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Marine observations with a harmonic single-beam echo-sounder

SEA TECH WEEK 2020

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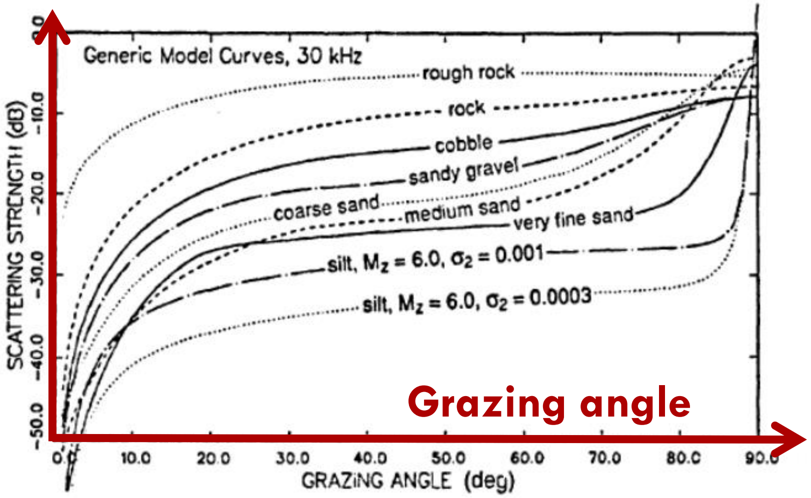
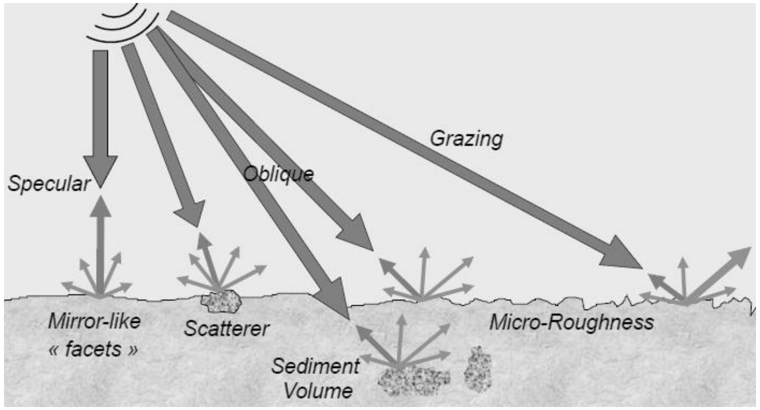
Introduction

- Seabed caracterisation: reflectivity dependencies = $BS(f,\theta)$

Acoutic response of the seabed



Xavier Lurton, Ifremer, GEOHAB Workshop, 2013



Xavier Lurton, Ifremer, GEOHAB Workshop, 2013

- Dependence on frequency and incidence angle
- Limitation: require several echosounders at several frequencies
  - expensive and bulky system

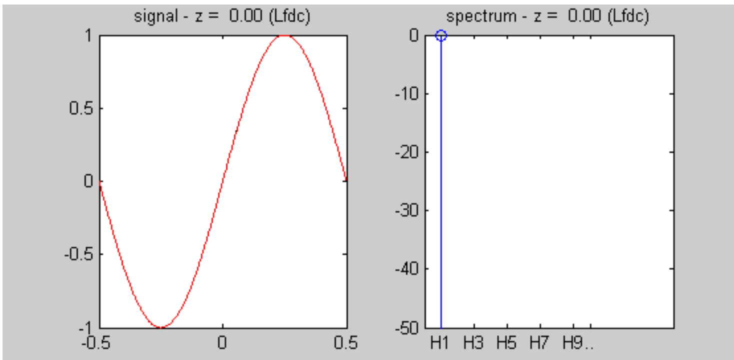
Introduction

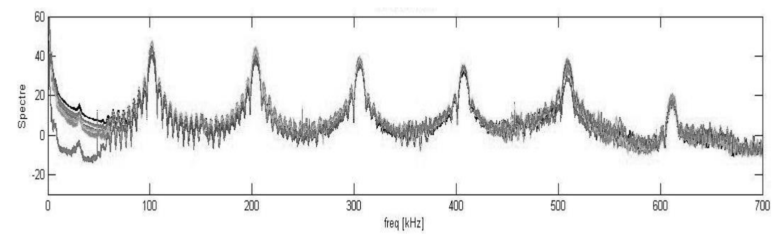
- Solution suggested: a single echo-sounder using several frequencies
- Goals:
  - Designing a prototype of echo-sounder (transmitter and receiver) able to generate multiple frequencies simultaneously and acquire their echos.
  - Analysing results of acquisition on different seabed types (at sea) in order to validate the feasibility of characterising seafloor with this echo-sounder.

