Underwater acoustic sensors

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Introduction to advanced marine technologies

SUMMER SCHOOL (SS1)

Almada, Portugal // June DD, 2016

STRONG MAR

Overview

Sensors and platforms

Acoustic Sensors, case studies:

Watercolumn suspended sediments study

Acoustic environmental impact study

Electro-Acoustic Instrumentation

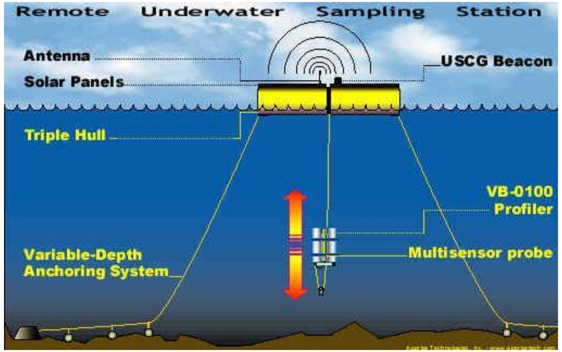
Acoustic transduces specifications

Why using sensors

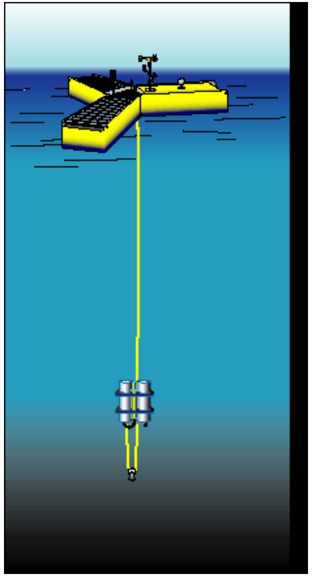
- **Ocean sciences are observational driven sciences.**
  - nearly all our knowledge of the ocean and the processes that occur there comes from observations made in the ocean.
- **To describe physical/chemical phenomenon of the ocean**
  - Temperature, currents at a given location, tidal component of the sea surface elevation, etc.
- **we need observations and to observe the ocean we need**
  - Platforms from which to make observations, Sensors to make measurements, Data conditioning circuits, Storage media, Power supplies, Analysis/Processing data
- **To good information from and experiment we need to:**
  - Place sensors in the ocean (surface buoy, ship, mooring line, bottom tripod, Rov, AUV, Glider)
  - Transducers/sensors which change the environmental signal into something we can measure

Sensors and platforms

Moored platform

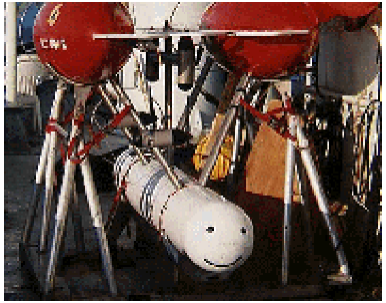


Drifting platform



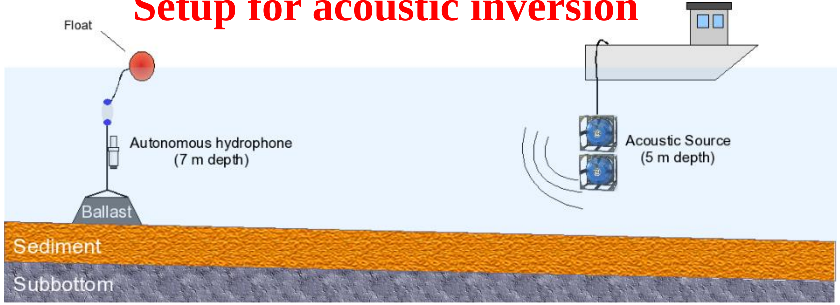
ADCP

Multi-Parameter Probe



Robotic platform

Setup for acoustic inversion



Piezoelectric acoustic transducers
Lab Experiments

- Transmitter - Transforms Electric Energy into Acoustic Energy
  - Chladni Plate

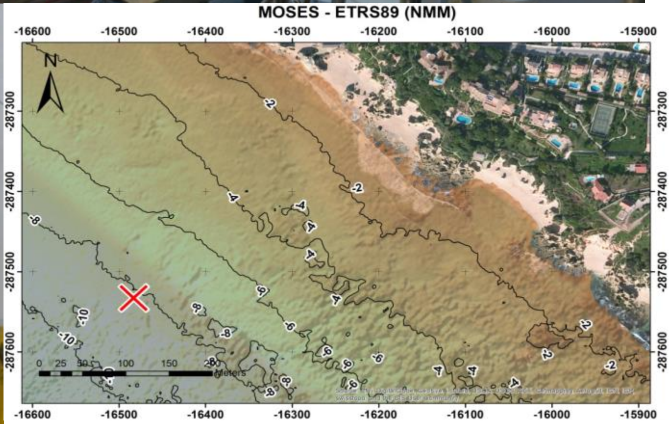
- Receiver – Transforms Acoustic Energy into Electric Energy
  - Harvesting Energy

Underwater Acoustic Sensors and Systems

- Underwater Acoustic Transmitter/Receiver
  - ABS – Aquatec
- Underwater Acoustic Transmitter (Tx)
  - Lubbel 911 - Lubbel
- Underwater Acoustic Receiver (Rx)
  - SR1 - Marsensing

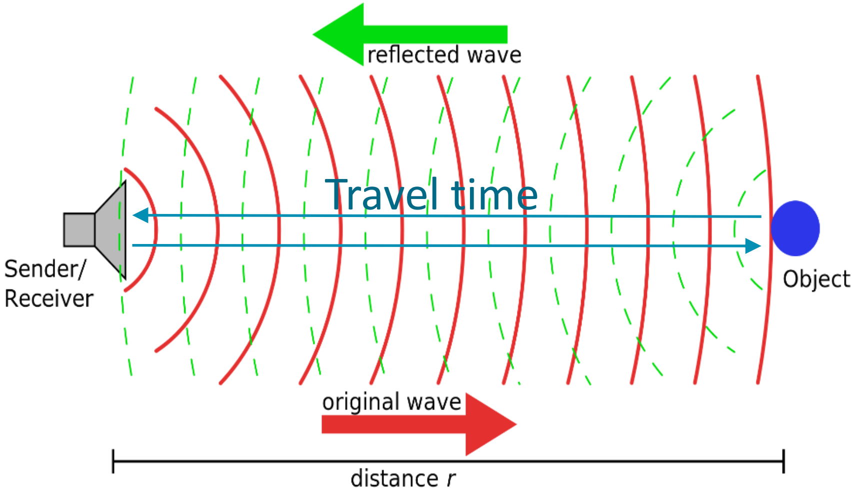
Watercolumn suspended sediments study

- Location, platform and sensor
- Ultrasound acoustic backscattering system
- Active Sensor:
    - 0.5MHz, 1MHz, 2MHz, 4MHz
    - Different frequencies
    - Different granularities



