Advanced Industrial Design in Acoustic

Spin-off of the University of Parma

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Not-Impulsive Techniques for Sonar Imaging

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Outline:

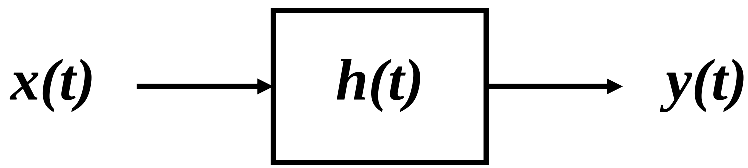
- Echo sounding, Impulsive and Not-Impulsive techniques theory;
- Test signals;
- Hardware and software implementation;
- Experiment results:
  - “Air” measurements;
  - “Water” measurements;

Echo sounding and impulsive signals:

- ***Echo sounding*** is an application of *Active Sonar*, this use of the sound waves allows to trace the sea-bottom profile measuring the distance between water surface and bottom.
- ***Impulsive technique*** has some defects:
  - High SNR $\Rightarrow$ large impulse amplitude $\Rightarrow$ resonanting tranducer $\Rightarrow$ tipically with limited bandwidth.
  - If wide-band sound pulses are required $\Rightarrow$ usually a high power sparker is employed $\Rightarrow$ this source requires large and expensive equipment.
  - The pulses produced are not very repeatable.

Not-Impulsive technique:

Considering a *“black box”*, an input *x(t)* (transmitted), the output *y(t)* (received), we want estimate the *Impulse Response h(t)*:



Choosing a couple of signals *x(t)* and $x(t)^{-1}$ (x(t) reversed on the time axis), that satisfy the relation:

$$x \otimes x^{-1} = \delta$$

and applying the commutative property of the product is possible obtain the IR, *h(t)*.

$$y \otimes x^{-1} = x \otimes h \otimes x^{-1} = y \otimes x \otimes x^{-1} = h \otimes \delta = h$$

Not impulsive signals (1):

MLS (Maximun Length Sequence)

- Continuous, periodic, wide-band signal with white-like spectrum (*shift register* and *XOR port*), fast (*real-time*) & easy IR deconvolution by Hadamard Fast Transform algorithm.

Linear & Logarithmic sine sweeps

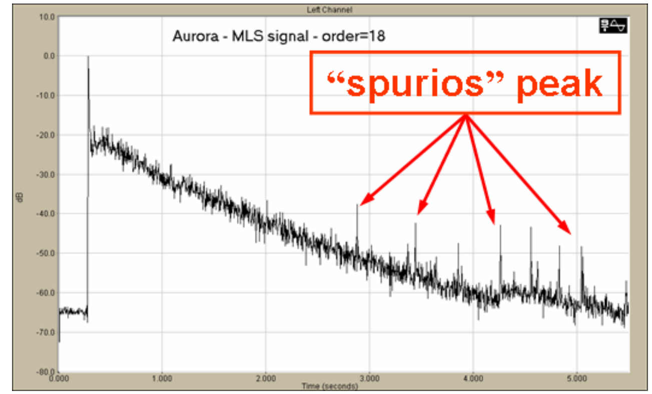
- signals in which the frequency increases or decreases *linearly* or *exponentially* with time.

Features

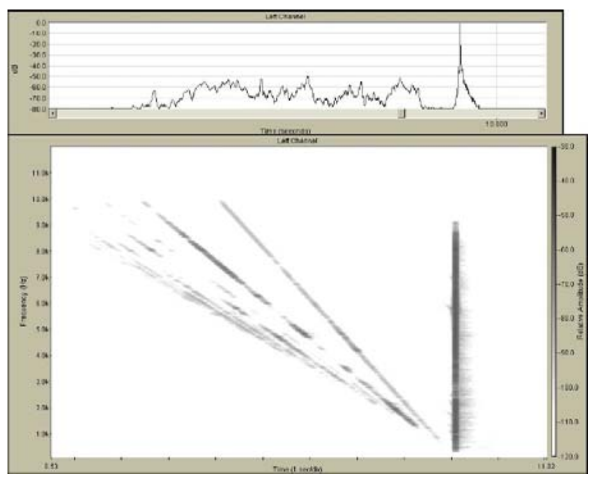
- Good Signal-to-Noise ratio (SNR).
- Possibility to pre-compensate for transducer's response.
- Possibility to create an excitation signal with arbitrary spectrum.

