Comparison of numerical seismic modeling results with acoustic water-tank data

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Outline

1. Introduction

Outline

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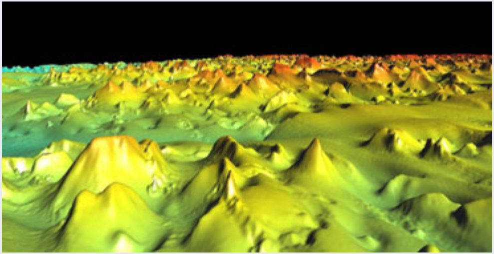
Ormen Lange



- Complex geological structures with great and rapid variations in topography
- Difficulties in simulating 3D wave propagation or seismic imaging

Synthetic data vs. Laboratory data

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1. Validation of methods for a well-described configuration

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  - Tip-wave Superposition Method (Ayzenberg et al., 2007 Geophysics 72, Aizenberg et al., 2011 73th EAGE)
  - Spectral-Element Method (Komatitsch and Vilotte, 1998 BSSA 88, Cristini and Komatitsch, 2012 JASA 131)

Marseille model

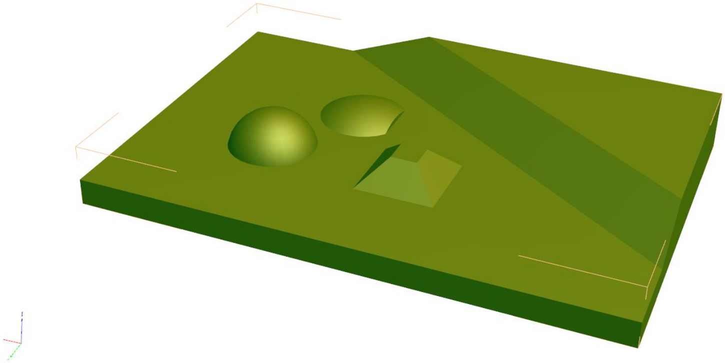
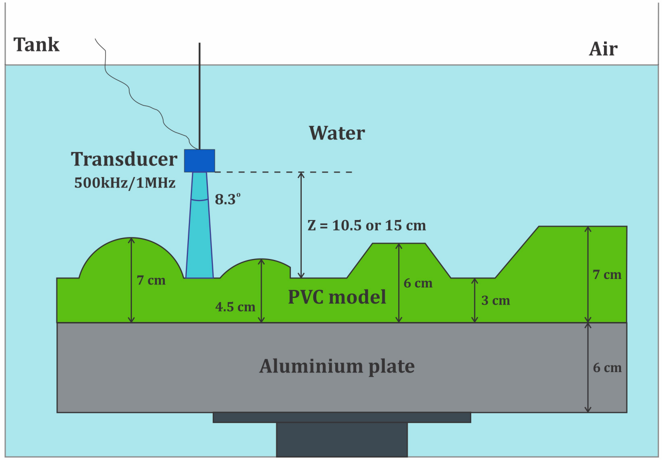


