Assignment 2 : Underwater Acoustics Report

Madhushree Sannigrahi
Abhimanyu Bhowmik

Underwater Acoustics Course

January 21, 2024

1 Introduction

The main idea of the assessment is to find the depth of the water column and depth of the source. A file containing the signals received by 9 receivers from the source has been used. The source can be found by sending back the signals received from the receivers and plotting an energy map to discover the energy concentration, which gives us the location of the source(transmitter). MATLAB software has been used and the code has been attached to this file for reference.

Problem 1

Let us consider a water channel, hm in depth, and let us assume that the velocity c is constant and equal to $1500m/s$. A signal is transmitted from a point-like source in the water and measured by a set of 9 receivers located along a vertical line at depths $25 * n$ meters, $1 \leq n \leq 9$. When hitting the (flat) boundaries, the acoustic waves are totally reflected.

The file 'Received.mat' contains a $9x32000$ array which provides the 9 received signals during 6.4 s with sampling path $dt = 2.e - 04$s. Line n corresponds to the receiver at depth $25 * n$ meters.

Plot the received signals and explain how you can get a rough estimation of the depth h and of the location of the transmitter from the various time delays. Improve the accuracy of this first estimate thanks to the simulation of the backpropagation of the time-reversed received signals.

Solution. The signal from the file "Received.mat" contains signals with dimensions $9x32000$ which corresponds to $32,000$ signals for each of the 9 receivers. After making a plot of the signal, the following plot was received.

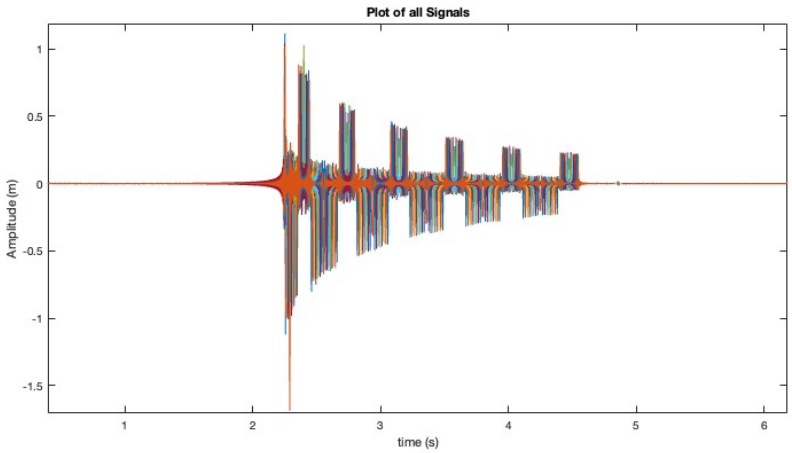

Figure 1: Plot of the 9x32000 Signals

For calculating the distance between the source and receiver 5 we need to take some assumptions which are,

a) That the source is parallel to the middle of the array of the 9 receivers, meaning, it is parallel to the 5th receiver because the 5th receiver got the signal first.

b) The 9th receiver got the signal from the source last.

c) This arrangement forms a right-angle triangle to make the computation easier.

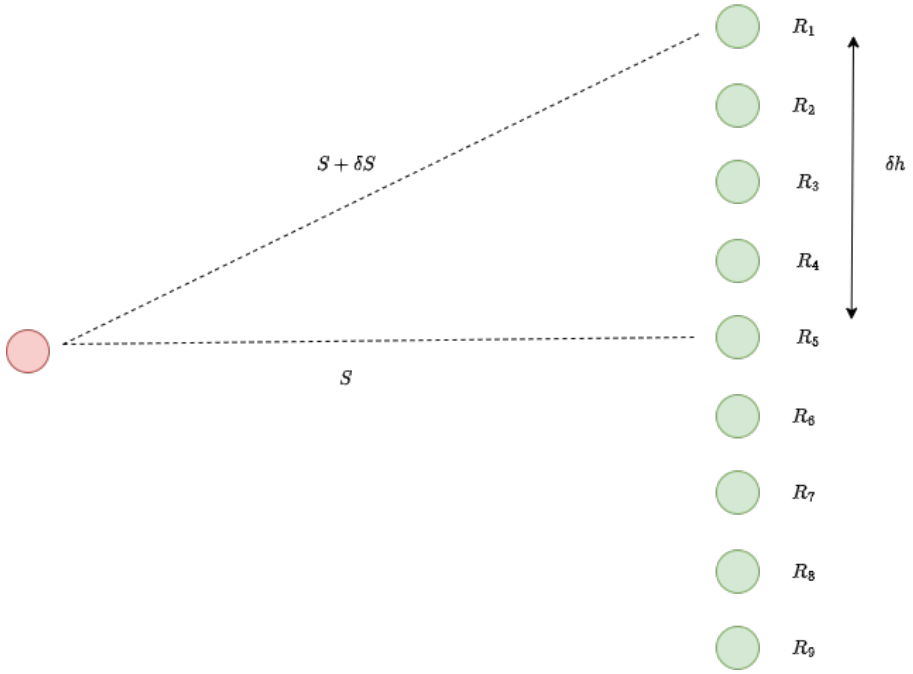

Figure 2: Plot of 9 receivers and the assumed geometry

$$s^2 + (dh)^2 = (s + \delta s)^2$$
$$\Rightarrow s^2 + (dh)^2 = (s + c \cdot \delta t)^2$$