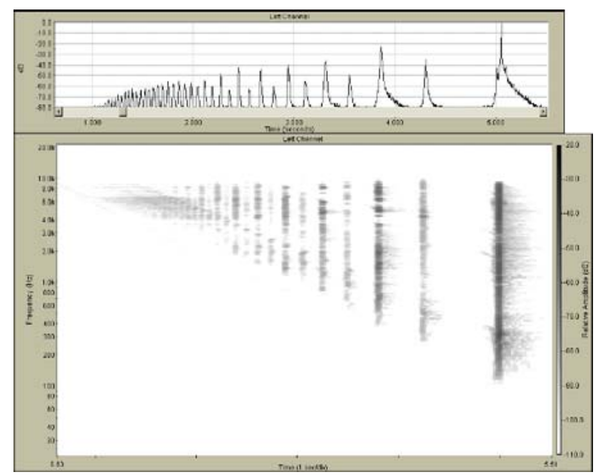
Not impulsive signals (2):

- Transducer's Non-Linearity causes, after deconvolution process with MLS, the presence of "spurios" peak in the Impulse Response.



- Distortions appear before the Impulse Response.





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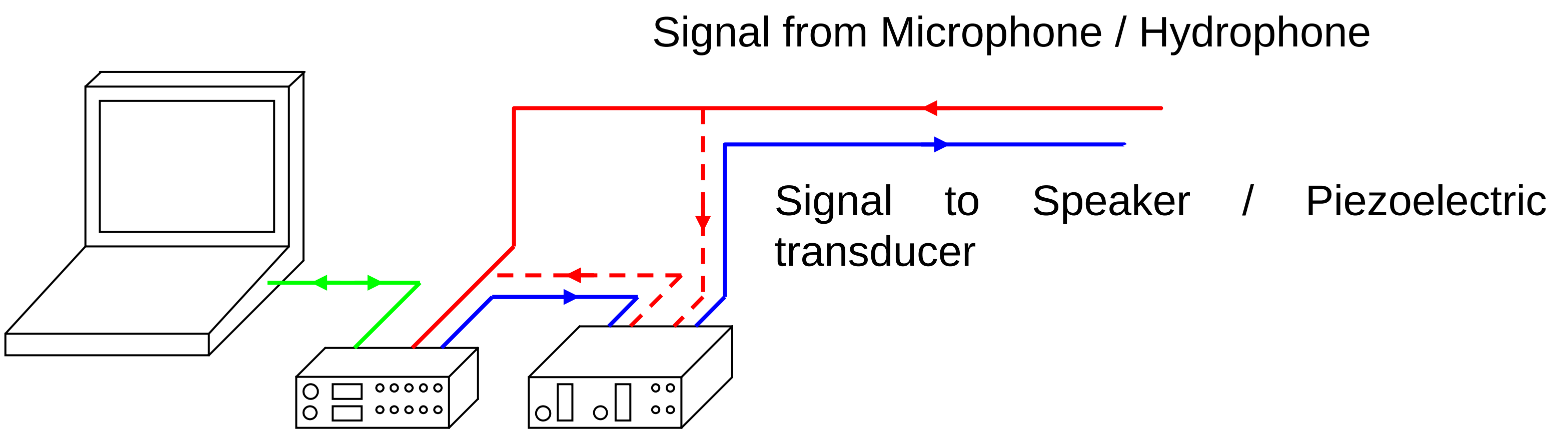
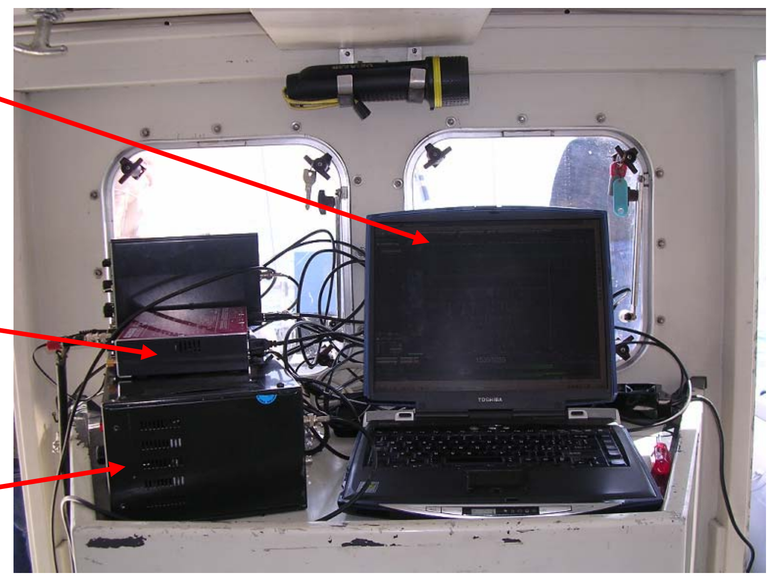
Hardware & Software (1):