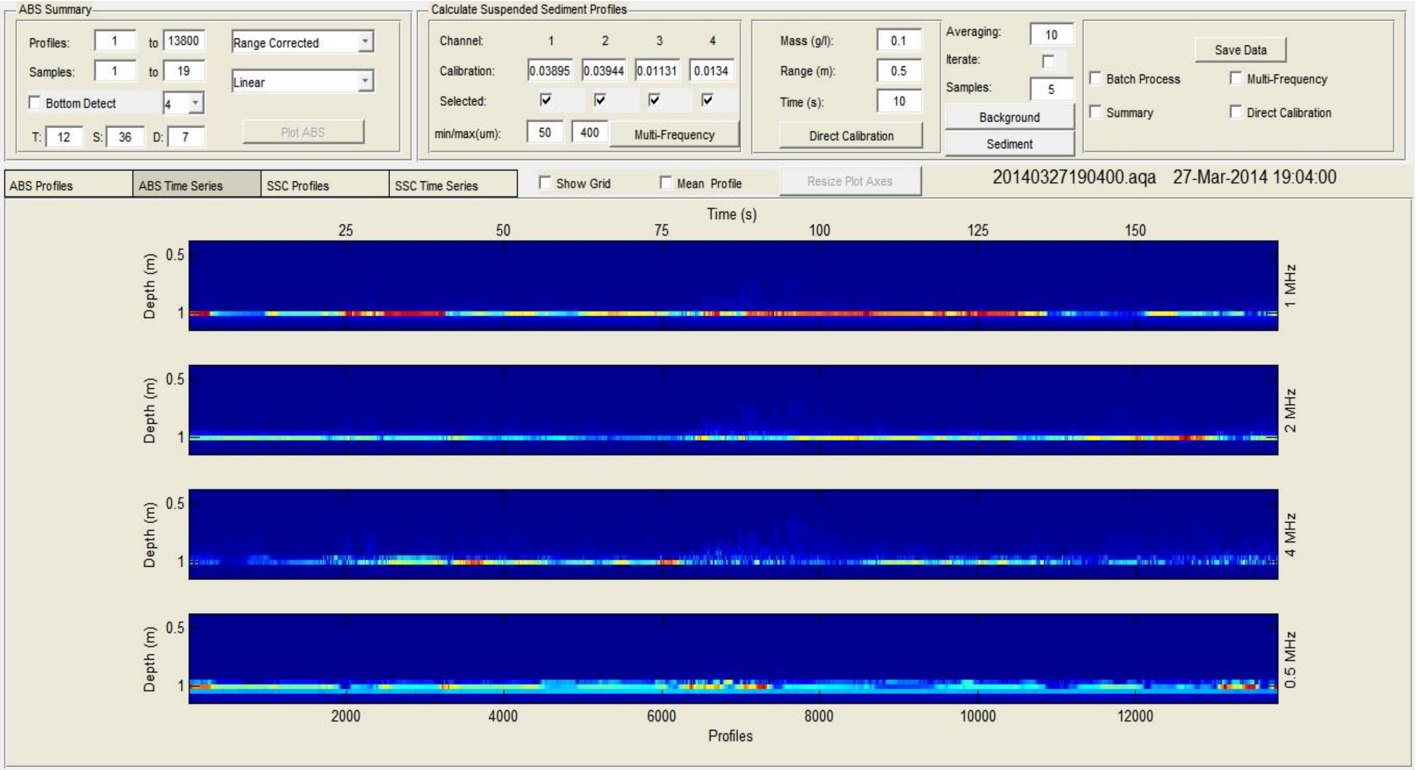
Physical principal of active acoustic sensors

- Wavelength < object diameter
  - Backscattering (echo)
  - Higher frequencies detects smaller objects
- Wavelength > object diameter
  - Rayleigh scattering