Figure: Based on the French model, 1974 Geophysics 39

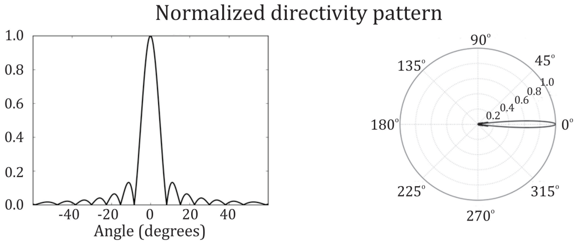
Zero-offset configuration

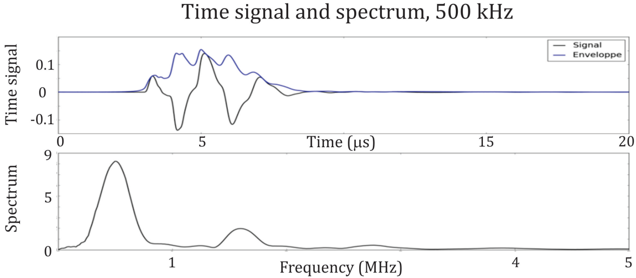


Properties of the materials

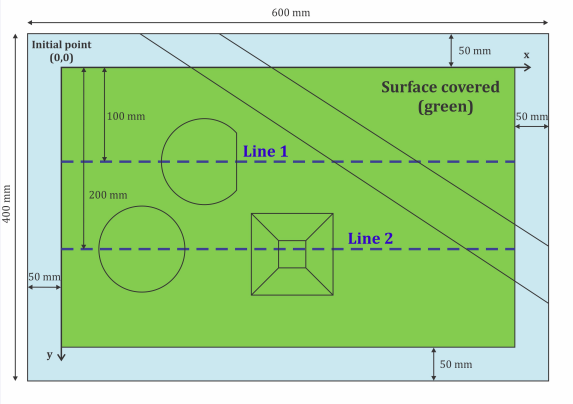
	Density	$\mathbf{V_p}(m/s)$	$\mathbf{V_s}(m/s)$	$\mathbf{Q_p}$	$\mathbf{Q_s}$
Water	1000	1476	–	∞	∞
PVC	1412	2220	1050	$49-60$	$27-31$
Aluminium	2700	6400	3170	∞	∞