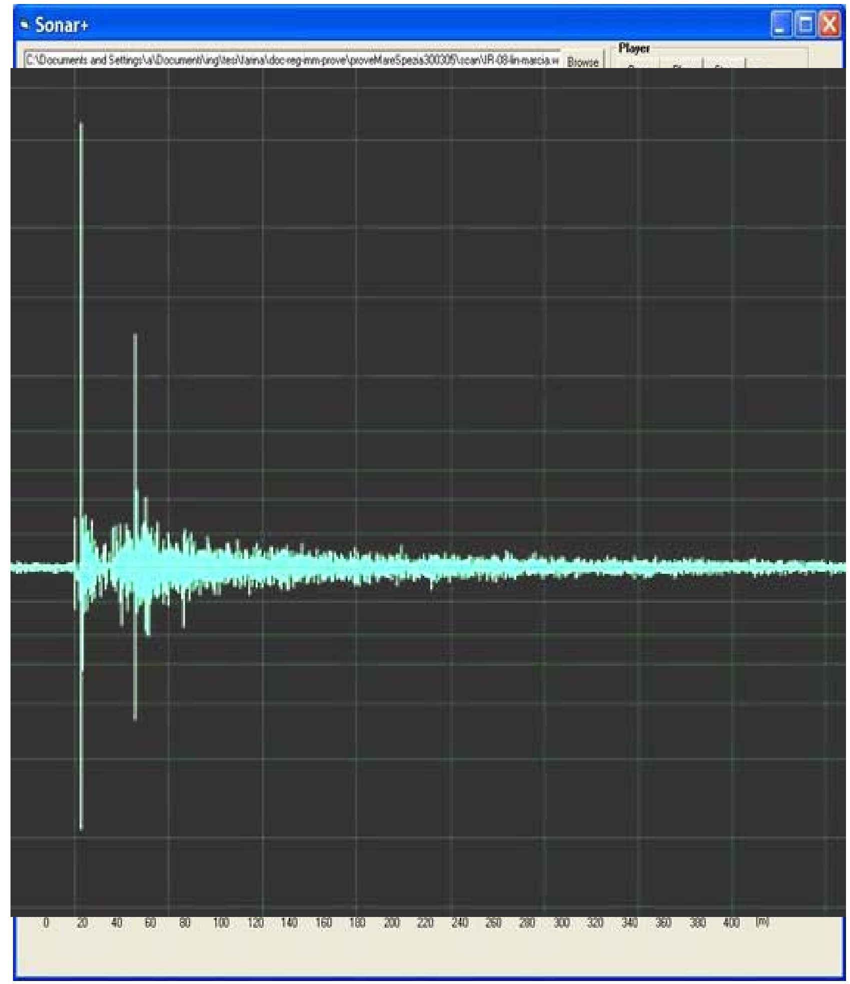


1. Notebook supplied with Adobe Audition 1.5® and Aurora plug-ins.
2. Edirol FA-101 sound card (8 ch I/O and Fsmax = 192kHz) connected to PC by a firewire cable.
3. Power Amplifier.



