Study of acoustical imaging with Romarin

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Introduction

We use sonars for multiple purposes: one for analyzing the compositions of sediments under large oceans, and another for scanning the surface of sediments to obtain an image of seabeds. In the course of one my subjects at Sorbonne Université, I had the opportunity to understand how sonars work in a nutshell. Part of the **Romarin** project, the goal of this project is to make a functional sonar in order to obtain a seafloor mapping of the Seine in Paris. In order to do so, colleagues and I decided to first understand the sonar that the personnel at Saint-Cyr had, get a better understanding of the electronics, and most importantly, try and obtain images of the floor of the pool.

Sonar

A sonar is made of multiple transducers, an instrument that transforms one physical quantity into another. For a lateral sonar, transducers are placed in the same axis, which allows for the creation of a strong intensity beam located at the center of the sonar. It's opening beam is defined by two angles in the two planes. As shown in the figure, our sonar emits acoustic waves to its left (along the y-axis) at an angle α, and similarly along a small width defined by β (along the x-axis).
As suggested by the diagram, the angle β is very small compared to α. It is important to know the values of these angles in order to better map the seafloor. The angle β will allow us to determine the spacing between each measurement, and the angle α will tell us how far we can look. We conducted two experiments to determine these angles. A theoretical angle is also plotted.

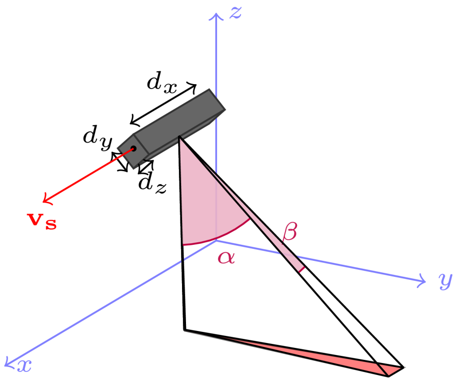

Figure 1: Schematic of the sonar

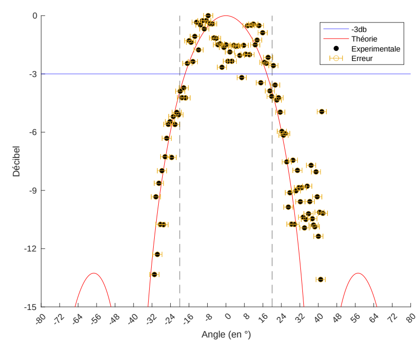

Figure 2: Determination of the α angle

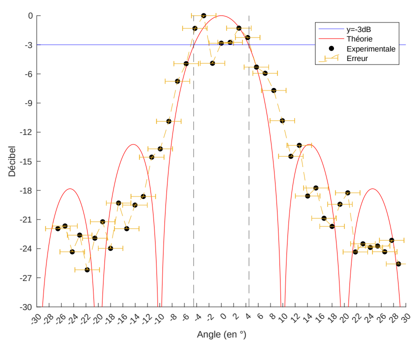

Figure 3: Determination of the β angle

Our sonar works best for frequencies neighboring $100Khz$. We generated a linear chirp signal with a pulse generator to have a good special resolution of $1.875cm$. The sonar being able of also receiving acoustic waves, returns our signals to a TiePie box, where we are able to use Python to visualize our data. Finally, to reduce the noise, we convolve the Fourier transform of our received signal with that of the chirp signal, removing all other frequencies that the sonar might of have captured.

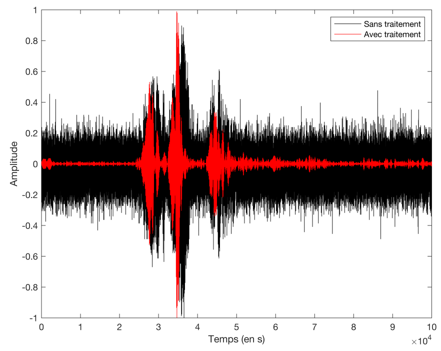

Figure 4: Red signal after signal processing

Experimental measurements and results

Here is an example where we place multiple objects in a pool. We immersed the sonar $50cm$ in the water, and tilted it at a 45° angle towards the bottom of the water. Since the pool has borders along its sides, it is difficult to space out the objects properly. However, to occupy a large portion, we placed a ladder to have its legs oriented towards the sonar to observe the resolution of our sonar. We also have a ball and a PVC pipe. These objects are interesting because they are echogenic, making them, in principle, easy to observe them. For this experiment, we decided to place all our objects as far away from the sonar, to simulate a "real" situation as if we were in the Seine. Measurement were taken ever $5cm$ to ensure the same precision and a better quality image. We can clearly see the ladder in this experiment. Unfortunately, the metal ball and the PVC tube remain invisible for now.