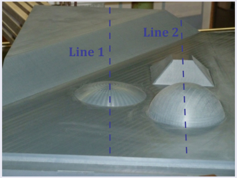
Transducers



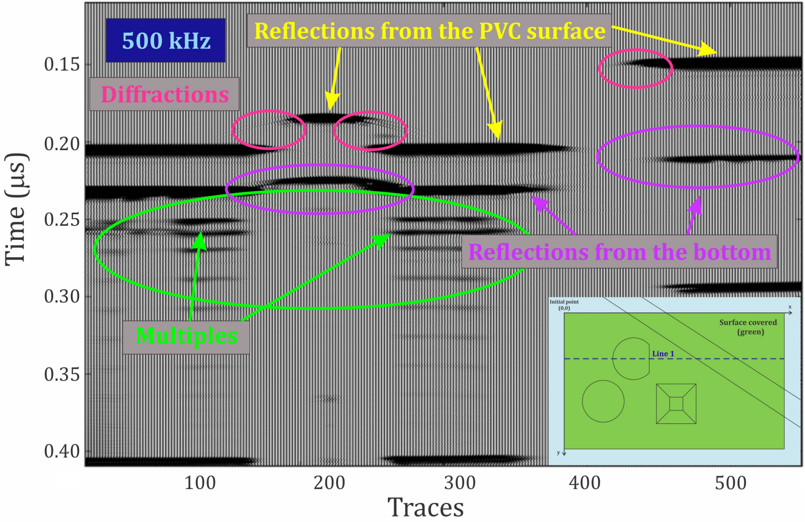


Acquisition design

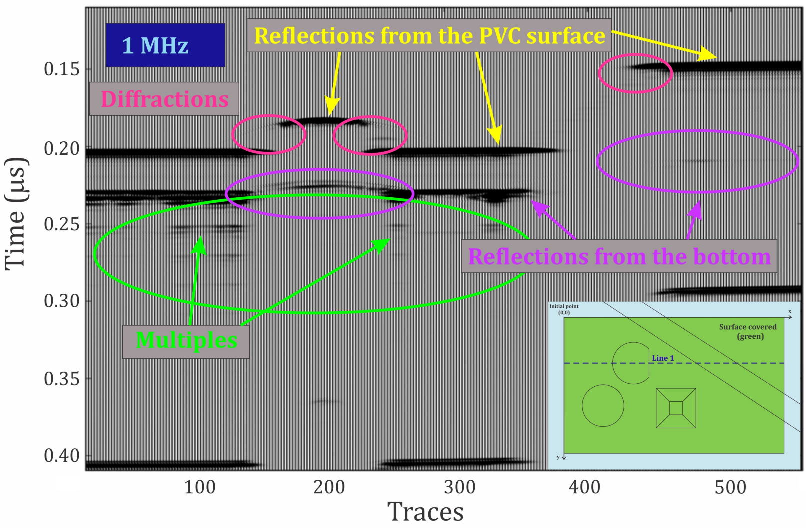




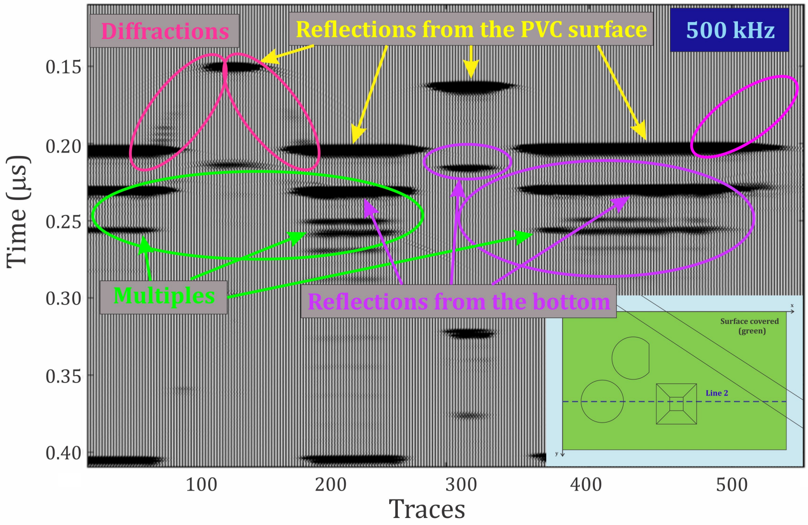
Line 1, 500 kHz



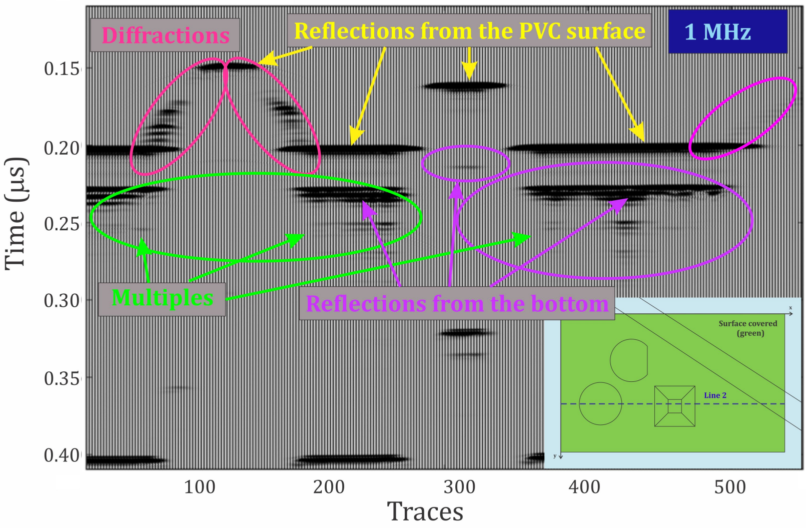
Line 1, 1 MHz


1 MHz
Reflections from the PVC surface
Diffractions
Reflections from the bottom
Multiples
Time (µs)
0.15
0.20
0.25
0.30
0.35
0.40
100
200
300
400
500
Traces
Initial point
(0,0)
x
y
Surface covered
(green)
Line 1

Line 2, 500 kHz



Line 2, 1 MHz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1 MHz
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Reflections from the bottom
Surface covered (green)
Line 2
x
y
0.15
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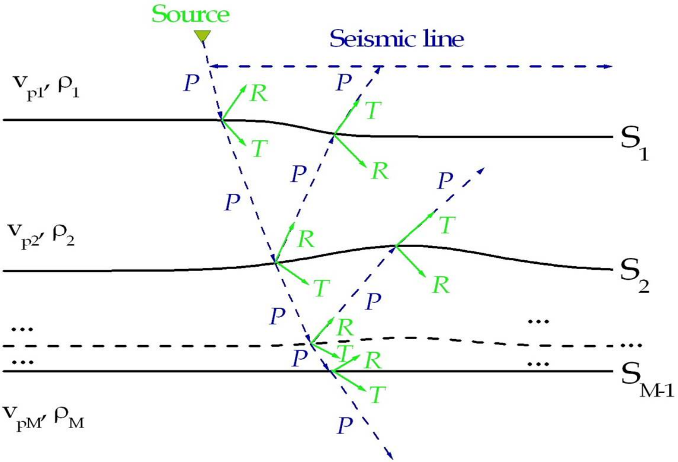
Traces