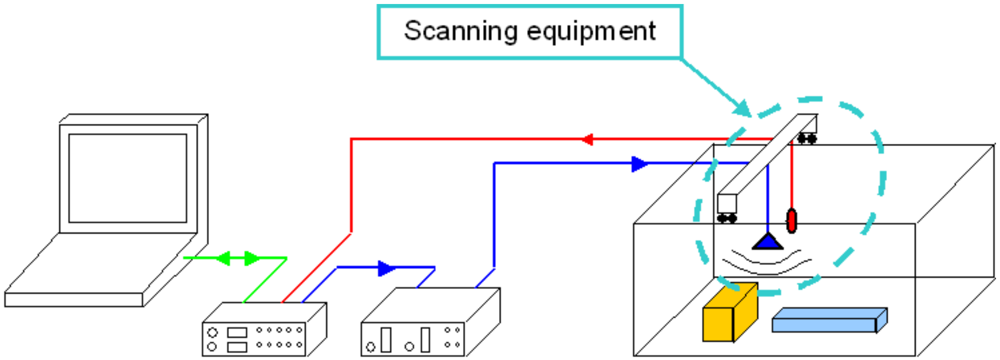
Hardware & Software (2):

1. Signals generated and recorded by Adobe Audition 1.5® and Aurora plug-ins.
2. Collection of IR's calculated by deconvolution in post-processing mode.
3. Using a separate visualization program (SONAR) makes it easy to display the sequence of impulse responses as a traditional sonar graphical plot;
4. Using a GPS receiver is possible trace the route.



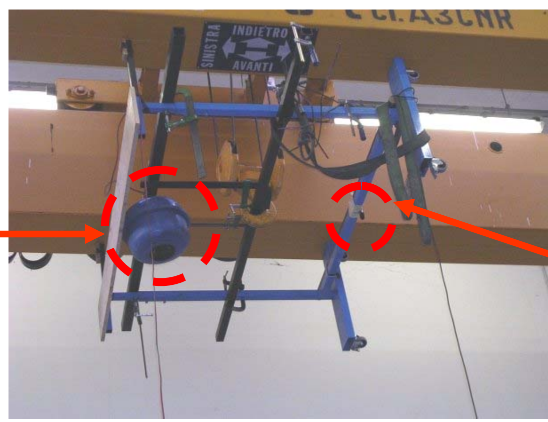
"Air" measurements (1):

- To draw the profile of the furniture inside a large shed (IED – University of Parma);



Scanning equipment:

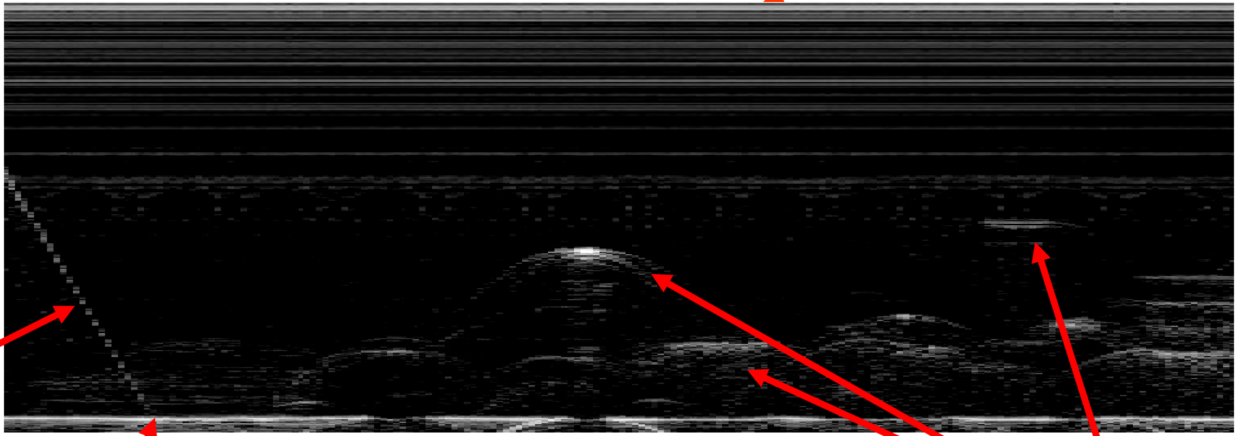
- (self-powered speaker & microphone)
- suspended at 5.5 m over the floor;
- moving at a speed of 0.13 m/s thanks to the loading bridge installed in the shed.



