13.00 Introduction to Ocean Science and Technology
Problem set 9

---

1. Ocean Acoustic Tomography System

You are part of a team that is designing an acoustic ocean climate monitoring system for deployment in the Pacific Ocean. The system will have an omnidirectional source, operating at 200 Hz with a power of 20 Watts, deployed off the coast of the Hawaiian Islands. Five vertical line arrays of hydrophones (length = 200 meters) will be deployed at five locations: (1) the Aluetian Islands, (2) Tokyo, (3) Brisbane, (4) Punta Arenas, and (5) San Fransisco. Approximate distances from the source to each of the receivers are given below:

Location	Distance from source
Aluetian Islands	3000 km
Tokyo	6200 km
Brisbane	7500 km
Punta Arenas	12000 km
San Fransisco	3800 km

(a.) Calculate the travel time in hours for propagation from the source to each of the five receiver arrays, assuming a nominal sound speed of 1500 meters per second. What is the change in propagation time for each 1 meter per second difference in the sound velocity?

(b) The signal-to-noise ratio (SNR) in dB is given by the left-hand-side of the passive sonar equation:

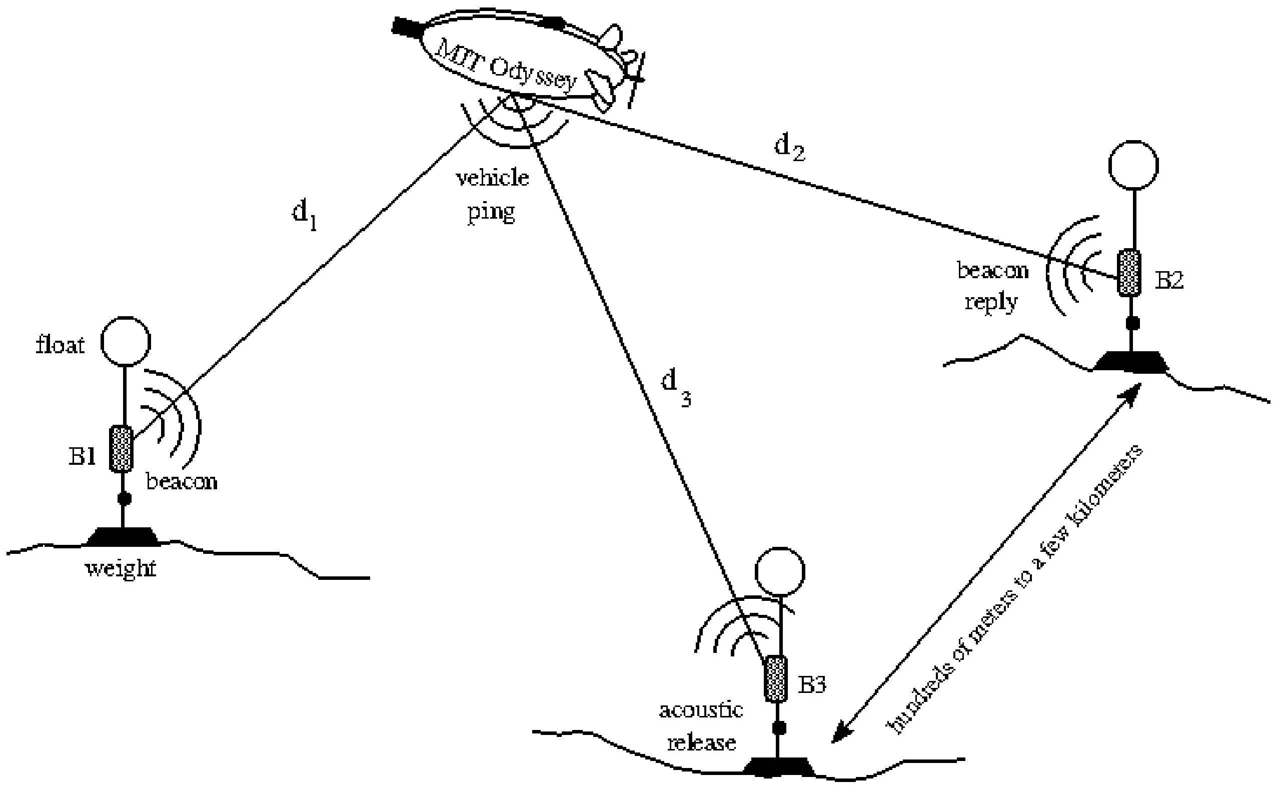
$$SL - TL - (NL - DI)$$

Calculate the predicted SNR that you would expect at each of the five receiver locations. To obtain a more accurate prediction of propagation losses, use a mixed propagation model that assumes spherical spreading plus absorption for the first 5 kilometers of sound propagation, and then cylindrical spreading plus absorption for the remaining distance. Do you think that the signal can be detected reliably at all five locations?

