INF-GEO 4310 Sonar exercise 2011

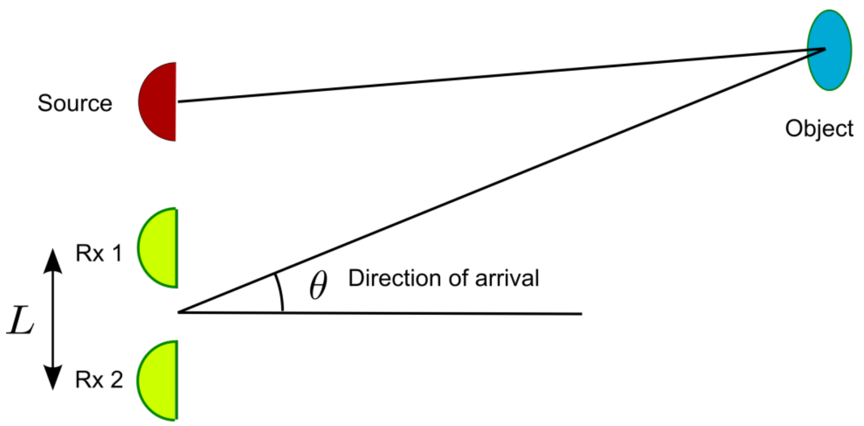
1 Multiple choice

1. To improve the range resolution in sonar, one has to:
   - ❑ Increase the frequency of the transmitted signal
   - ❑ Increase the number of transducers
   - ❑ Transmit more power
   - ❑ Increase the pulse length of the transmitted signal
   - ❑ Decrease the pulse length of the transmitted signal

2. Sound travels over large distances under water. The sound is influenced by the marine environment in what way?
   - ❑ Sound refracts towards the sea surface
   - ❑ Sound refracts towards the sea floor due to gravity
   - ❑ Sound propagates in straight lines and can therefore travel large distances
   - ❑ Sound is trapped in sound channels and can therefore travel large distances
   - ❑ Sound refracts towards higher sound velocity and propagates therefore faster

2 Regular exercise

Assume a sonar source and two receivers forming a plane as illustrated below. The receivers are displaced L apart. The source transmits a pulse with wavelength λ. The transmitted signal is reflected by an object. The reflected signal propagates to the receiver array with velocity c. Rx 2 observes the reflected signal δt delayed compared to Rx 1.



1. Assume that the reflector is in the far field. What is the direction of arrival of the reflected signal expressed by the terms given in the exercise?

From geometry and assuming far field (⇔the beams from the reflector to the elements are parallel): difference in travel distance = $\Delta x = L \sin\theta = c\ \delta t$ => $\sin\theta = c\delta t/L$

2. Assume that the smallest time difference possible to detect is equivalent to 1/8 period. What is then the angular resolution (or accuracy) for the system?

Smallest time difference is $\delta t = T/8$ => one can separate between beams at $q_0=0$, q_1, q_2 ... where the angles are given by
$\sin\theta_n = cn\delta t/L = ncT/(8L) = n/(8L)(c/f) = n\lambda/(8L)$. Due to this constraint in the estimation of time difference, this will be determine the accuracy of pointing in the system.

3. How does the angular resolution, as defined in 2, change with frequency? Explain.

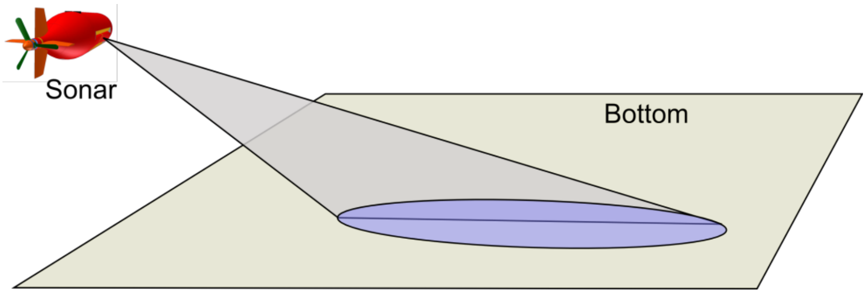
Increase with increasing frequency. Because the element separation L becomes larger measured in wavelengths for increasing frequency.