Summary

Transmission of multiple frequencies

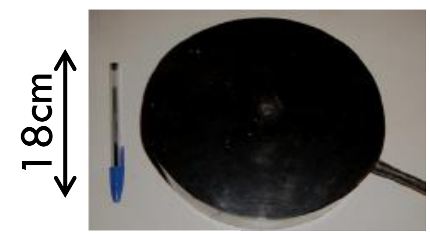
- Generation of harmonics during propagation in the water column



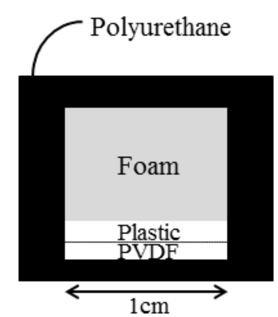


L. Di Marcoberardino, J.Marchal and P.Cervenka,
Nonlinear multifrequency transmitter for seafloor characterization,
Acta Acustica, 97(2), 202-208, 2011.

  - Transmission of a single frequency at a high power level => produces harmonics during propagation

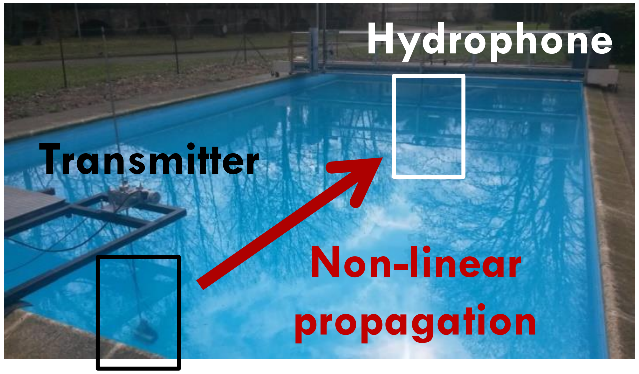


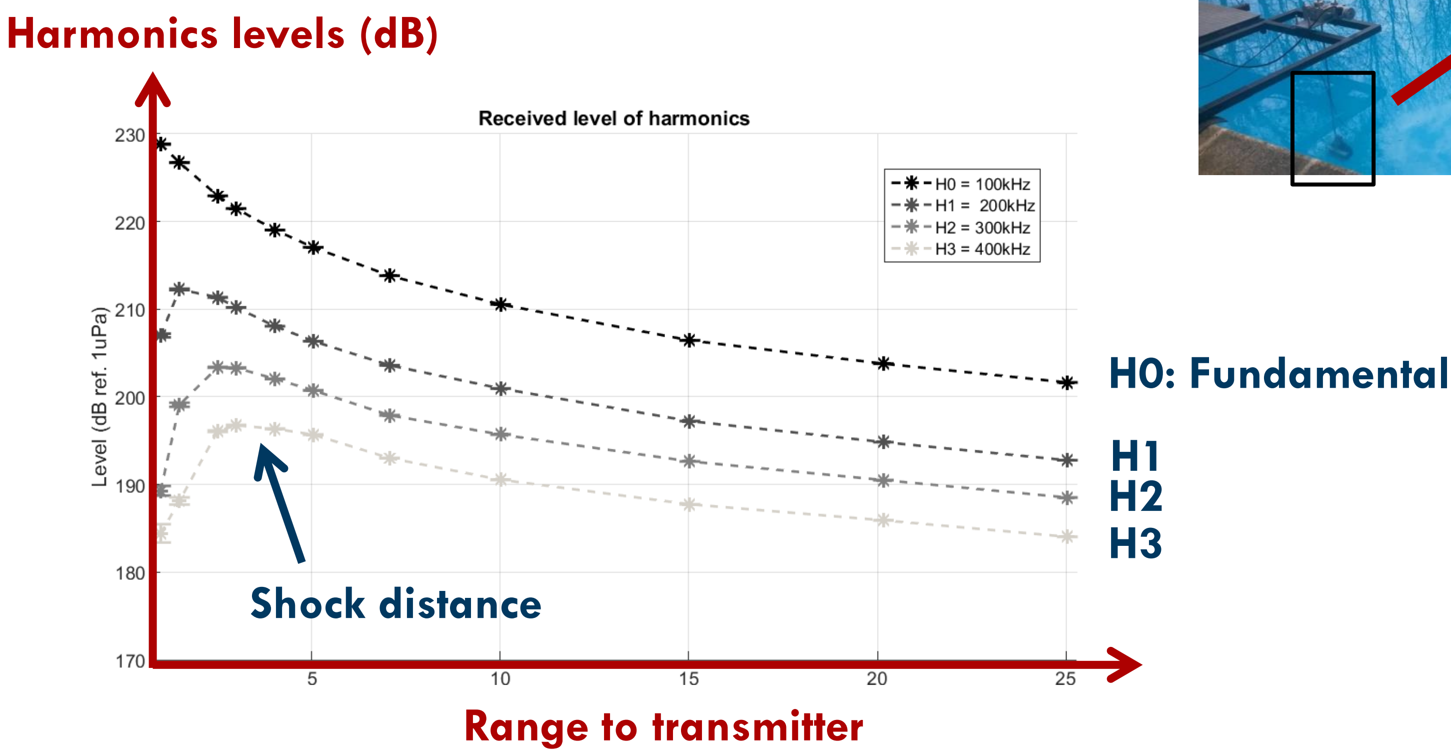
- Transmitter: Ø18cm – 100kHz – Piezoelectric composite disk
- Receiver : Ø1cm – Wideband – PVDF + Plastic + Syntactic foam