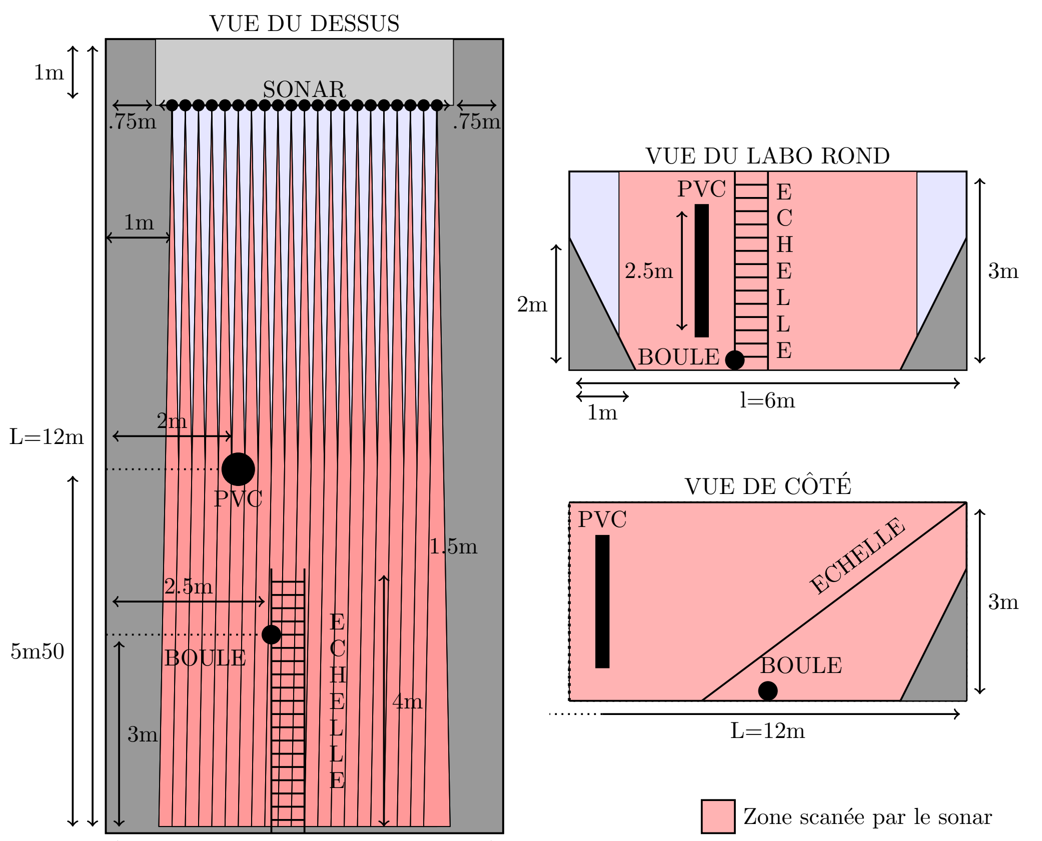

Figure 5: Schematic of experiment

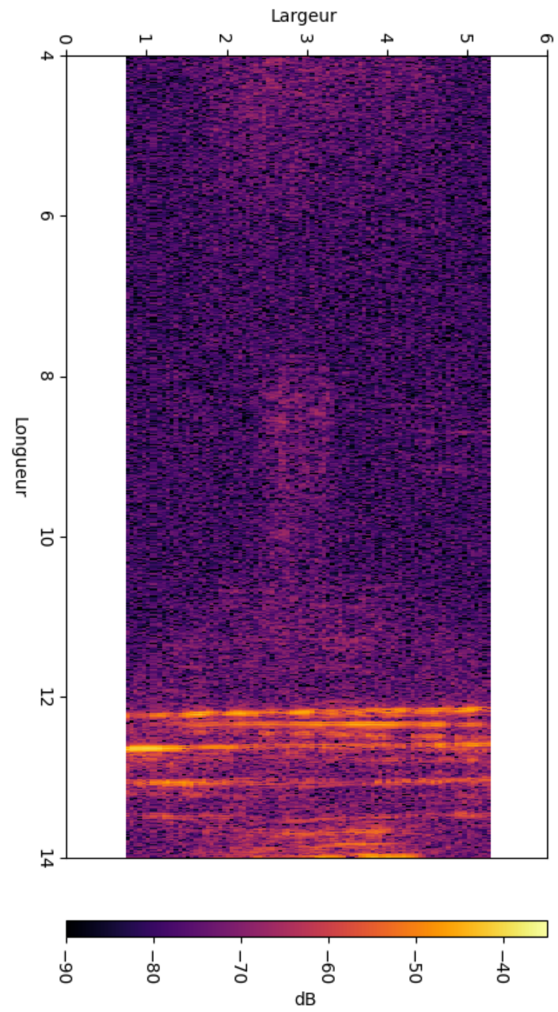

Figure 6: Output acoustical imaging