"Air" (2): "log sinesweep" results

Test signal: "log" sine sweep, (200 Hz ÷ 20 kHz), duration 1.0 s.

Acoustic "cross-talk"

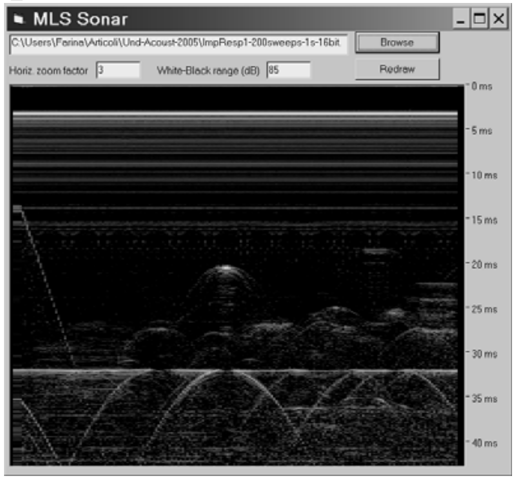


Wall reflection

Floor

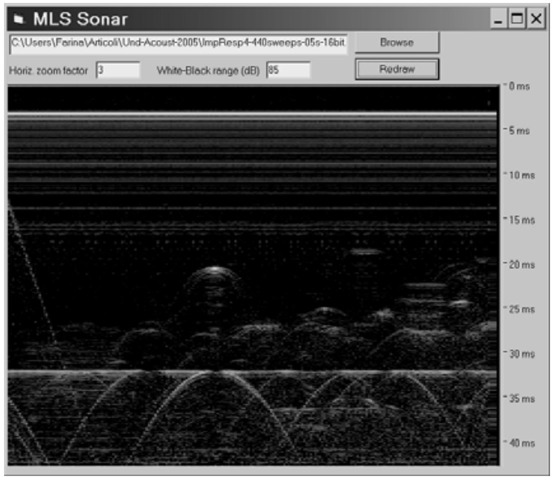
Furniture and mechanical equipments

"Air" (3): results



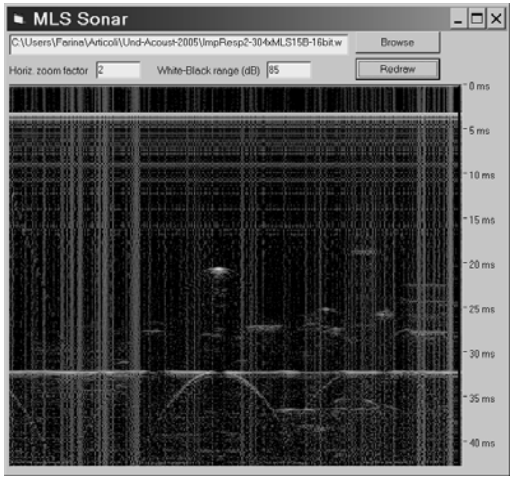
"Log" sine sweep

- 200 Hz to 20 kHz
- duration = 1.0 s.



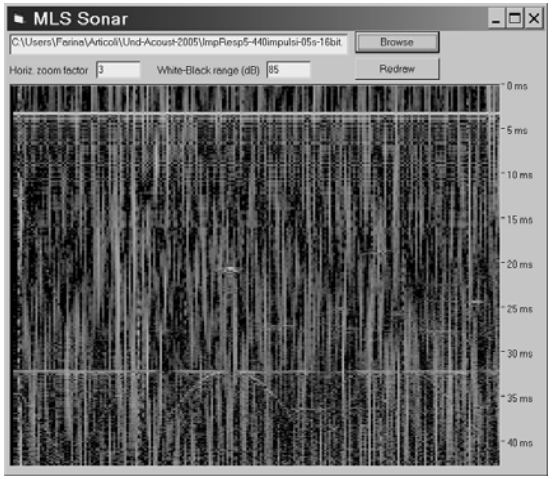
"Lin" sine sweep

- 200 Hz to 20 kHz
- duration = 0.5 s.