Transmitter functional validation

- Validation of harmonics creation : tank measurements at Sorbonne University – St Cyr (France)



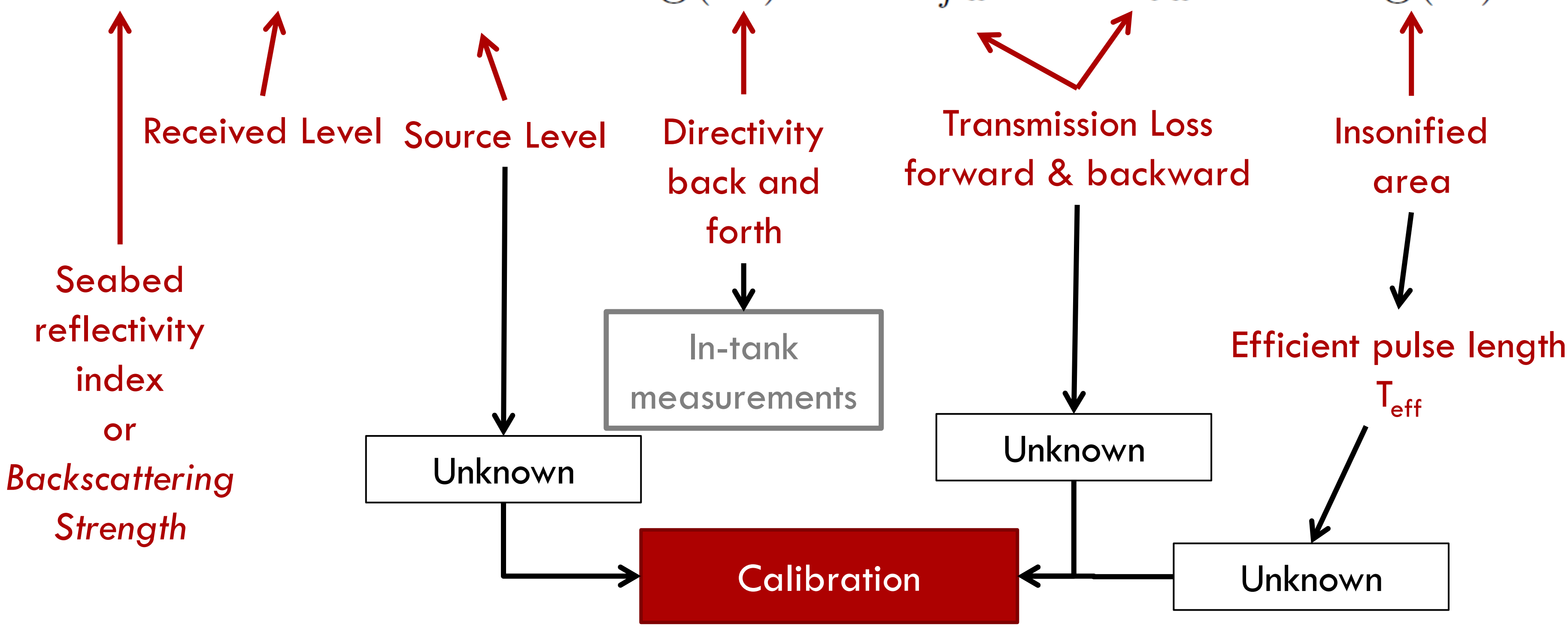


Summary

Seabed reflectivity index calculation

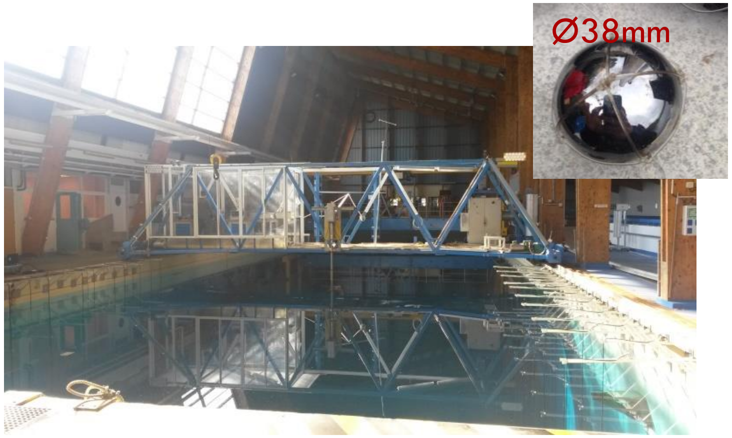
- Process:
  1. Sonar equation

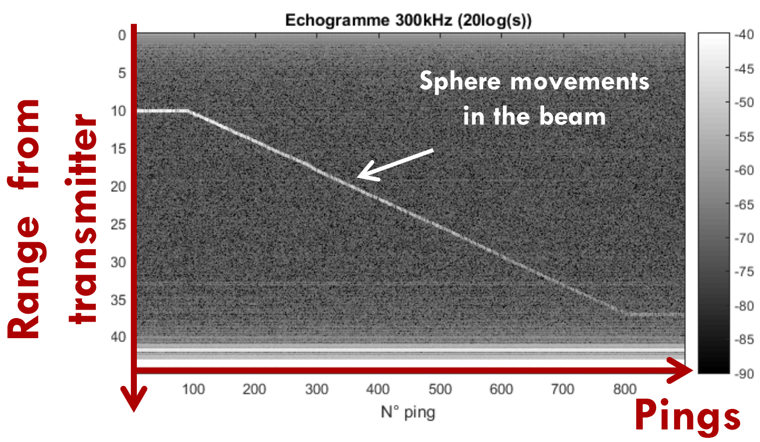
$$BS = RL - SL + 20\log(D) + TL_{fw} + TL_{bw} - 10\log(A)$$

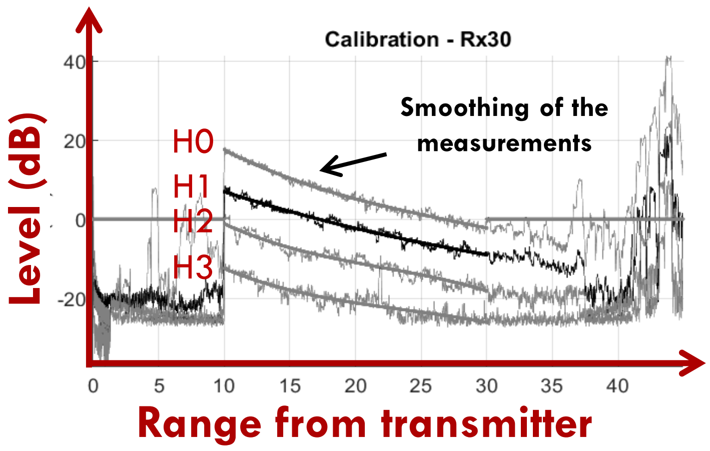


Seabed reflectivity index calculation