Tip-Wave Superposition Method



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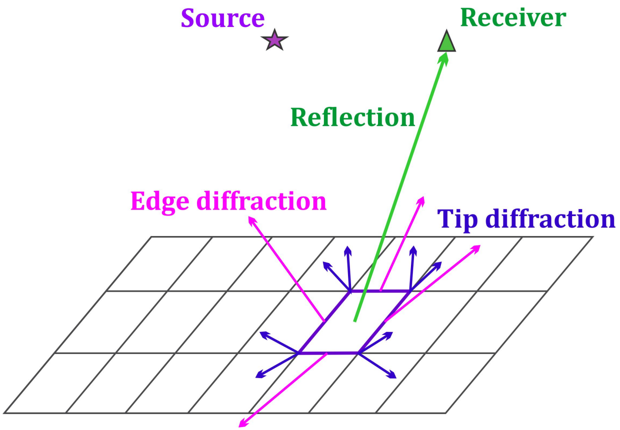
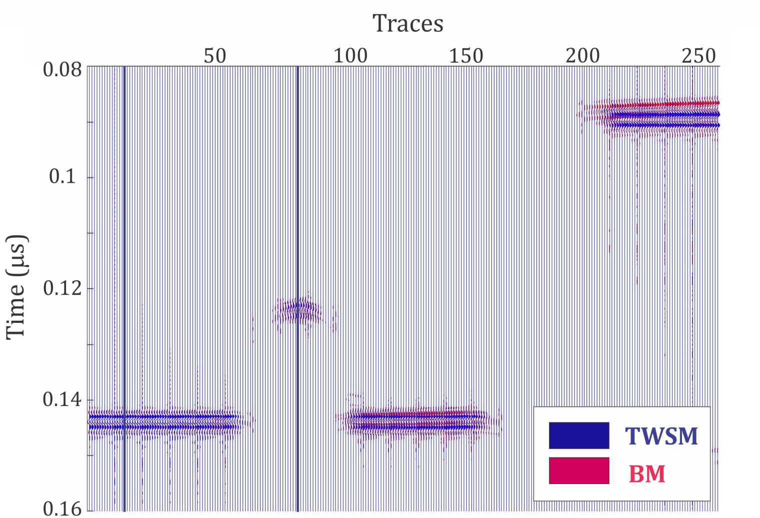


Figure: Klem-Musatov et al. (2008) Edge and Tip Diffractions: Theory and Applications in Seismic Prospecting. SEG

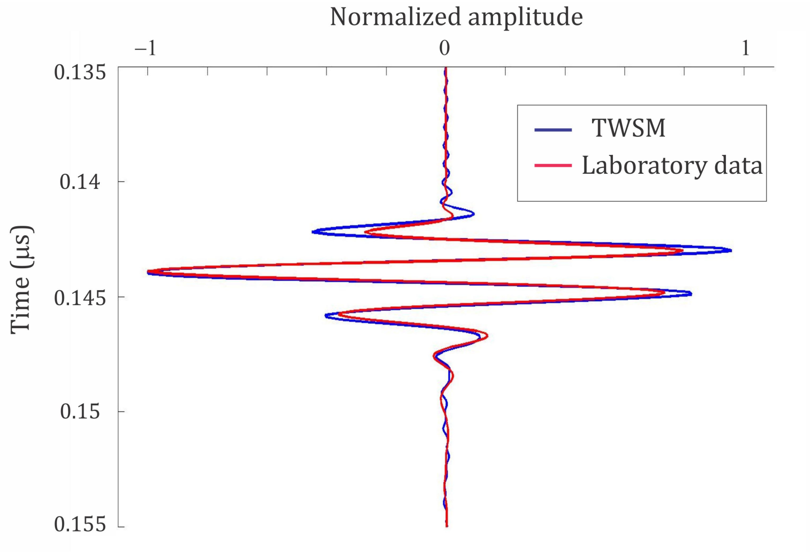
Modeling using TWSM

- Primary reflection at the top of the Marseille model.
- Distance source-flat surface of the Marseille model = 10.5 cm.
- Ultrasonic transducer with 500 kHz frequency.
- Directivity pattern of the transducer $H(\theta) = \frac{J_1(x)}{x}$, where $x = \pi D \frac{\sin(\theta)}{\lambda}$, $J_1(x)$ is the Bessel function.
- Effective coeffisients on dominant frequency.