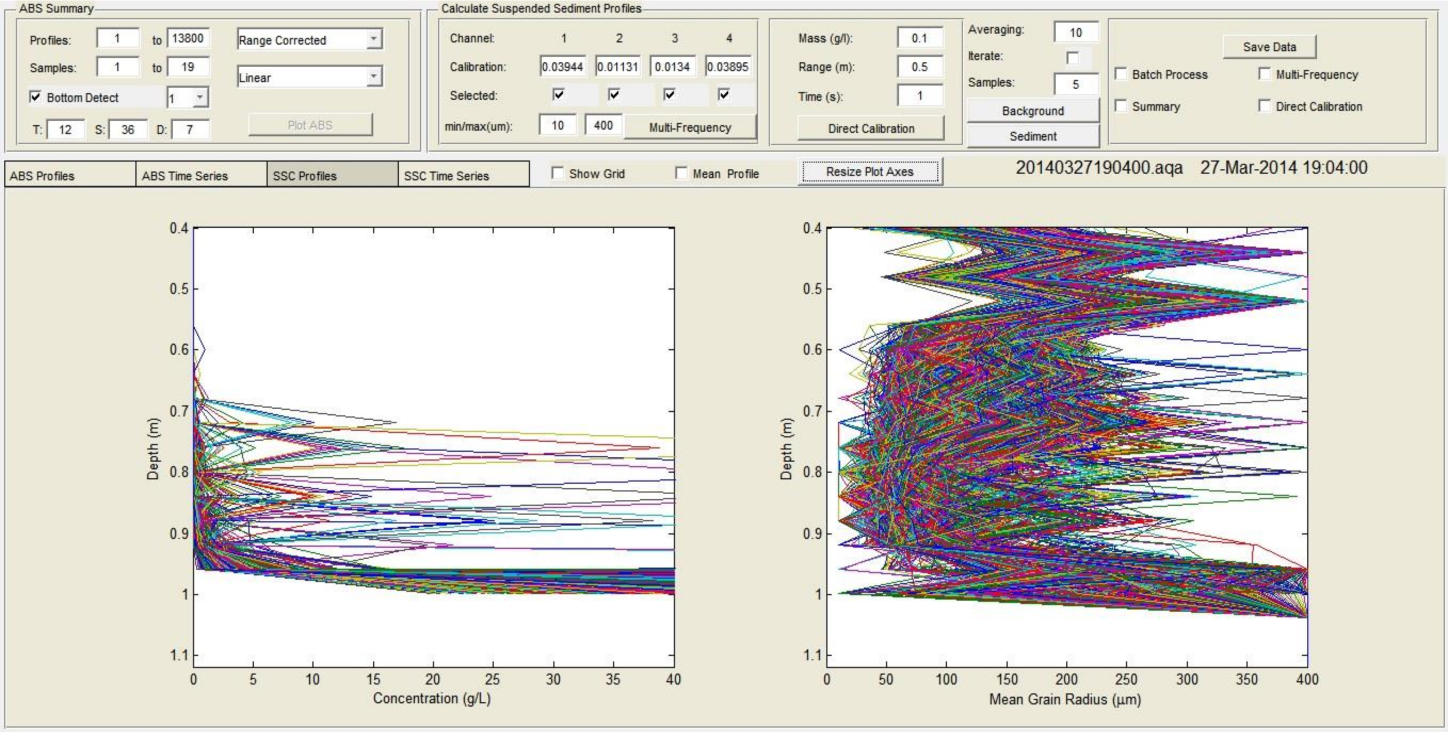


distance = (travel time x sound speed)/2

Sediments concentration measurements



Sediments concentration information

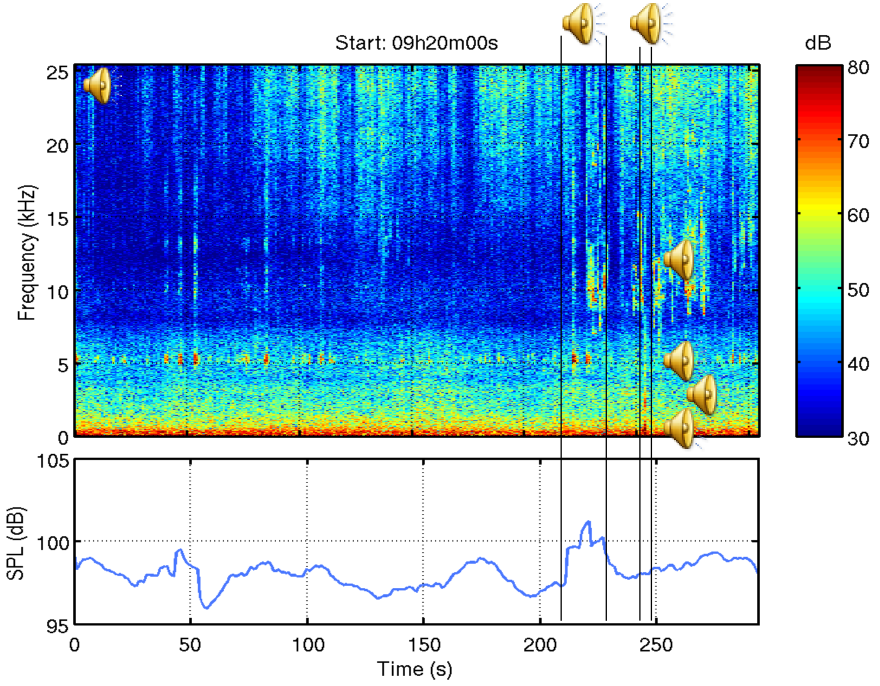


Measurements and Information for an environmental impact study

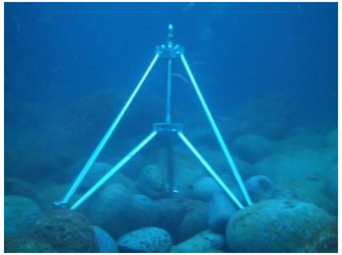
- Motivation
- Environmental Impact Studies
- The Self Registering Hydrophone
- Results

Centro Empresarial - Pavilhão A5, *Campus* de Gambelas 8005-139 Faro www.marsensing.com e-mail: contact@marsensing.com

Motivation



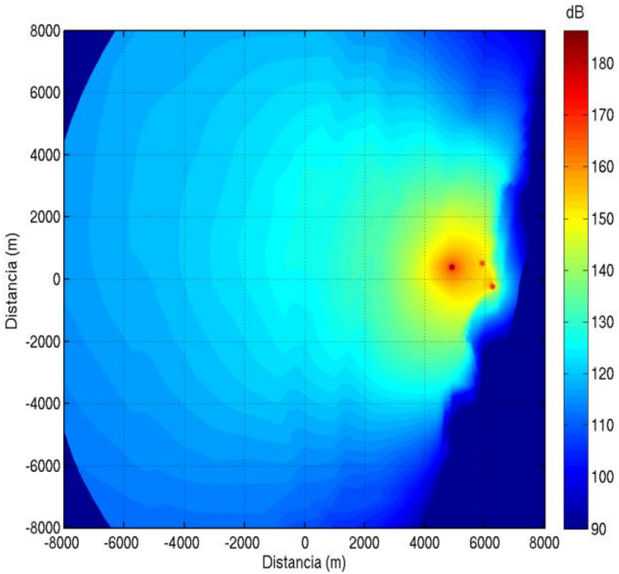
There is a need to establish procedures to carry environmental studies and for protecting sensitive areas and species.



Environmental Impact Studies

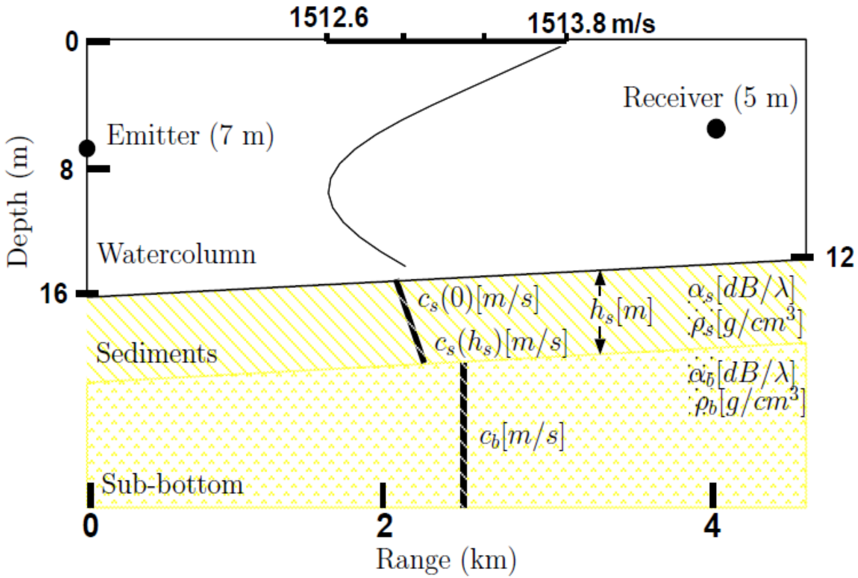
- In littoral waters man-made acoustic noise is a environmental descriptor of increasing concern

- Impact of pneumatic hammers acoustic noise on mammals, during an offshore construction



Acoustic (noise) propagation problem

- **Physical parameters that affect underwater sound propagation**

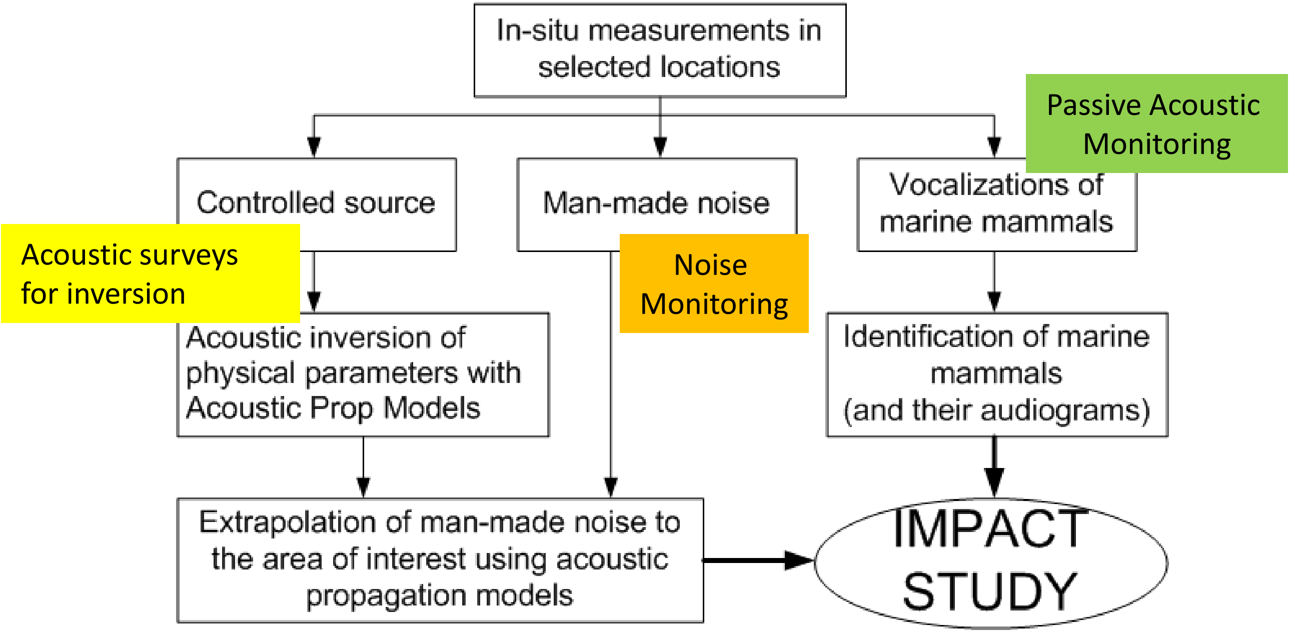


The sound dose not propagate homogeneously over range, depth and azimuth

This may imply to take recordings at many positions in the area of interest

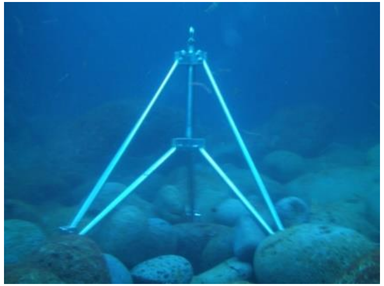
Noise measurements of today can lose validity tomorrow due to the water temperature strong variability