Here, $\delta t = 2.249400 - 2.246600 = 0.0028m$
and $d = 100m$

$$\Rightarrow s^2 + (dh)^2 = s^2 + c^2\delta t^2 + 2sc\delta t$$
$$\Rightarrow (dh)^2 - c^2\delta t^2 = 2sc\delta t$$
$$\Rightarrow s = \frac{(dh)^2 - c^2\delta t^2}{2c\delta t}$$

If the distance s is calculated using 1st and 5th receiver,

$$s = \frac{100^2 - 17.64}{8.4} = 1188.37m$$

If the distance s is calculated using 5th and 9th receiver,

$$s = \frac{100^2 - 36}{12} = 830.33m$$

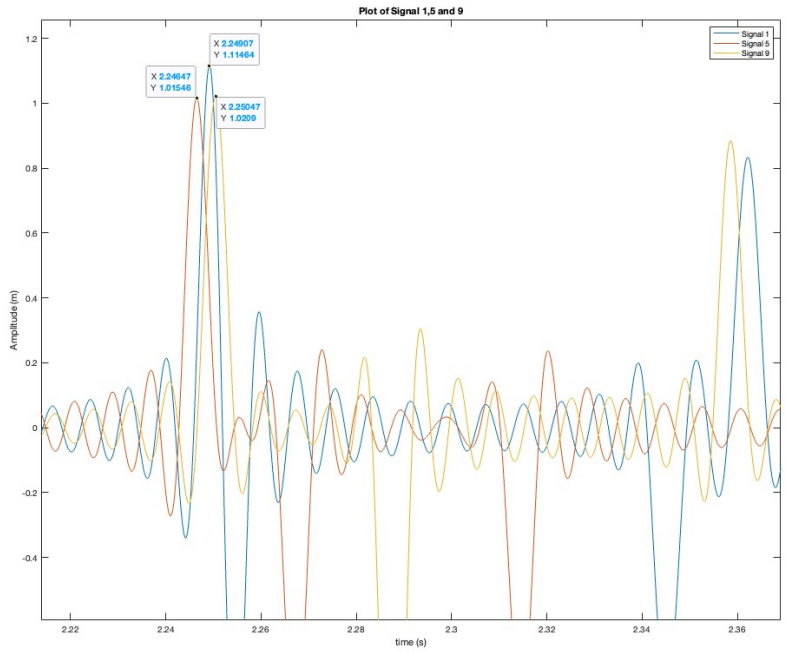

Figure 3: Plot of 1st,5th and 9th receivers and zoomed image of the first set of peaks of signals

We can consider the average distance as,

$$s_{avg} = \frac{1188.37 + 830.33}{2} = 1009.35$$

From these calculations, we can understand that the estimate of the distance between the receivers and the source is around 1000 meters. This gives us an idea of the area to search to get the location of the source.

For calculating the depth of the water column from the source, we need to draw a figure of the distance and channel depth . Here h is depth of the seafloor from the transmitter, S is the distance between the transmitter and receiver. We assumed that we have total reflection from flat boundaries and that angles for incoming and reflected beams are equal.

From the diagram, we can say that:

$$\begin{aligned} 2a - s &= \delta t \cdot c \\ a - \frac{s}{2} &= \frac{\delta t \cdot c}{2} \\ \Rightarrow a &= \frac{s}{2} + \frac{\delta t \cdot c}{2} \end{aligned} \tag{1}$$

