Study on acoustics : phononic crystals and the existence of band gaps

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Introduction

We use sonars for multiple purposes. One is analyzing the compositions of sediments under large oceans. Another is to scan 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. As previously seen, the sonar's opening beam is defined by two angles in the two planes. If we position the sonar as shown in the figure below, our sonar emits 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).

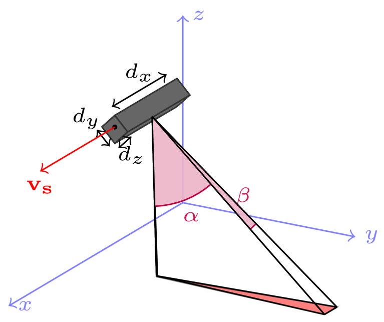


Figure 1: Schematic of the sonar

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.

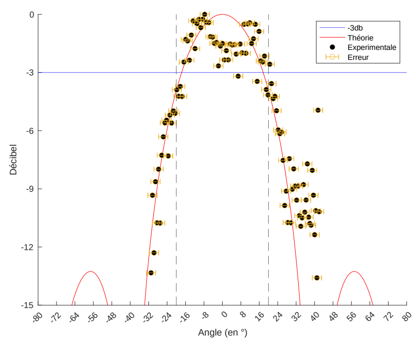


Figure 2: Determination of the α angle

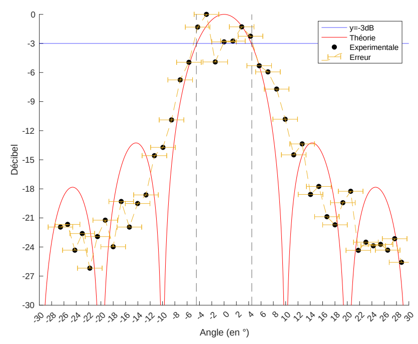
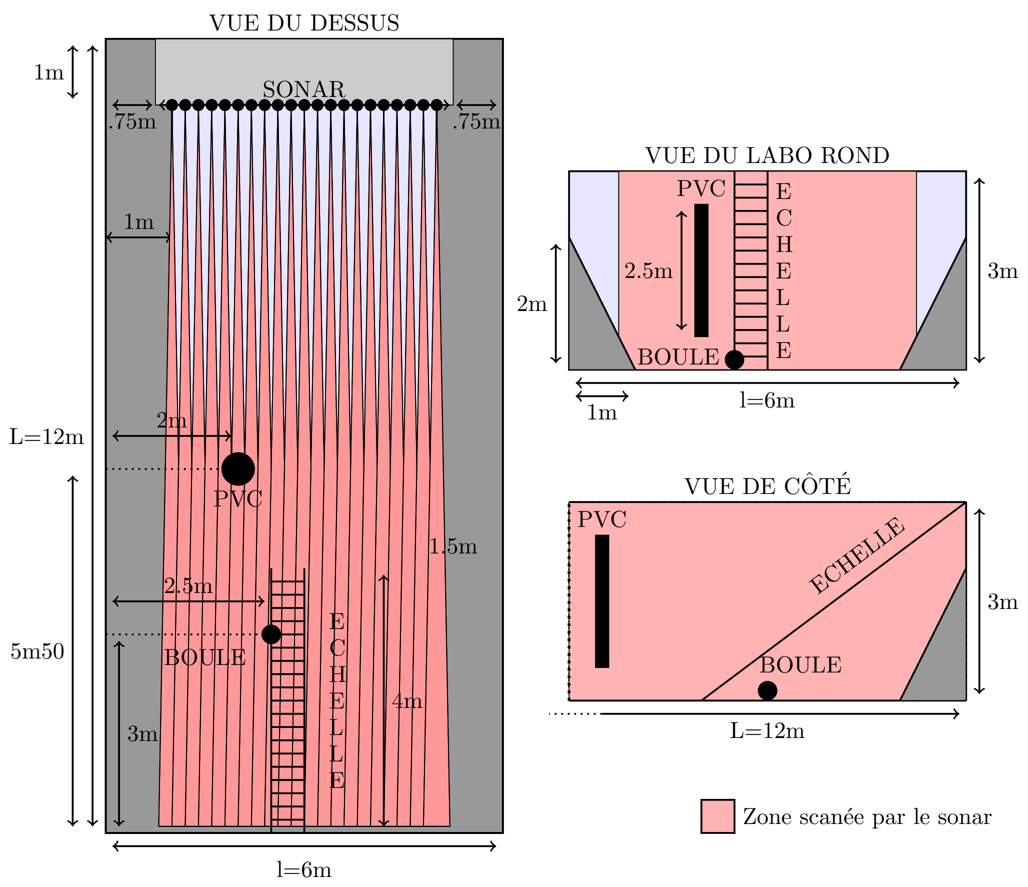


Figure 3: Determination of the β angle

Sonar

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 the 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 as possible and close to the width of the pool. We wanted 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.



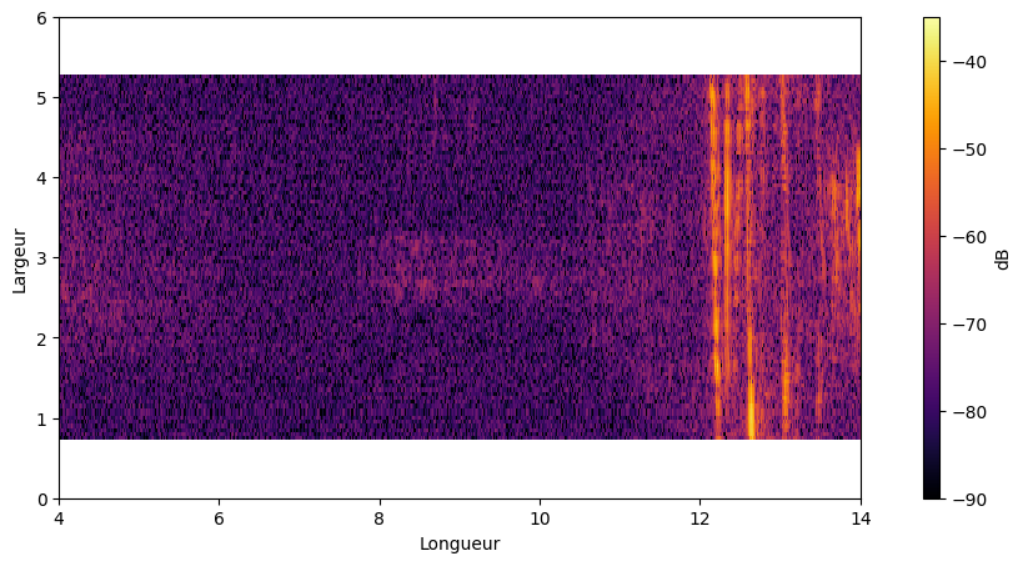


Figure 4: Image of the third experiment

Figure 5: Beamforming output for a turbulent-boundary-layer-trailling edge noise with different frequencies of interest