Environmental Impact Studies



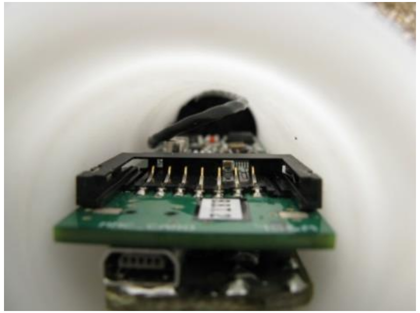
The SR-1 autonomous recorder

- To carry on man-made noise environment impact studies:
  - underwater noise monitoring;
  - acoustic surveys;
  - passive acoustic monitoring of cetaceans.
- The SR-1 autonomous recorder was developed to respond to these challenges



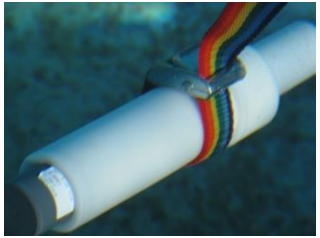
The SR-1 autonomous recorder hardware

- Compact cylinder (made from Delrin): 323mm x 50mm.
- Bandwidth (3 dB): 122 Hz – 24.9 kHz.
- Voltage sensitivity: -164 dB *re* 1 V / 1uPa.
- Voltage gains: 0, 6, 12, 18, 24, 30, 36 dB.
- 50781 samples/s; 16 bits stored.
- Memory: 2GByte flash card (5h20m of data).
- Battery: 3.7 V lithium type 18650 (10 h).
- Other characteristics: USB interface; magnetic switch
- **Electronic noise is lower than the sea state zero**



The SR-1 autonomous recorder Software

- Acquisition program:
  - controls the start and stop of acquisition;
  - setting of the *programmable gain amplifier*;
  - retrieval of sampled data from the ADC;
  - storage of data (.wav files) on the external flash card.



The SR-1uses the USB interface for device programming:

- setting the real-time clock
- programm acquisition time table
- data file length
- PGA settings

The SR-1 autonomous recorder Operation

Convenient for moored operation:

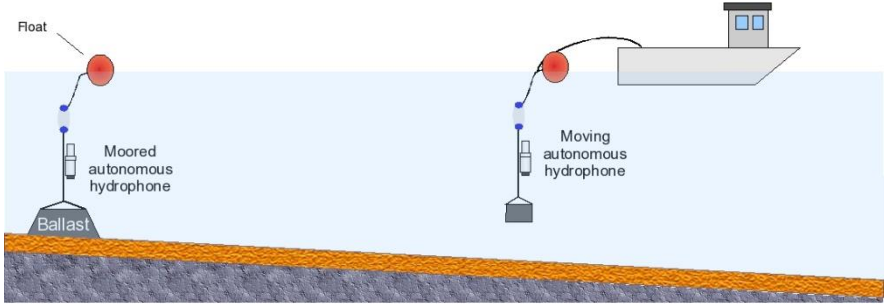
- simultaneous recordings at multiple locations;
- recordings without human presence:
  - impossible or undesired presence of human resources;
  - recordings over long periods.

Underwater

Noise and

Passive acoustic

monitoring

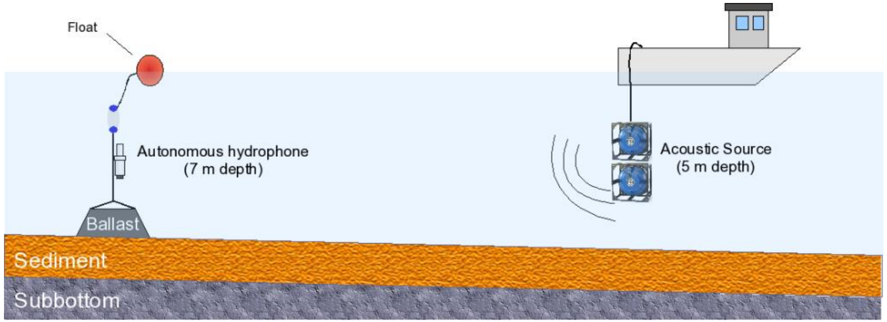


The SR-1 autonomous recorder Operation

To study the acoustic propagation:

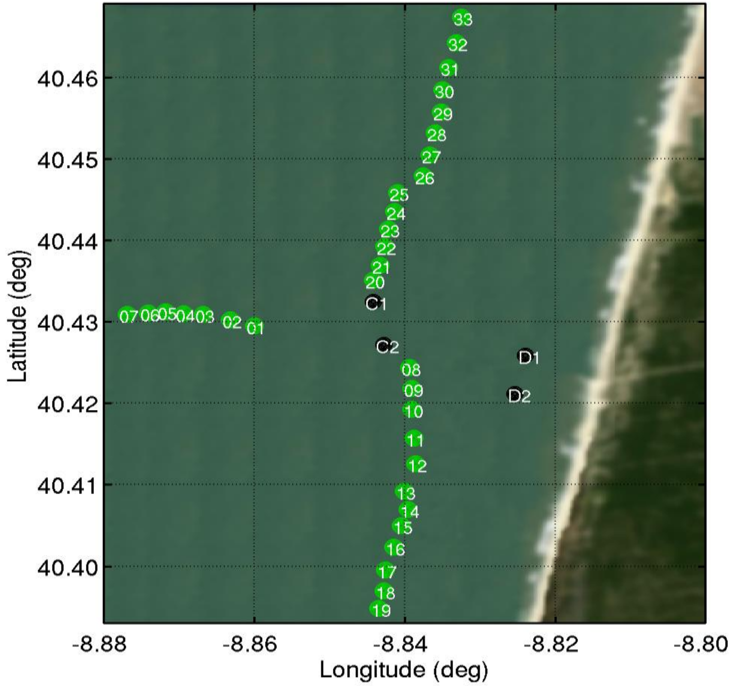
- The autonomous hydrophone is moored at a reference position.
- A boat navigates a light acoustic source away from the receiver.
- Repeated transmissions over range provide curves on transmission loss as a function of range and frequency.