MLS order N =15

- T = 32762 sampl.
- T = 0.683 s @ fs = 48kHz

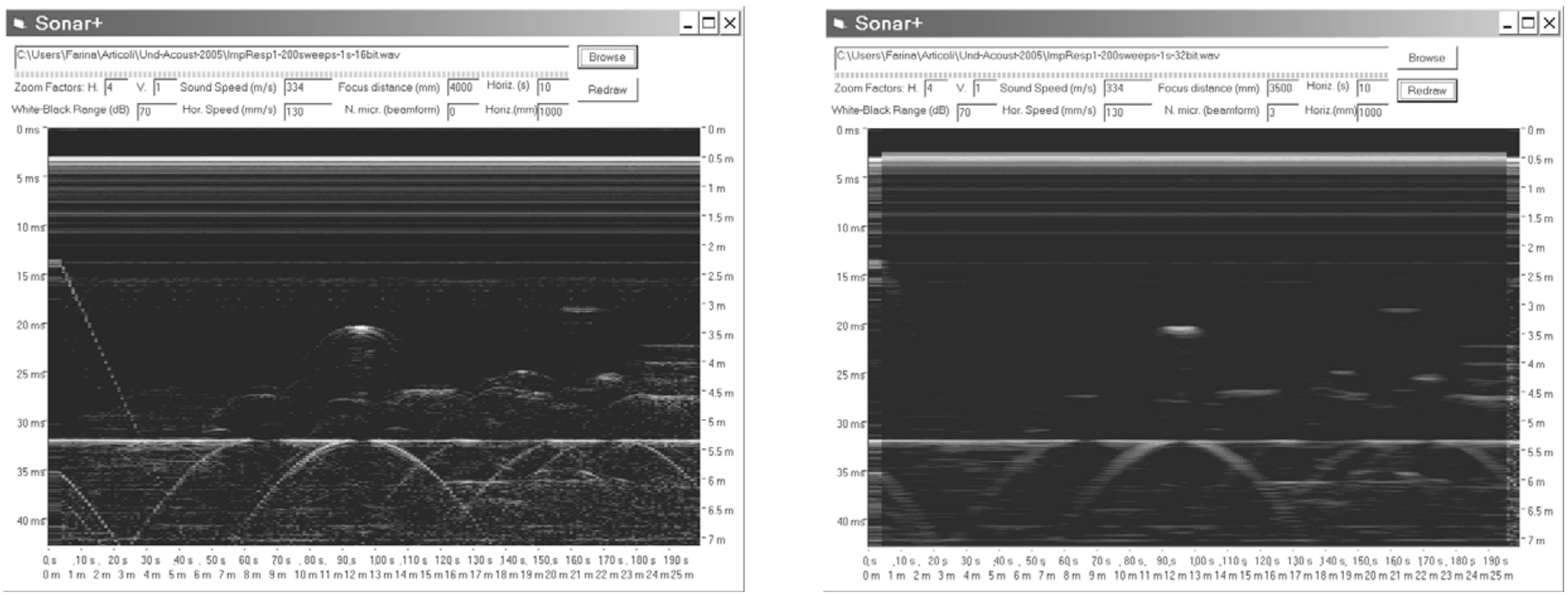


Impulse

- Series of pulse
- Repetition rate = 0.5 s

“Air” (4): virtual beamforming

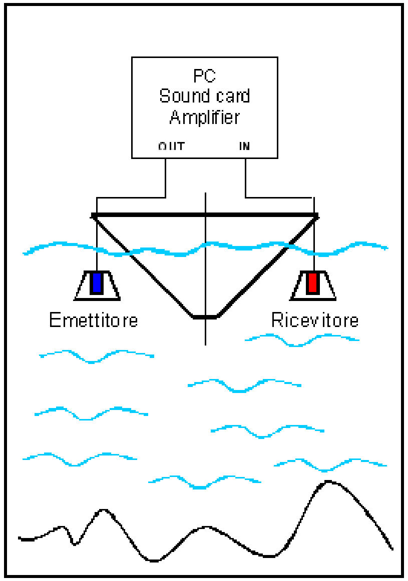
To increase the directivity of the scanning equipment processing software has been modified, allowing a *<u>“virtual” beamforming</u>* making use