Master MIR – Underwater Acoustics
2024-2025

Homework 1

Here, the fluctuations of the velocity c with respect to horizontal coordinates are neglected and we focus on the trajectory of the rays in a vertical plane, taking into account the dependence of c with depth z. In the following, the reference velocity c_0 is the velocity at the water surface, $z = 0$.

Arctic Ocean

The simplest model for the velocity profile in this ocean is an affine function of depth :

$$c(z) = c_0 + \gamma_0 \mid z \mid$$

where $c_0 = 1450$ ms^{-1} and $\gamma_0 = 1.63 \times 10^{-2}$ s^{-1} with seafloor at depth $h = 3.50$ km.

1/ Let us consider a transmitter at depth z_S. What are the geometrical characteristics of the trajectory of a ray transmitted with an initial angle θ_0 toward sea bottom (measured from the horizontal axis) ? Plot this ray for $\theta_0 = 2°$ and $z_S = 500$ m with the help of your ray tracing software.

2/ We wish to establish a communication between two hydrophones located at $(0,0,z_S)$ and $(x,0,z_S)$, respectively. Express, as a function of c_0, γ , x and z_S an emission angle θ_0 generating a ray whose path passes through both hydrophones. Check the result using ray tracing software for $x = 20$ km and $z_S = 500$ m (to the nearest 0.1° for θ_0). Use the simulator to explore other possibilities. Have you found any? If so, which solution do you propose to use in operational conditions, and why?

Mediterranean Sea

Because of the higher water temperature at the surface, we observe a decrease of the sound velocity over 700 hundred meters, with -0.026 s^{-1} gradient, before returning to a pressure-driven behavior, as described above for the Arctic Ocean ($\gamma_0 = +1.63 \times 10^{-2}$ s^{-1}).

3/ We now plan to establish a communication with a receiver located 10 km away, at a depth of 1000 m. At what depth z_S and emission angle θ_0 would you suggest transmitting? Do we have the choice for transmitter depth? If operational conditions require to find rapidly a solution, suggest a strategy.

N.B. Please, provide the code used to plot the rays, or let me know which software you have used.