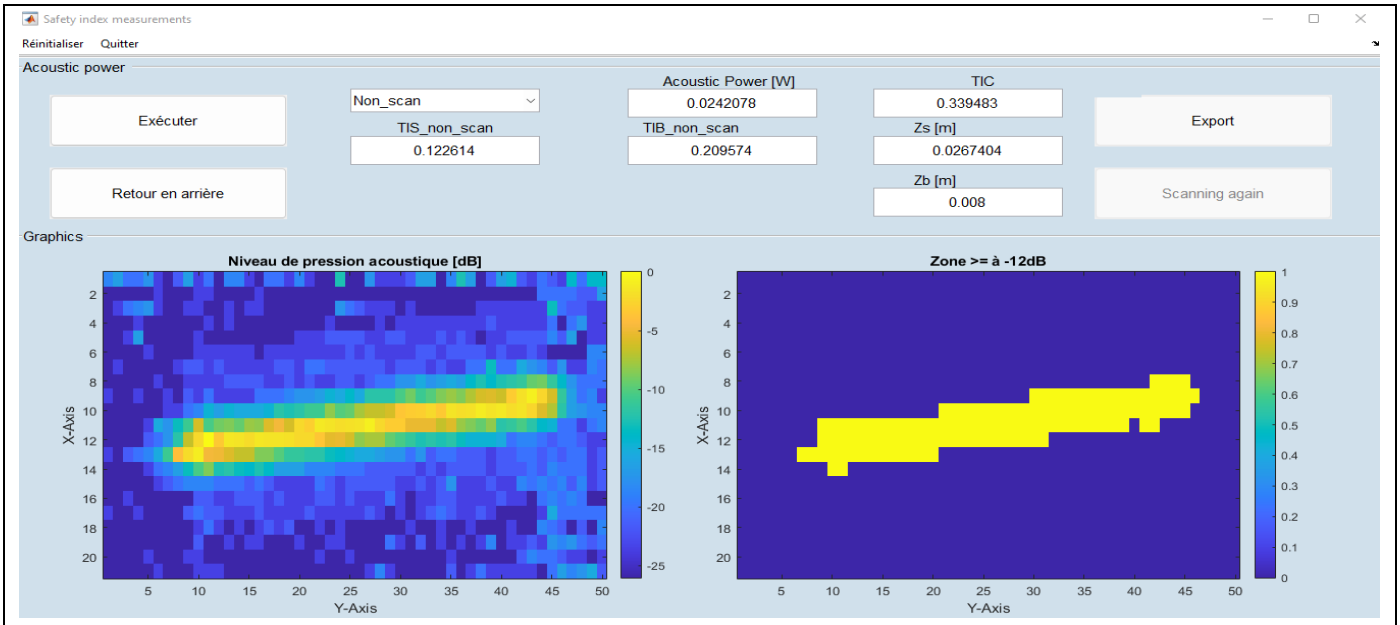

Figure 1 : IHM of one of the steps of the protocol to measure safety acoustic index.

Project description

One problem remains: the detection of the maximum and minimum pressure with the current method has too large an uncertainty. We would like to test several solutions to improve this:
- algorithmic solution: interpolation and/or reconstruction of the pressure field and find the maximum by iteration. Gradient descent solutions will also be explored in addition. The trainee(s) will have to realize first a technical-scientific watch on this subject, implement the algorithm solutions and test them with already acquired pressure field data and finally, if one of the algorithms is retained, implement it to add it to the existing protocol.
- optical solution : The trainee(s) will have to realize first a technical-scientific watch on vibrometry laser, conduct the experiments and analyse the results.

Keywords:
Ultrasound, scalar-field reconstruction, instrumentation, Matlab programming, vibrometry laser

Methods: *(Experiments, analytical modeling, numerical simulation…)*

Experiments :

Ultrasound

The ultrasound technical platform, of the multimodal imaging platform (PILoT), has a three-axis linear motion bench controlled by a software manufacturer (OWIS) and by Matlab which allows to perform acoustic measurements by hydrophone and recovered on an oscilloscope.

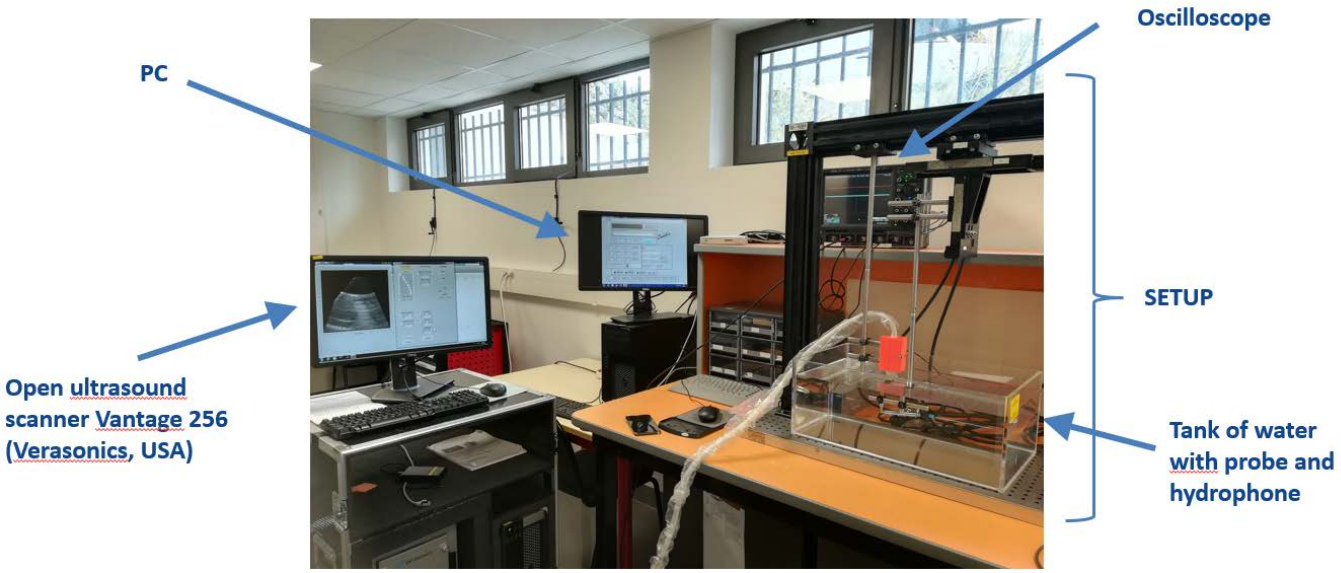

Figure 2 : experimental setup for the measure of the safety acoustic index

Optics :

We can use the vibrometer of the LVA Lab.

Pressure Field reconstruction and analysis:

The key idea of these experiments is to reduce the quantity of acoustic measurements, by driving the acquisition process by the maximum search: given few measurements, we will estimate the pressure field in the volume, predict the locations of the new measurements, perform the new measurements, estimate, and loop until convergence.

We will study different approaches to sample and reconstruct the pressure field.
The first approach consists in reconstructing a global approximate of the pressure field from few measurements (e.g., 5x5x5 samples in the acquisition area), and to sample measurements around the reconstructed field maximum. Multi-resolutions sampling strategies will be considered.
The second approach focuses on local techniques where the pressure field is reconstructed from local measurements (e.g., in the sub-part of the whole volume). Then, iterative approaches such as gradient descent, will be used to perform new measurements and search for the function maximum.