- Process:
  1. Sonar equation
  2. Calibration
     - Tungsten sphere which target strength *TS(f)* is perfectly known
     - Abacus of acoustic level at different ranges from the echosounder (10m to 30m).







Seabed reflectivity index calculation

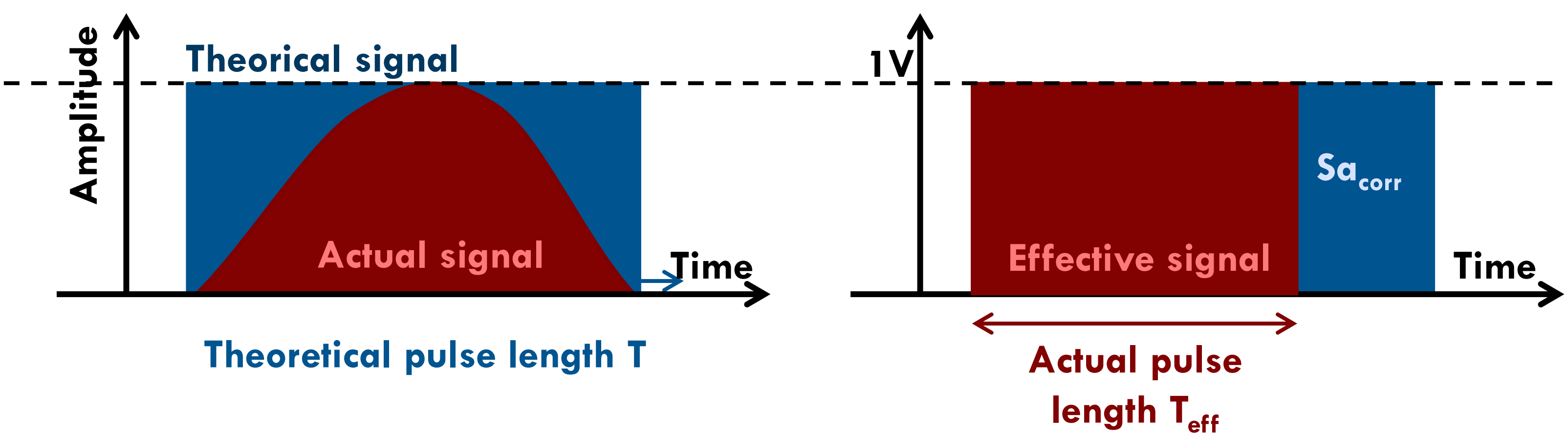
- Process:
  1. Sonar equation
  2. Calibration
  3. Calculation of T_{eff}
     - Correction of effective energy transmitted:
     - Use of calibration data