(c.) An extremely important concern with this type of system would be its effect on marine mammals. Research has shown that at least some whales will change their behavior if they are exposed to sounds at sound pressure levels of 120 dB or greater (source: http://www.cnie.org/nle/mar-2.html). How close would a whale have to come to your source for its behavior to be changed?

(d.) Based on your answer to part (c.), and other readings you have been given in the class, Do you think that systems of this type should be used in the ocean? Are they safe for marine mammals? How can we understand better the effects of sound on marine mammals?

2. Odyssey navigation system performance analysis



MIT Sea Grant uses two types of long-baseline (LBL) navigation system with the AUV Odyssey. The standard LBL navigation system operates at 10 KHz. For more accuracy over a smaller area, another system, called SHARPS (Sonic High Accuracy Ranging and Positioning System) is used. This system operates at 300 kHz.

detection threshold is 20 dB, and the source level is 180 dB re 1 μPa at 1 meter.

1. What is the *transition range* for each system, i.e., the range at which the rate of the increase of the transmission loss changes from cylindrical to (spherical) spreading?
2. What is the (one-way) transmission loss (TL) for each system at the ranges of 10, 100, 1,000, and 10,000 meters, assuming spherical spreading? Assuming cylindrical spreading?
3. If the noise level at 10 kHz is 80 dB, what is the maximum operating range of the standard LBL system?
4. If the noise level at 300 kHz is 80 dB, what is the maximum operating range of the SHARPS system?
5. Why is the SHARPS system more accurate than the standard LBL system?

3. Robodolphin

You have been asked to design a new active sonar system for "RoboDolphin", a new underwater robot being developed at MIT. RoboDolphin will be a one meter long, free-swimming, highly maneuverable vehicle that utilizes the flapping foil propulsion system first developed for RoboTuna. RoboDolphin will be used to try to mimic the sensing strategies performed by dolphins during echolocation. You would like your system to have a maximum range of 300 meters and to be able to operate in moderately rough sea conditions. The beampattern of the dolphin has been determined experimentally to have $\theta_{3dB} = \pm 10$ degrees (for both transmit and receive), with a radiation pattern that matches a circular disc transducer.

(a.) Design a sonar system for the RoboDolphin to fulfill these characteristics. (Fill in the parameters on the table of below.) Choose the source level for your system so that it is just able to detect a 0.5 meter diameter fishing float at maximum range. Document any assumptions you make about various system parameters to come up with a complete design.

receiver DI:	$\mathrm{DI}_R =$	__________
pulse length:	$\tau =$	__________
source level:	$SL =$	__________
array diameter:	$D =$	__________
noise level:	$NL =$	__________
transmission loss:	$TL =$	__________
wavelength:	$\lambda =$	__________
source DI:	$\mathrm{DI}_T =$	__________
time-of-flight:	$T =$	__________
ping interval:	$T_p =$	__________
frequency:	$f =$	__________
target strength:	$TS =$	__________
range resolution:	$\delta =$	__________
acoustic power:	$\mathcal{P} =$	__________
average acoustic power:	$\overline{\mathcal{P}} =$	__________

(continuation of problem 4)

(b.) A bottle-nose dolphin has been shown to be capable of detecting a 3 cm diameter ball bearing at 72 meters range in an environment where NL = 100 dB. (This high noise level was caused by snapping shrimp in Kaneohe Bay, Hawaii, which is where many US Navy experiments with dolphins have been performed.)

Would the system you designed be able detect a 3 cm diameter ball bearing at 72 meters range in an environment where NL = 100 dB? If the answer is no, how would you change your design to be able to perform this task?