of a number of adjacent impulse responses (optimal results ⇔ virtual array of 7 mic.).



Measure without beamforming (left) and with fixed focalization at 3.5 m (right).

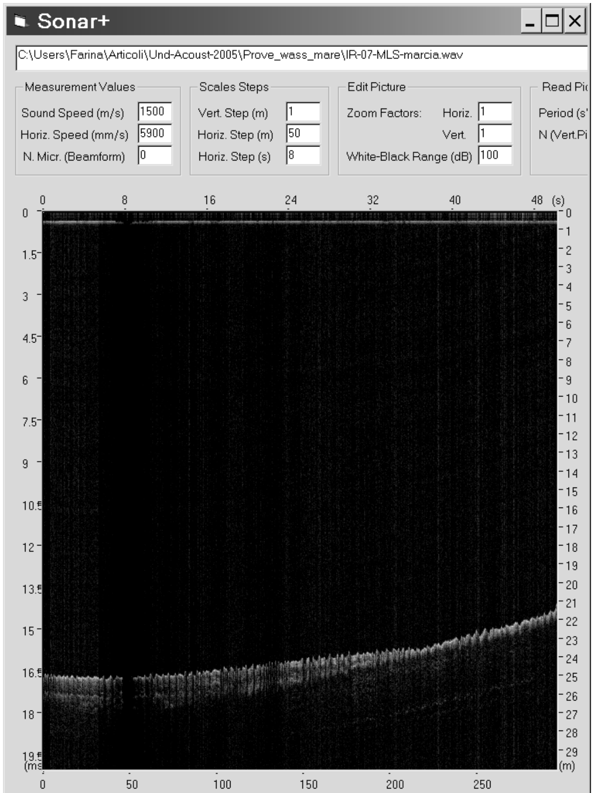
“Water” measurements (1):

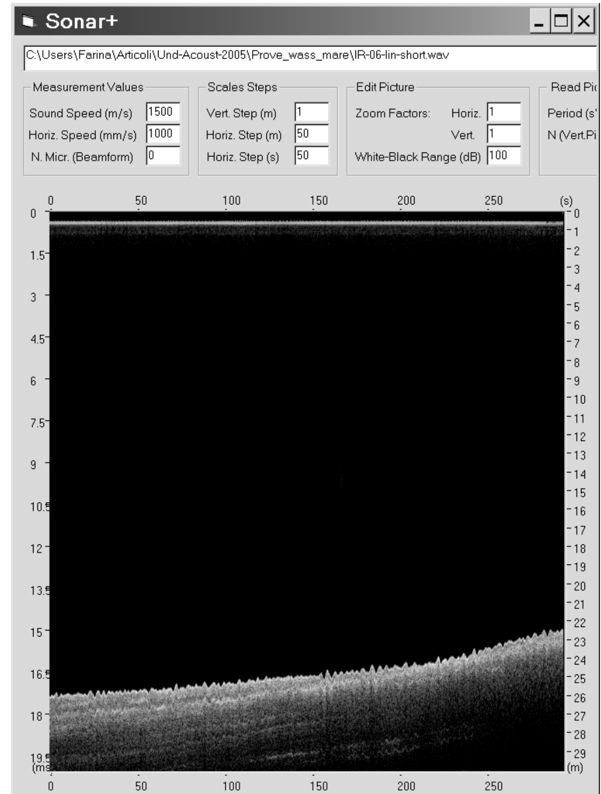
To draw the profile of the sea-bottom in front Palmaria island (near gulf of La Spezia – Italy).