Acoustic surveys and Acoustic inversion



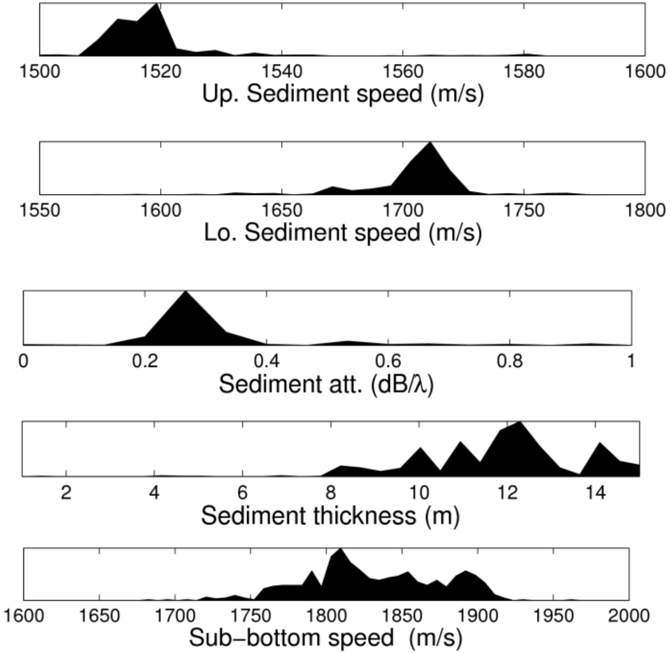
Acoustic surveys
Operation

- The autonomous hydrophone was moored at C1 or C2.
- Acoustic transmissions up to 4 km range.
- Transmission: multi-tones 250, 500, ..., 1250, 1500 Hz.
- Amplitude 160 to 175 dB.
- The experiment was completed in appr. 2 days

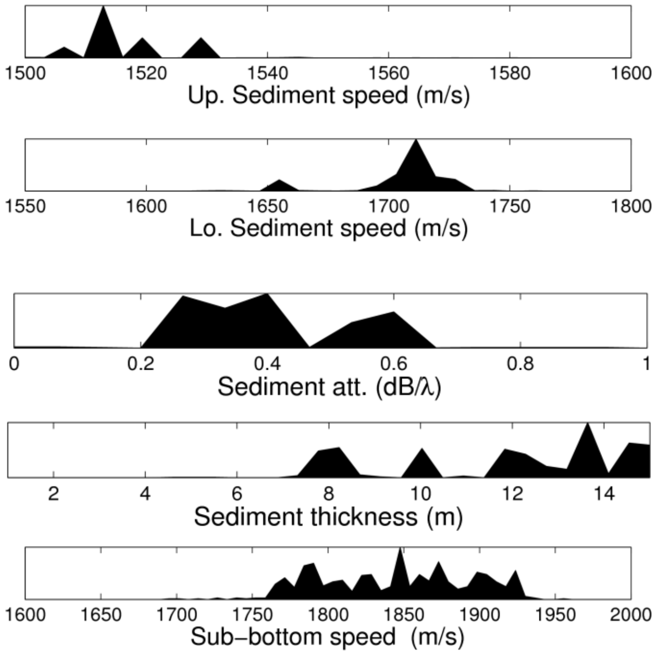


Acoustic surveys experimental results

North transect

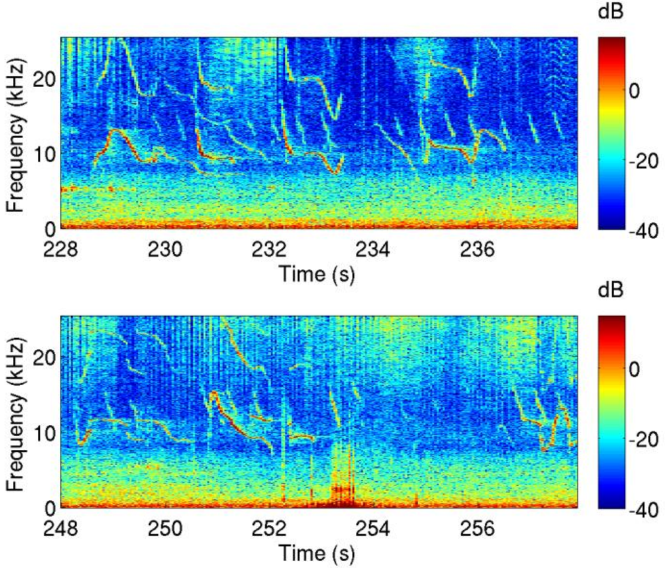


South transect



Passive Acoustic Monitoring Results

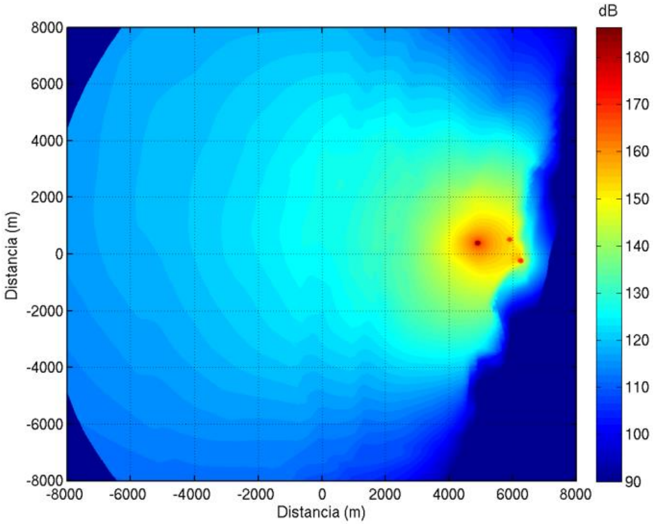
- Passive acoustic monitoring (PAM) is an interesting complement in cetacean monitoring.



- The use of autonomous recording devices:
- acoustic monitoring over long periods.
- monitoring without human presence.

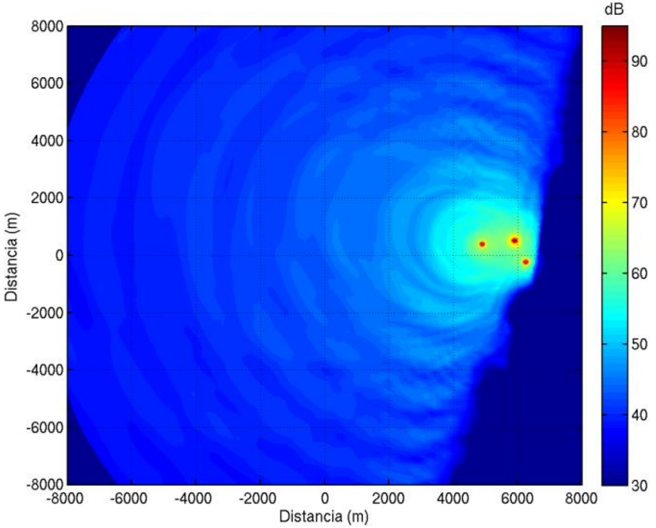
Impact Study

- Noise map (3D) - pneumatic hammer



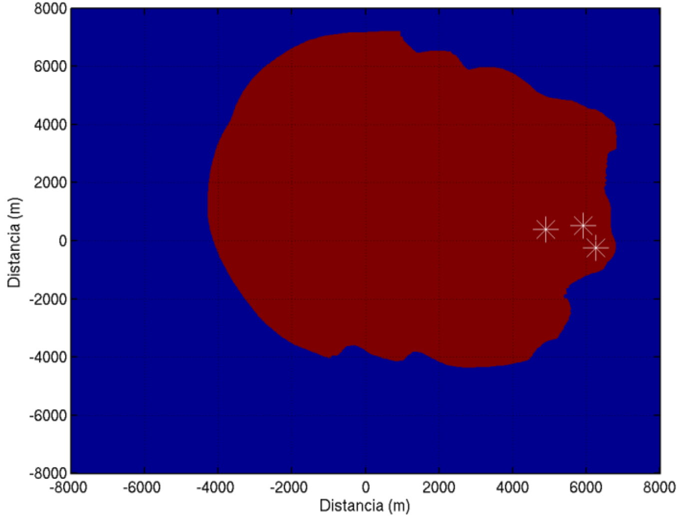
Levels of sound sensation of dolphin

(after calibration with the audiogram)