Theoretical pulse length

Effective pulse length

$$10\log(T) = 10\log(T_{\text{eff}}) + Sa_{\text{corr}}$$

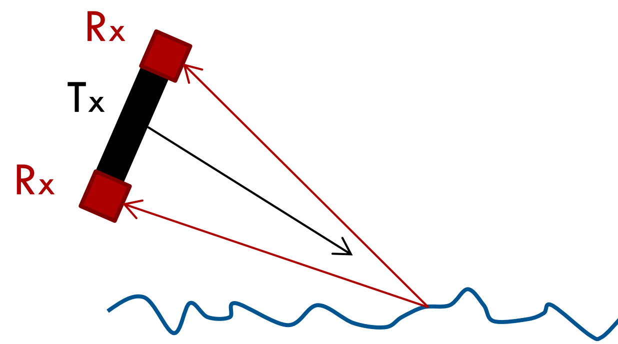
Backscatter calibration of high-frequency multibeam echosounder using a reference single-beam system, on natural seafloor.
D. Eleftherakis et al., Marine Geophysical Research, 2018

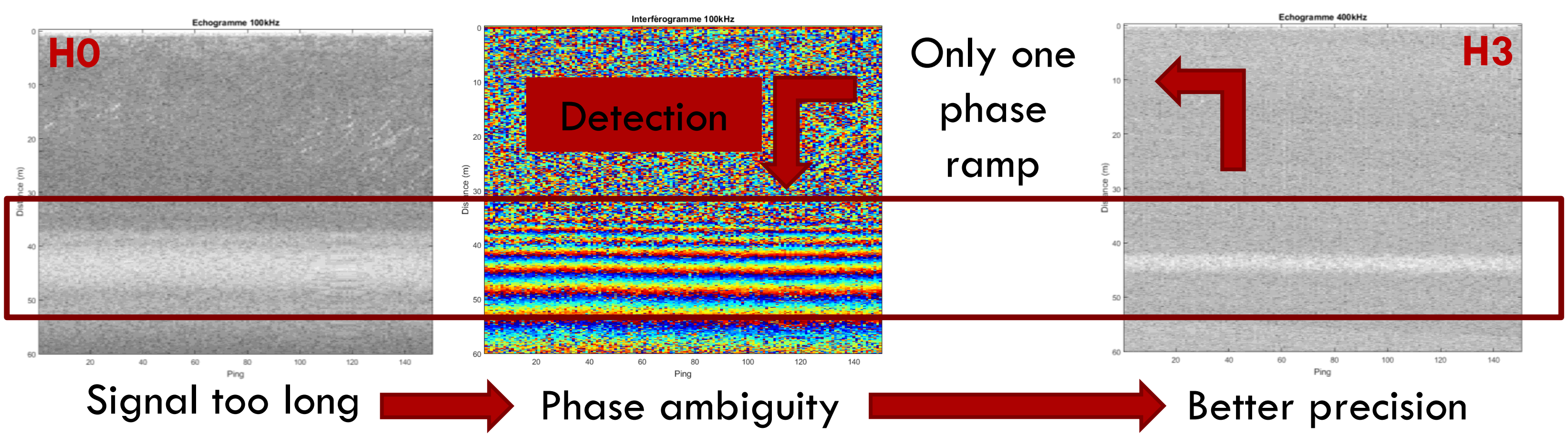


Seabed reflectivity index calculation

- Process:
  1. Sonar equation
  2. Calibration
  3. Calculation of T_{eff}
  4. Seabed detection

  - Use of amplitude and phase data at several frequencies

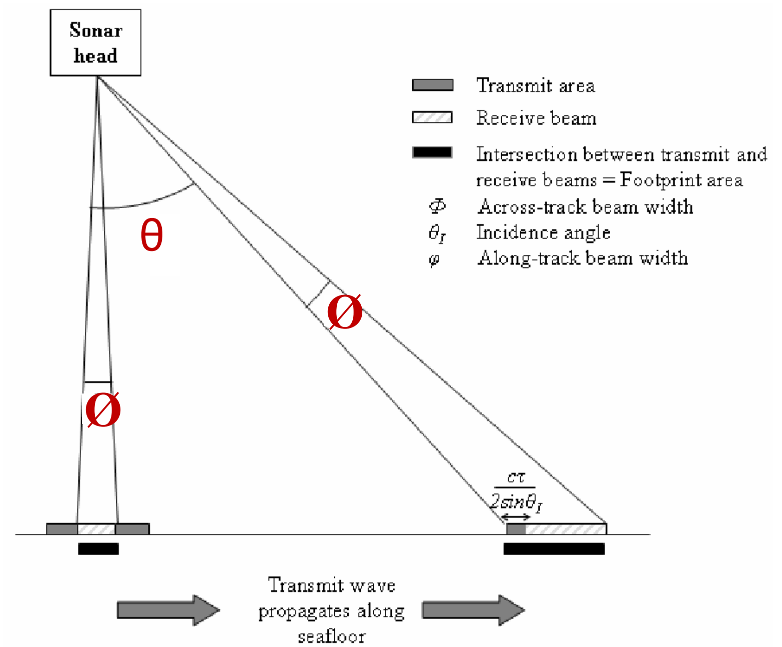




Seabed reflectivity index calculation

- Process:
  1. Sonar equation
  2. Calibration
  3. Calculation of T_{eff}
  4. Seabed detection
  5. Insonified area calculation

     - Classical insonified area formulae:



I. Parnum, Benthic habitat mapping using multibeam sonar systems, 2007

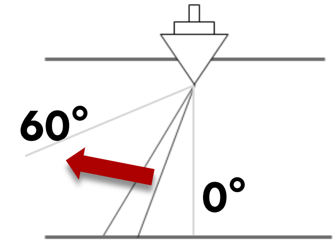
$$A_{th} = \min\left((r.2Ø_{-3dB})^2, \frac{cT_{\text{eff}}}{2\sin(\theta)}.r.2Ø_{-3dB} \right)$$

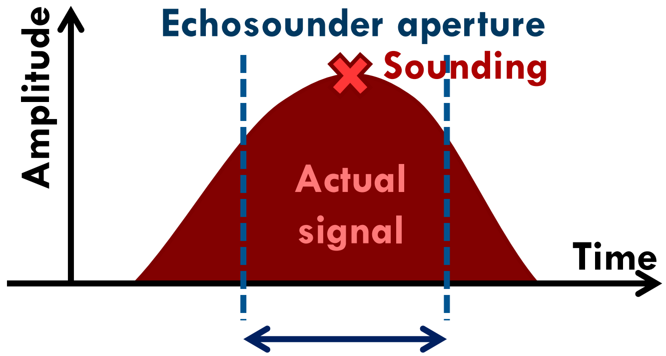
Echosounder aperture

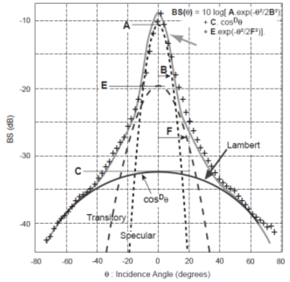
Incidence angle

Estimation and modelling of *BS(f,θ)*

- *BS*(f,θ) estimation:
  - Mechanical movements of the echosounder
  - For each angle: retaining intensity values around the detection inside the -3dB aperture (i.e. snippets).
  - Mean of these values
- *BS(f,θ)* modelling
  - GSAB model (X. Lurton)





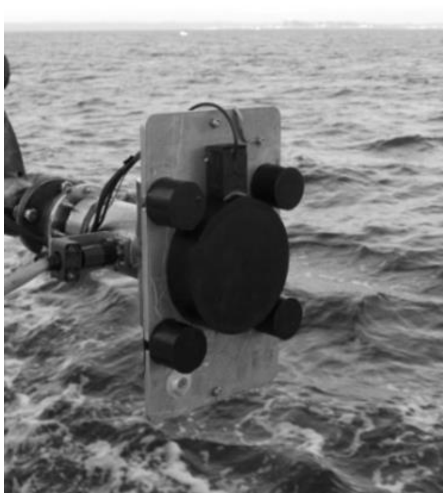


$$BS(\theta) = \underbrace{A.exp(-\frac{\theta^2}{2B^2})}_{\text{Specular}} + \underbrace{C.cos^D(\theta)}_{\text{Grazing}} + \underbrace{E.exp(-\frac{\theta^2}{2F^2})}_{\text{Transitory}}$$