- Special marine vessel “Whitehead III” (WASS), marched at 2 knot.
- 2 hydrophones ITC 5264 equipped with parabolic reflector.
- Pre-equalized test signals (2.4 ÷ 45.0 kHz).

“Water” measurements (2):



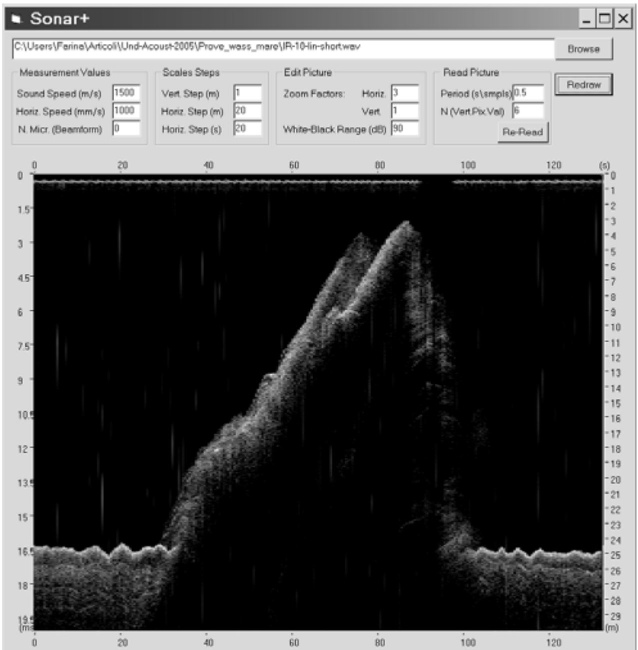


MLS (left) produces an image with lower resolution and larger noise contamination respect to “Lin” sine sweep (right).

“Water” measurements (3):

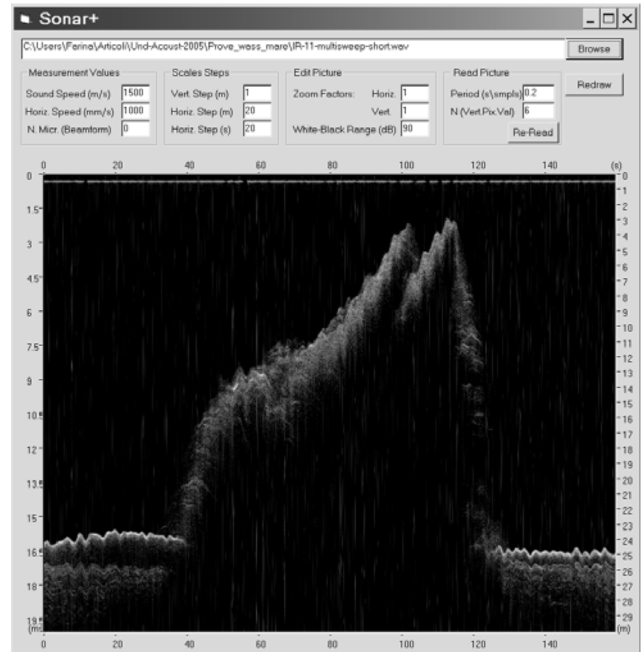
“Lin” sine sweep

2.4 to 45.0 kHz - duration = 0.5 s.



“Lin” sine multi-sweep

2.4 to 45.0 kHz



- Measurements performed in the open sea, in front of the Tinetto cliff.
- The micro ripple on the bottom profile is due to the boat pitching.
- Different bottom layer are well-defined.

Conclusion:

- Not-impulsive techniques are very appealing for sonar imaging.
- The linear sine sweep shows the highest SNR. Its high immunity to external noise, coupled with the very fast and easy processing required for the deconvolution of the impulse responses, makes it very appealing for underwater measurements.
- Good penetration in the sediments.
- Signals MLS and Sine Sweeps are well-masked in a noisy environment.

Future Work:

- Implementation a low-cost system and software, operating in real time, using a DSP platform or a PC.