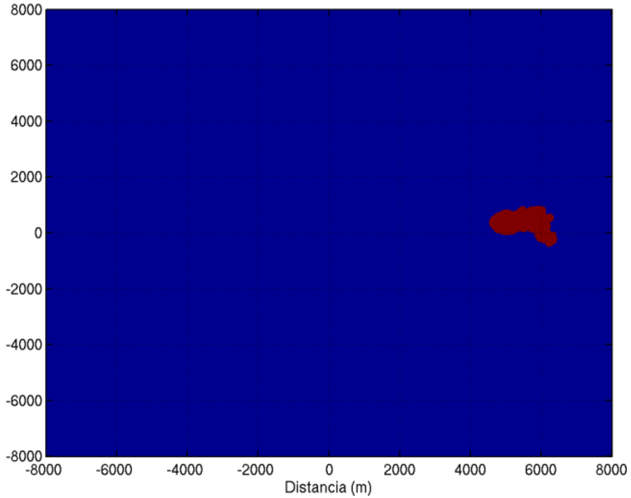


Impact Study

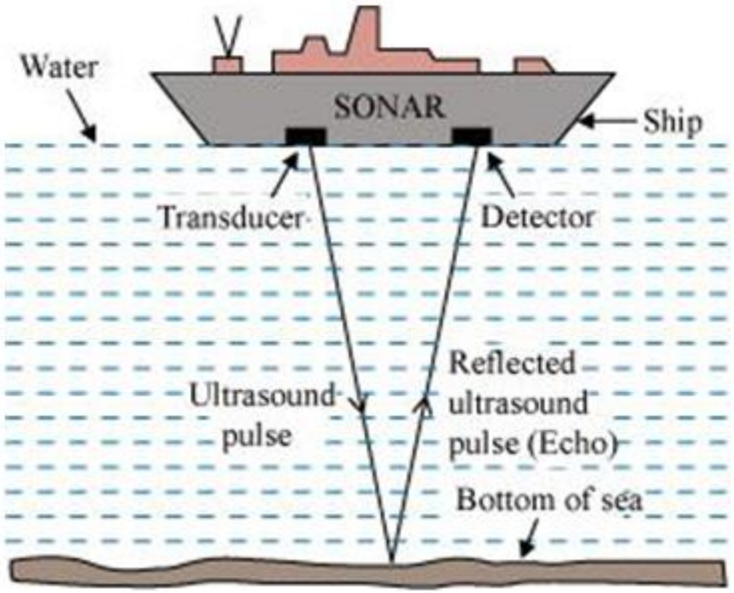
- Area of audibility

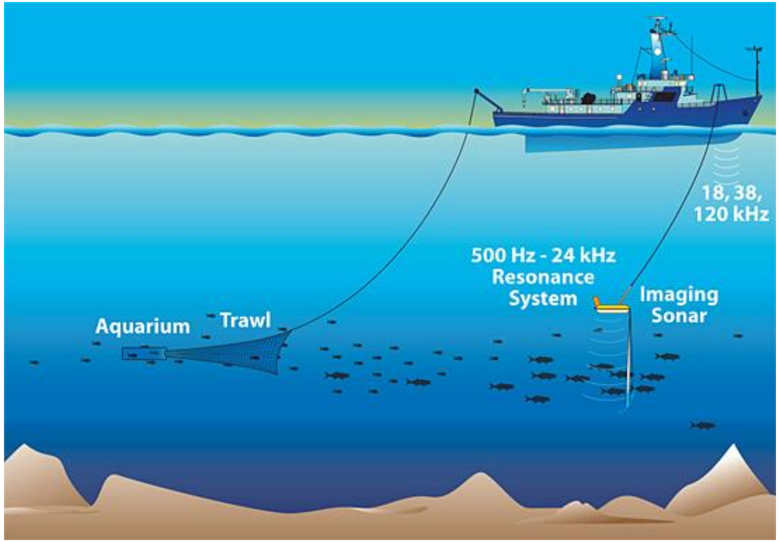


- Area where the dolphin lose hearing sensitivity

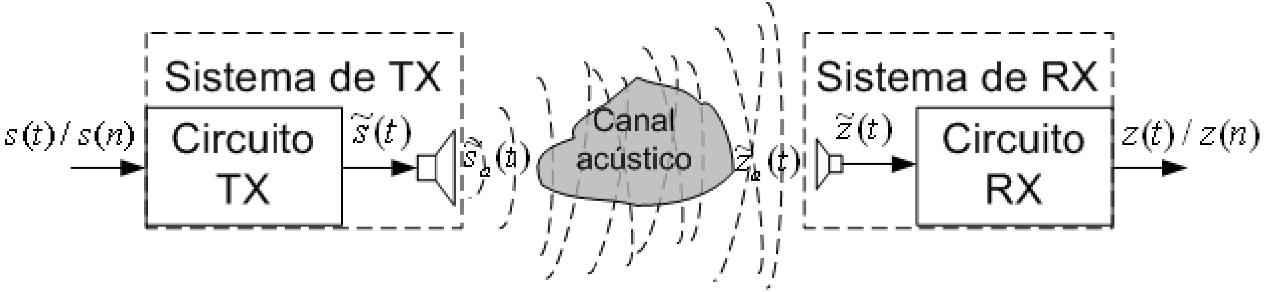


Other underwater acoustic applications





Electro-Acoustic Instrumentation



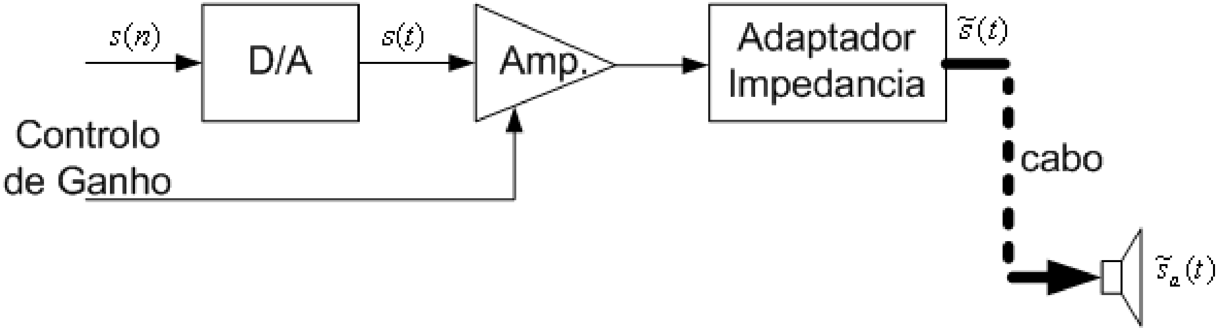
- In an ideal system–> *z(t)* = G T[*s(t);* acoustic channel]