3 Multiple choice

1. Change in the sound speed changes acoustic wave propagation in what way?

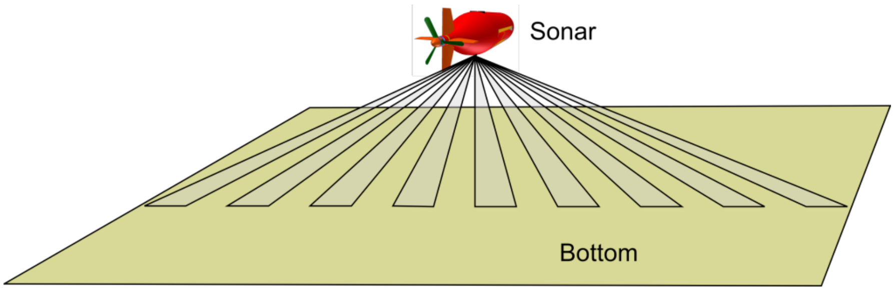
- ❑ The acoustic amplitude changes when the sound speed changes
- ❑ The acoustic waves refracts towards higher sound speed
- ❑ The acoustic effect is reduced such that the energy is lower
- ❑ The acoustic waves refracts towards lower sound speed
- ❑ The acoustic frequency changes when the sound speed changes

2. Scattering and reflection are basic mechanisms for sonar. What is correct for sidescan sonar imaging of the seafloor (see Figure)



- ❑ The seafloor must have high impedance to impose acoustic reflection from the seafloor.
- ❑ The seafloor must be rough for the transmitted acoustic field to be scattered and reach the receiver
- ❑ The sound speed in the seafloor must be different from the sound speed in seawater for acoustic reflection to happen
- ❑ The seafloor must be plane such that the transmitted acoustic waves are reflected and reach the receiver
- ❑ The sound speed in the seafloor must be different from the sound speed in seawater such that the acoustic waves are refracted and reach the receiver

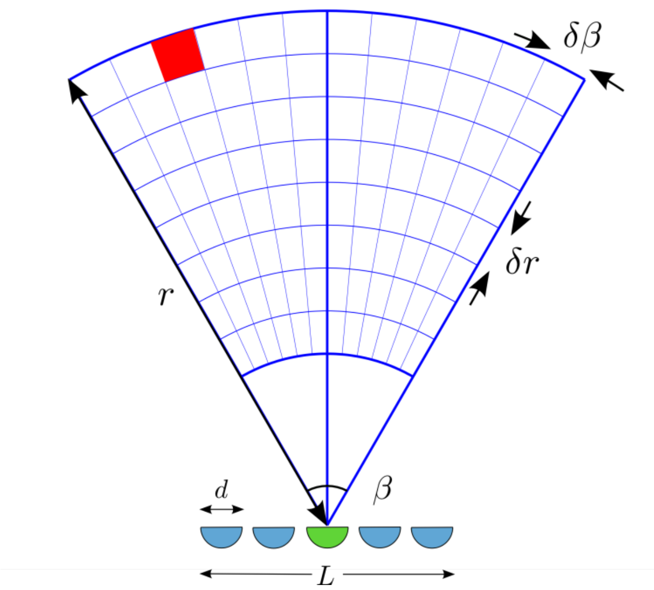
3. A multibeam echosounder (see Figure) transmits and receives acoustic waves in multiple directions. What is the primary application:



- ❑ The sonar detects fish in every beam and estimates the size of fish schools
- ❑ The sonar collects the reflectivity of the seafloor in all directions, and calculates an image of the seafloor
- ❑ The sonar estimates the range in each beam, and calculates a bathymetric map of the seafloor
- ❑ The sonar looks in many directions to calculate an average reflection coefficient of the seafloor
- ❑ The sonar estimates the Doppler shift in many direction in order to calculate the vehicle speed relative to the seafloor

4 Regular exercise

Assume a sonar transmitter (green) and a receiver array (blue and green).
The receiver is a linear array with length L = 120 cm, where each element in the array have size d = 3.75 cm. The sonar system transmits pulses at center frequency f = 100 kHz. The sound speed is assumed to be 1500 m/s.



a) The sonar transmits a pulse each ¼-second. What is the maximum range of the system?

The maximum range is given by the maximum travel time T = ¼ second. $T_{max} = 2 R_{max} / c \Rightarrow R_{max} = T_{max} * c / 2 = ¼ * 1500 / 2 = 187.5$ m.

b) In which distance *r* is a pixel in the far field of the receiver array?

The far field is defined by where the wave front is approximately plane. Assuming that the wavefront curvature should be less than lambda/2, the far field becomes $R > L^2$ / lambda = 96 m

c) What must be done to the recorded data in each receiver element for the sonar to image the red pixel in the imaging scene? Draw figure if needed.

The timeseries from each array element must be delayed such that the response of the array is steered towards the pixel. Then the delayed data from each element are summed to form a beam in that direction. The delay must be in accordance with the wished range to the pixel.

d) What is the angular resolution (given as an equation)? What is the angular resolution for this system (given in degrees)? What is the angular resolution of an equivalent system with center frequency of 200 kHz? Is this system better?

The angular resolution is gives as beta = lambda / L. For this system, it becomes 1/80 * 180 / pi = 0.7 degrees. For an equivalent system of double the frequency, the angular resolution becomes half: 0.35 degrees. This is better.