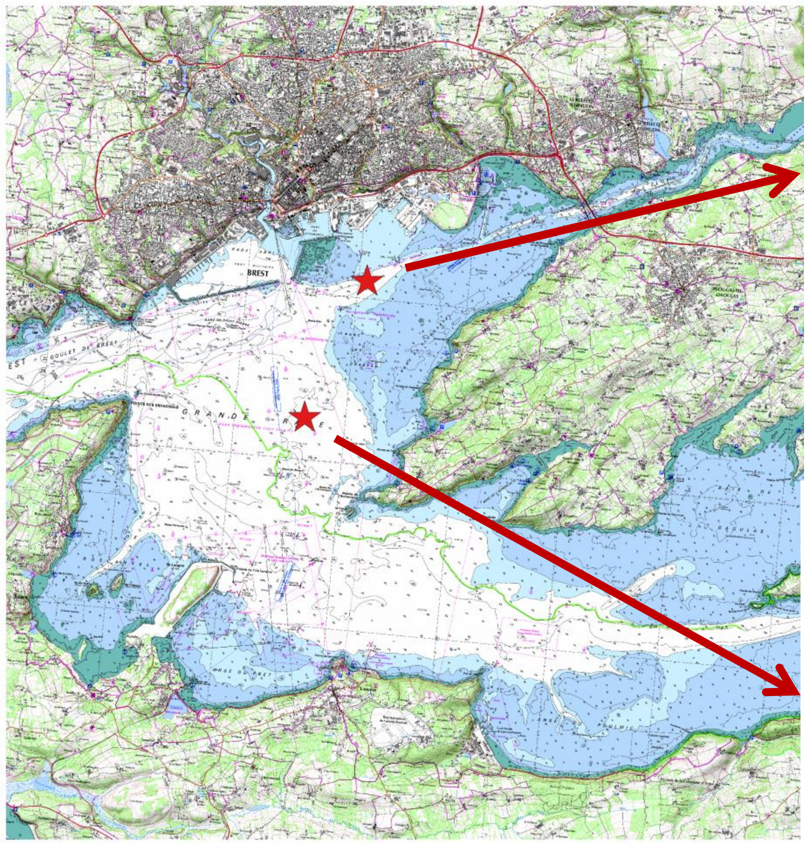
Summary

Survey description

- Thalia (Ifremer research vessel) in the bay of Brest



Echosounder fixed on a Pan&Tilt system, on a pool

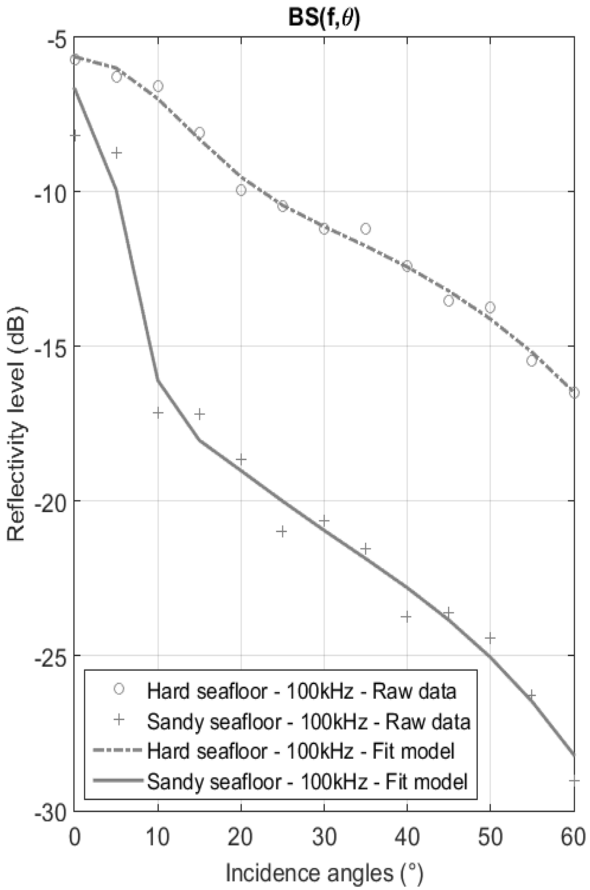


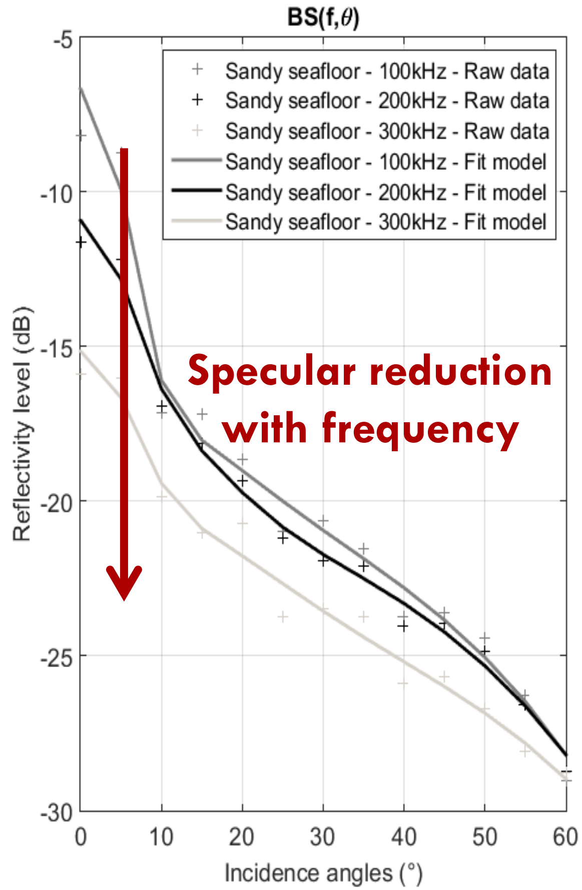
Mix of sand and mud that made dust clouds where the camera approaches – Dispersed small shells – Solitary starfish and some seaweed.

Hard seafloor with a lot of shells of different types – Rocks – Plenty of brittlestars.