$$\tilde{s}(t) = G_{TX} s(t) \qquad \tilde{s}_a(t) \equiv G_{cEA} \tilde{s}(t)$$

$$\tilde{z}(t) \equiv G_{cAE} \tilde{z}_a(t) \qquad z(t) = G_{RX} \tilde{z}(t)$$

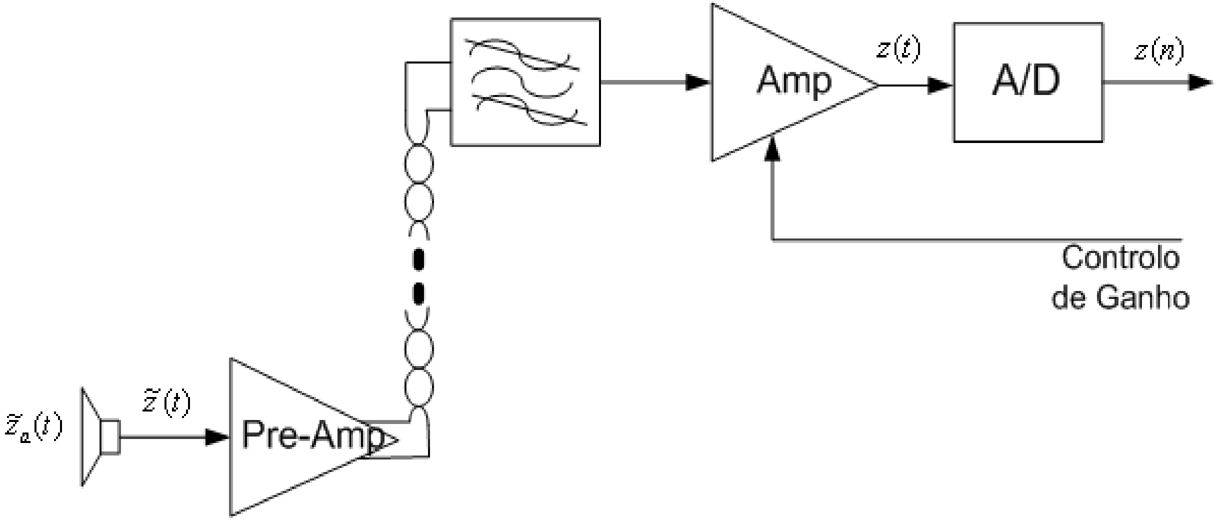
- In a real system - the TX and RX systems introduce a distortion that must be minimized

TX system



$s(n)$
D/A
$s(t)$
Amp.
Adaptador
Impedancia
$\tilde{s}(t)$
Controlo
de Ganho
cabo
$\tilde{s}_a(t)$

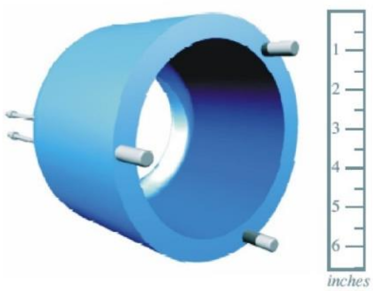
RX system



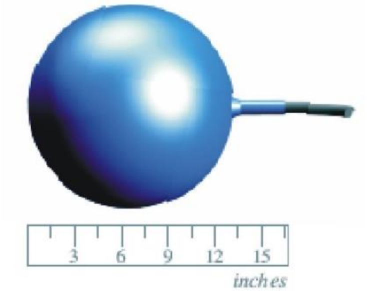
Underwater acoustic transducers

- The transducer selection, involves a mixture of acoustic, electrical and mechanical considerations
  - Mechanics: spherical, toroidal, aggregate, …
  - Electrical: capacitor, inductance

ITC-4008A



ITC-2002A



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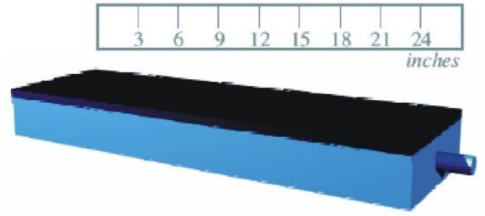
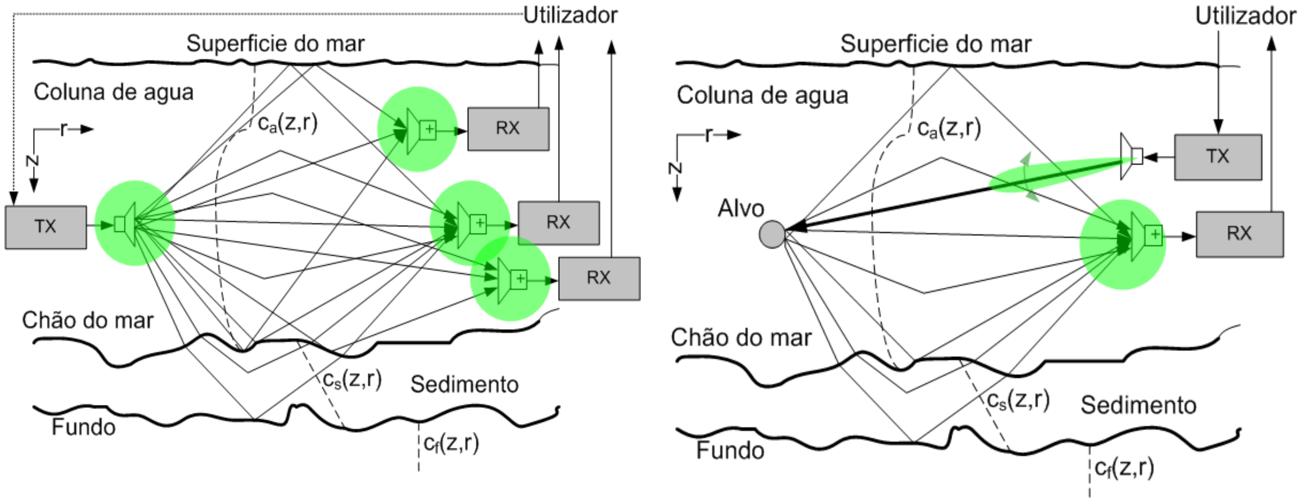


Physical configuration of the system

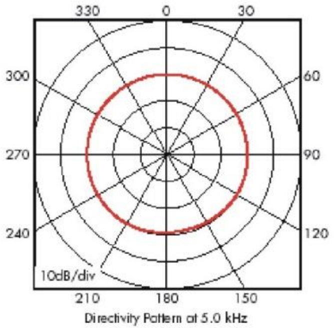


Radiation pattern: Omnidirectional, hemispherical directional,…

Physical configuration of the system

- Beam Pattern
  - Shows the sound pressure level (Tx or RX) in all direction, centered in the transducer
  - Omnidirectional <= spherical transducers
  - Directional <= transducer with a particular shape or an array of transducers merged into a single unit

ITC-4008A



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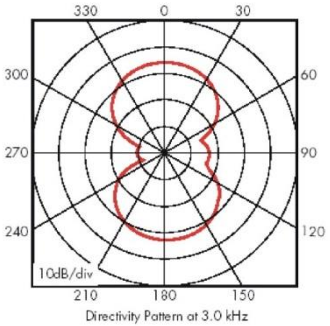
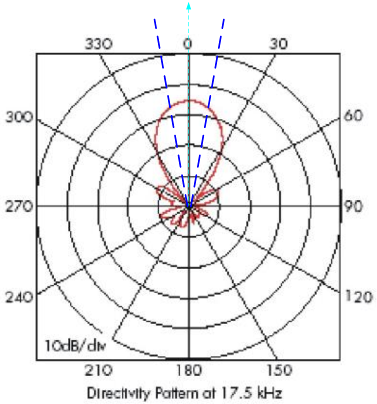


Physical configuration of the system

- Beam Pattern
  - Maximum Response Axis (MRA)
  - Beam Width – Beam -3dB re MRA
  - Main Lobe / Side Lobes
  - Directivity index:
    - DI = 10 $\log_{10}(4\pi/\theta)$
      - 4π – solid angle omnidirectional
      - θ – solid angle of the main lobe

ITC-3001



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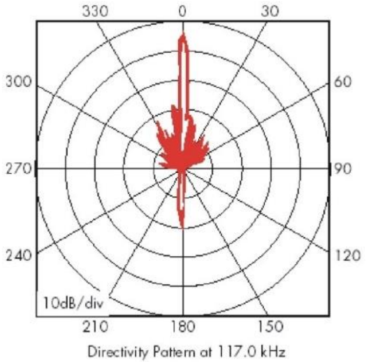
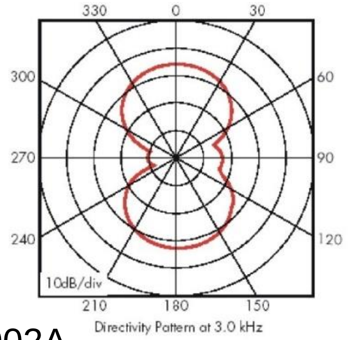