From Pythagorean theorem, we get,

$$a = \sqrt{h^2 + (\frac{s}{2})^2}$$

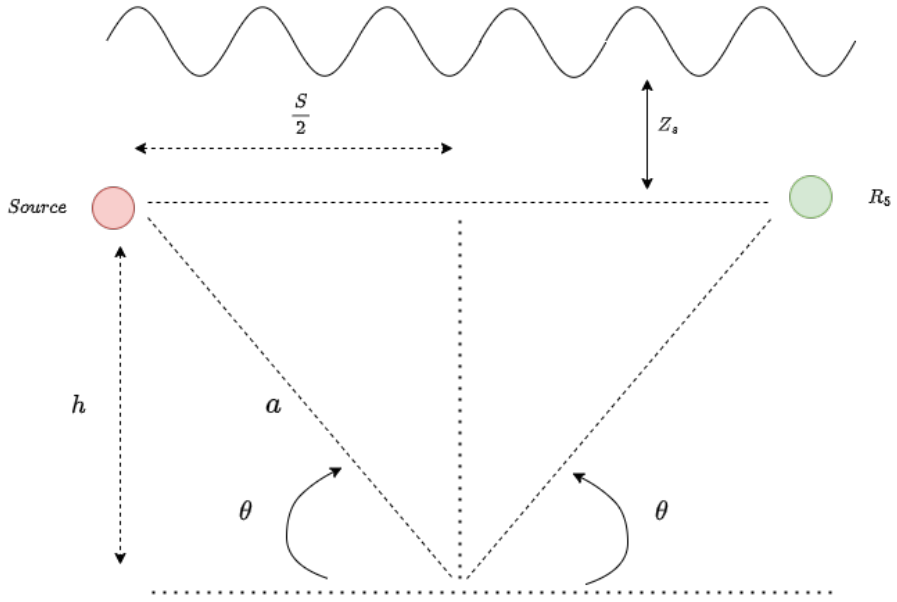

Figure 4: Different paths for signal on receiver 5

$$a^2 = h^2 + \frac{s}{2}^2$$

Substituting a using equation 1,we get:

$$\begin{aligned}
\frac{1}{4}(s + \delta t \cdot c)^2 &= h + \frac{s}{2}^2 \\
\Rightarrow h^2 &= \frac{1}{4}[(s + \delta t \cdot c)^2 - s^2] \\
&= \frac{1}{4}[s^2 + 2cs\delta t + (t \cdot c)^2 - s^2] \\
&= \frac{1}{4}[2\delta t \cdot c \cdot s + (t \cdot c)^2] \\
&= \frac{\delta t \cdot c \cdot s}{2} + (\frac{\delta t \cdot c}{2})^2
\end{aligned}$$

$$\Rightarrow h_{total} = \sqrt{\frac{\delta t \cdot c \cdot s}{2} + (\frac{\delta t + c}{2})^2} + z_s$$

From the figure 5 below we can calculate the time difference between the first peak and its first reflected peak. which is given as:

$$\delta t = 2.31447 - 2.24647 = 0.068s$$

Substituting the values we get:

$$\Rightarrow h_{total} = \sqrt{\frac{(0.068 \cdot 1500 \cdot 1005)}{2} + \frac{(0.068 \cdot 1500)^2}{4}} + 125 = 226.39 + 125 = 351.39m$$

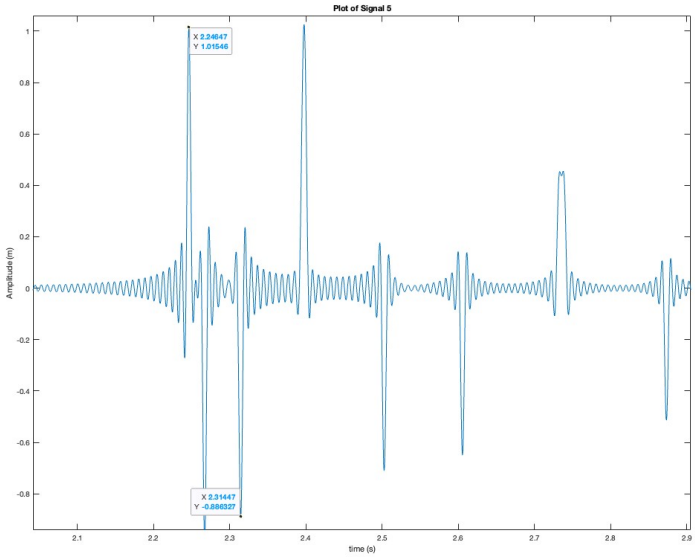

Figure 5: 2 Successive peak of Signal 5

1.1 Improving the Accuracy

Using obtained estimations for distance and depth we can simulate backpropagation in a specific area (search grid). To improve the accuracy of the plot from the simulation, we reduced the search to 920 to 1020m on the x-axis and the plot we got in the Figure. For simulation, we have used MATLAB script which is attached herewith. Obtained values for

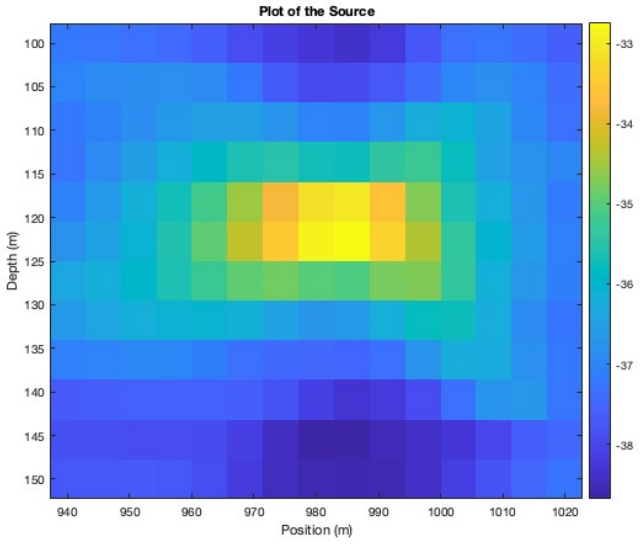

Figure 6: Plot of the Source Location

S and $depth_{source}$ are: S = about 990m $depth_{source}$ = between 120 - 125m