Introduction to acoustic propagation in the ocean

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Sounds in the ocean are mechanical vibrations that propagate as waves (see Appendix I). They are emitted at a certain level known as the **source level** (SL) and are received at a lower level called the **received level** (RL). The difference between the SL and RL is referred to as **transmission loss** (TL) (Fig. 1). The modeling of TL depends on the type of wave propagation: plane, cylindrical (from a line of sources), or spherical (from a point source), with TL values of 0, 10, and 20 dB decade^{-1}, respectively (Fig. 1). In the ocean, an intermediate formula is typically used (Fig. 1).

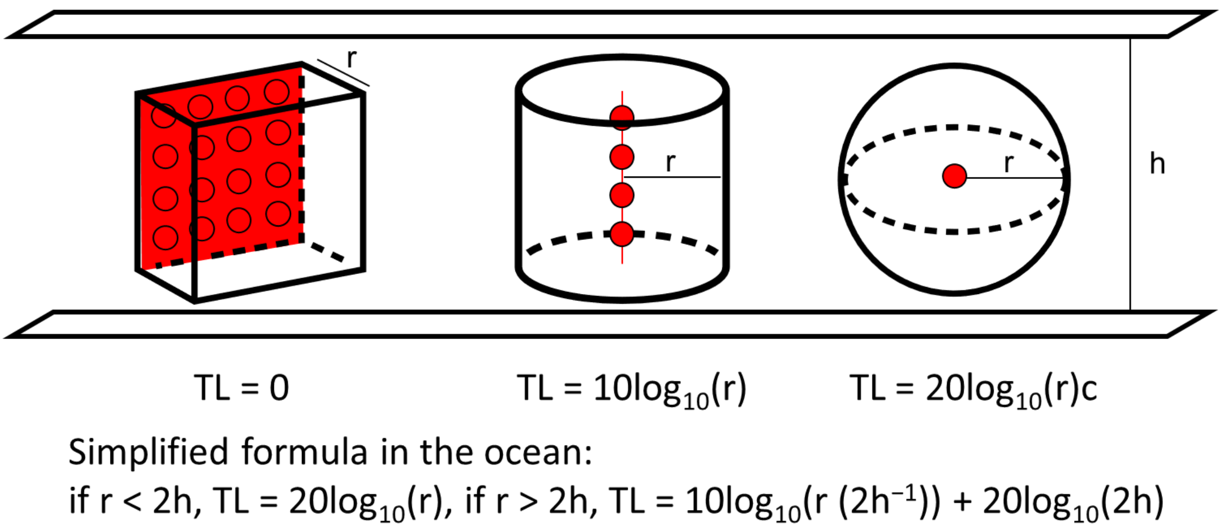

Fig. 1 Transmission Loss (TL) for plane, cylindrical, and spherical waves, along with a simplified formula applicable to real ocean conditions.

Sound waves are affected by various physical phenomena, including reflection, diffraction, absorption, and refraction. **Reflection** occurs when a wave encounters a boundary between two media, such as the sea surface or the ocean floor. The different sound speeds and densities of these media (air/water, ground/water, or water/water) determine the behavior of the reflected signal [1]. **Diffraction** occurs when a wave encounters an obstacle and bends around it. **Absorption**, also known as **attenuation** (α, in dB km^{-1}), is the process in which acoustic energy is converted into heat. Absorption depends on seawater properties, such as temperature, salinity, acidity, and the frequency of the sound [2–5]. While absorption contributes to the overall transmission loss (TL), it is typically a minor factor compared to the spreading of the acoustic wave propagating away from the source. Various models exist for calculating absorption, taking into account factors such as boric acid, magnesium sulfate, and water viscosity. The **François and Garrison** model (1982) is commonly used (e.g. [6,7]), but is not accurate for French Polynesia due to high water temperature. Therefore, the **Ainslie and McColm** model (1998) was employed in this thesis. Lastly, **refraction** occurs when there is a change in sound speed or a gradient in sound speed, often caused by gradual changes in water temperature, leading to a blending of the wave [1].

Due to these various phenomena and the fact that sound propagation in the ocean is influenced by physical parameters such as temperature, salinity, and pressure [8–11], modeling acoustic propagation becomes complex. The main approaches used include ray theory, the normal mode approach, and the parabolic equation approximation [1]. However, none of these approaches is perfect: the ray theory is not valid for low frequencies, while the latter two are not suitable for near-field studies (Gervaise, personal communication).

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