Physical configuration of the system

- The directivity Index and the Beam with depends on the plane and frequency
- (empirically) Higher frequencies => narrow beams => higher directivity index



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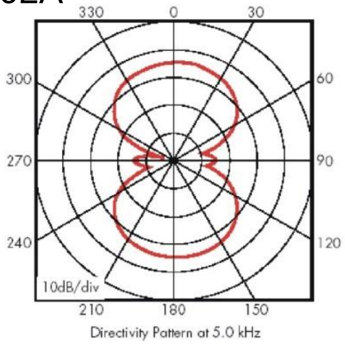

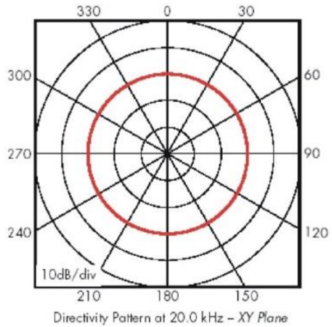

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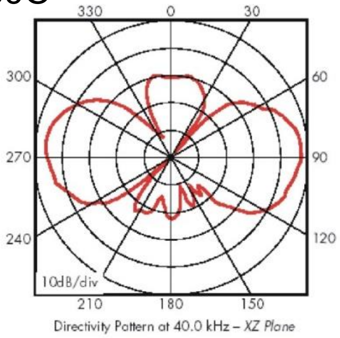
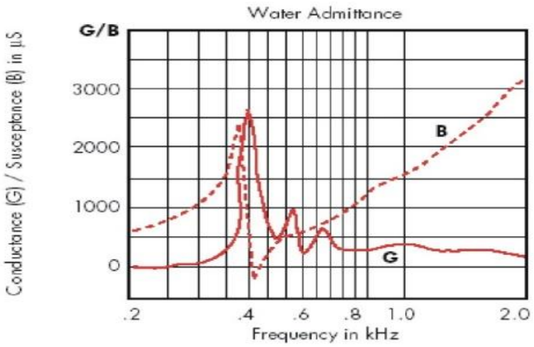


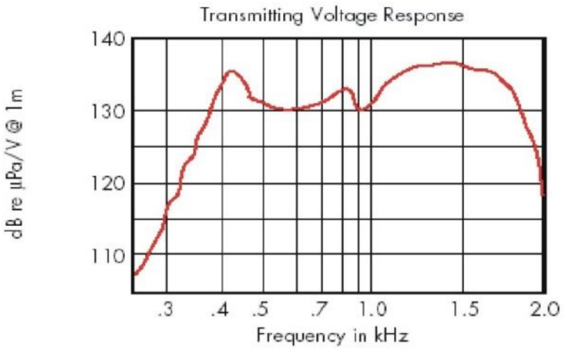
Specifications of the TX/RX system

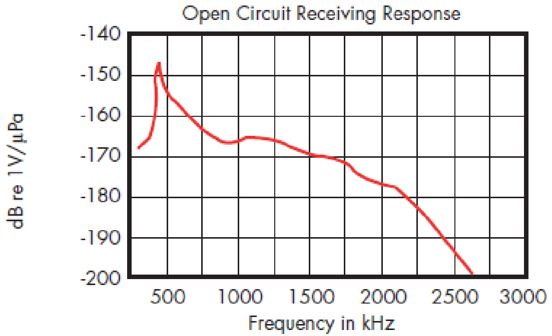
- Transducer electric equivalent model
  - Conductance (G), Susceptance (B), Admittance (Y)
- Transmitting Voltage Response
- Open circuit receiving response

$$Y = G + jB$$

ITC-2062





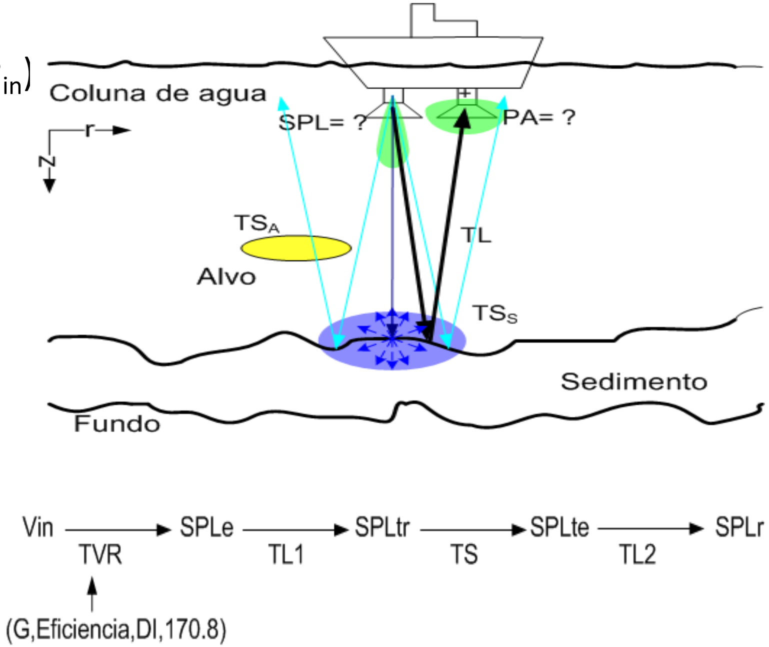


Specifications of the TX/RX system

- SPLe = TVR + 20 log(V_{in}) = TVR – 10 log(G) + 10 log(P_{in})

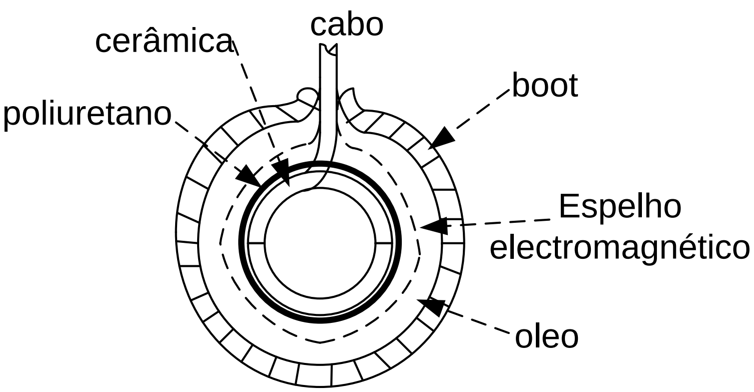
- With the sonar equation we can compute the SPLr:
- PA = $10^{(SPLr/20)}$ [μPa]

- $v_{out,dB}$ = OCV + 20 log(PA) [dB re V];
- $v_{out} = 10^{Vout,dB/20}$ [V]



Specifications of the TX/Rx system

- Other practica specifications:
  - Maximum operating depth
  - Cabels and connectors
  - Maximum SPL
  - …



ITC-2062

Resonance Frequency f_r	.44 & 1.4 kHz
Depth	Unlimited
Envelope Dimensions (in.)	32D x 22H
TVR at f_r	135 & 136 dB//µPa/V@1m
Beam Width (-3dB) at f_r	60 & 90 deg
Beam Type	Toroidal
Input Power	10,000 watts

Thank you for your attention!

STRONG
MAR

www.strongmar.eu

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The STRONGMAR project is funded by the European Commission under the H2020 EU Framework Programme for Research and Innovation (H2020-TWINN-2015, 692427).