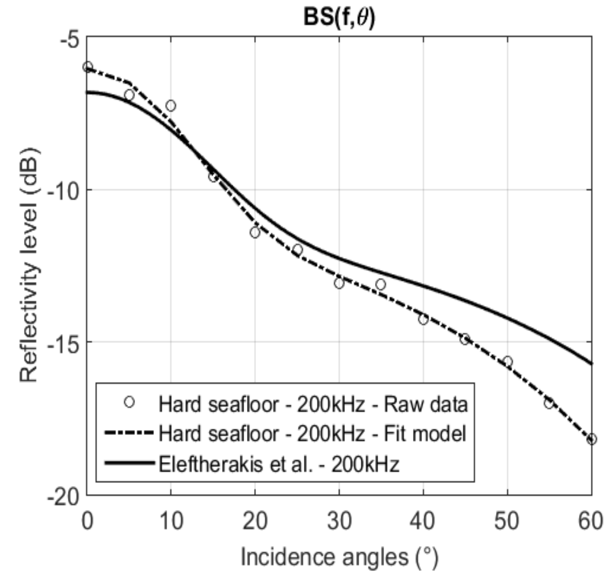
Seafloor characterisation results

- *BS(f,θ)* curves example





Specular reduction with frequency



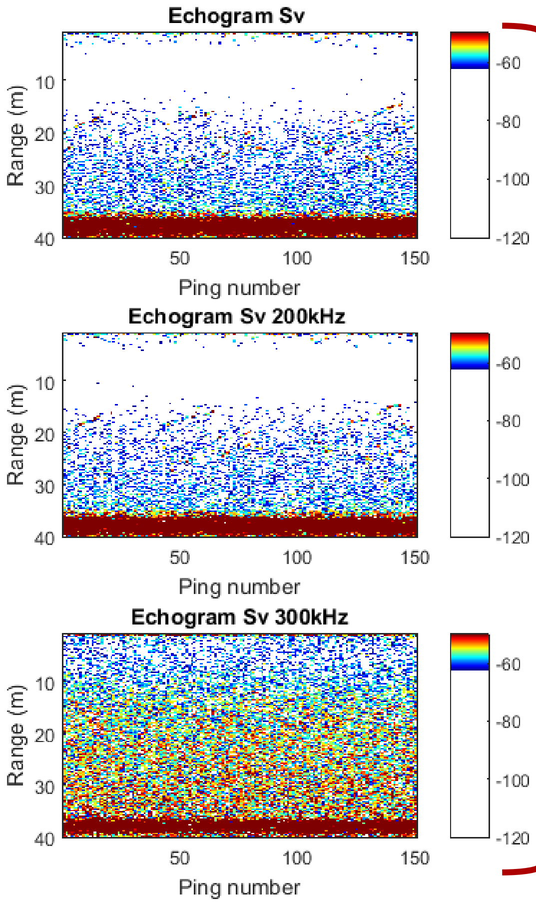
Results close to Eleftherakis et al. calibration curve

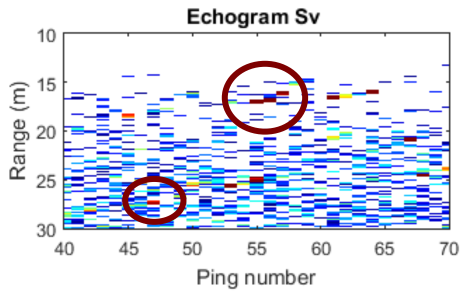
Different seafloors = Different curves shapes

Seafloor characterisation = Feasible solution

Application to fisheries acoustics

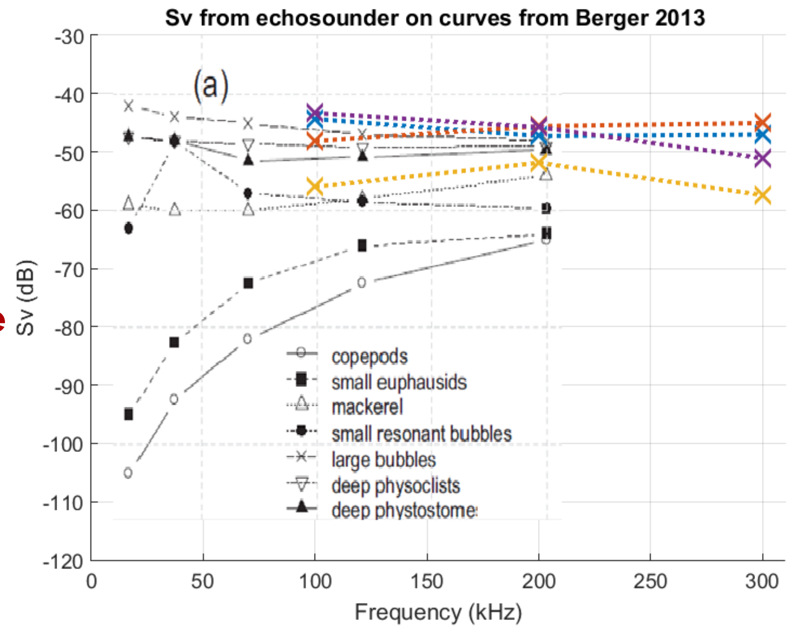
- Example of echograms





Targets are observable

Perfectly in phase



Results in the order of magnitude of Berger et al. measurements

Sv or Ts estimation = Feasible solution but better with a higher ping rate and sensitivity

Conclusion and perspectives

- Proof of concept of multifrequencies systems: ok
  - High level source and harmonic creation ✓
  - Wide band receivers ✓
  - In-tank processing chain calibration on sphere ✓
  - Relevant singlebeam echosounder results ✓
- Limitations
  - High transducer sensitivity to noise (ambient, vessel, …) ✗
  - Mechanical tilt for several pointing angles ✗
- Perspectives
  - Use of lower frequencies and their harmonics (10-40kHz) for seafloor characterisation ?
  - Optimisation of rate and sensitivity for fisheries acoustics applications ?
  - MBES ?