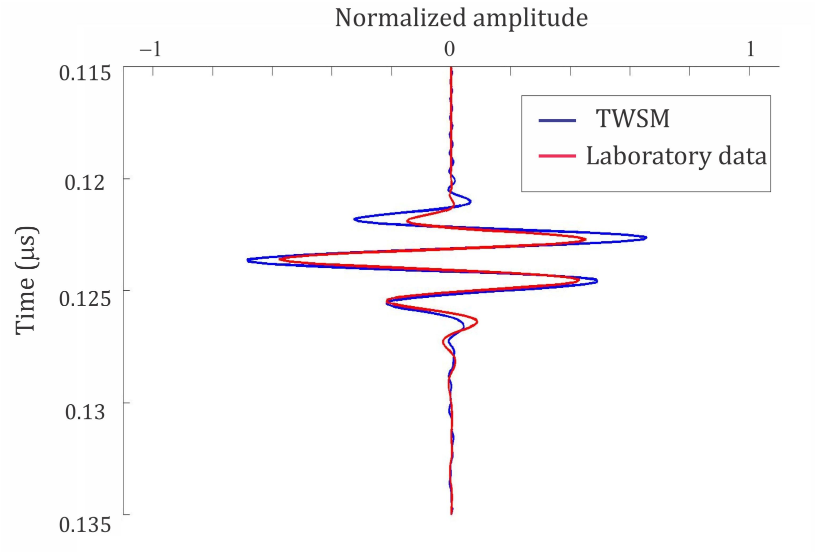
Comparison of seismograms, Line 1



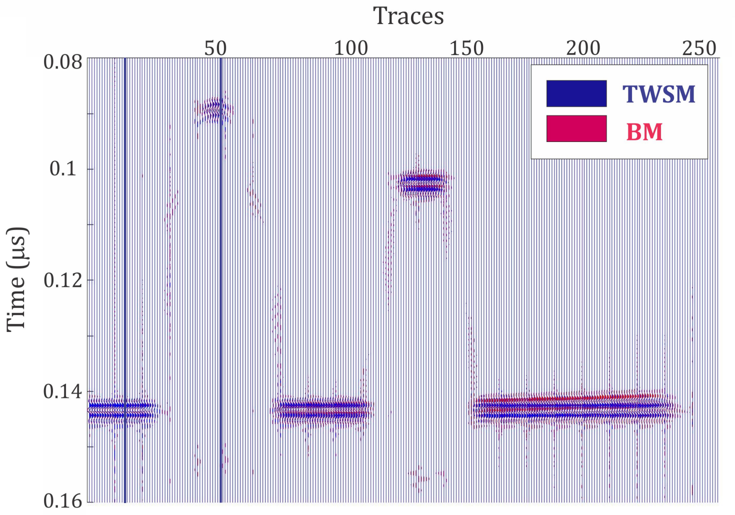
Comparison of traces, trace 15



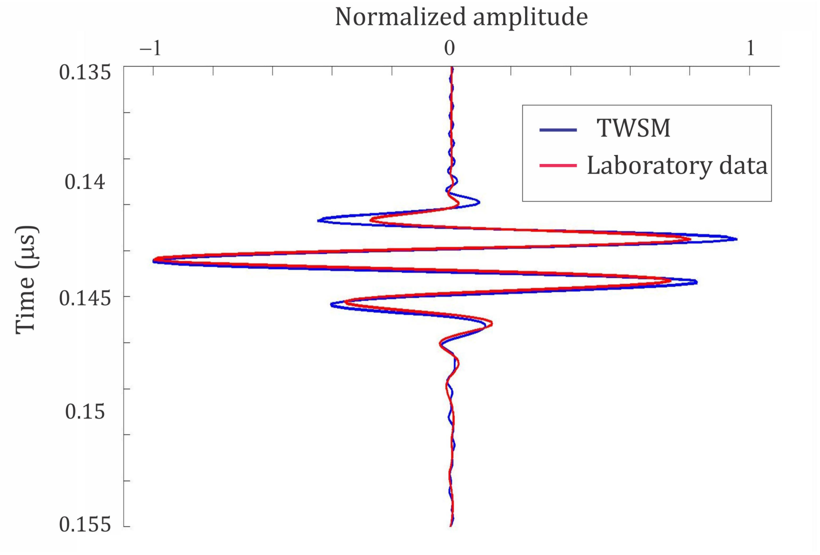
Comparison of traces, trace 84



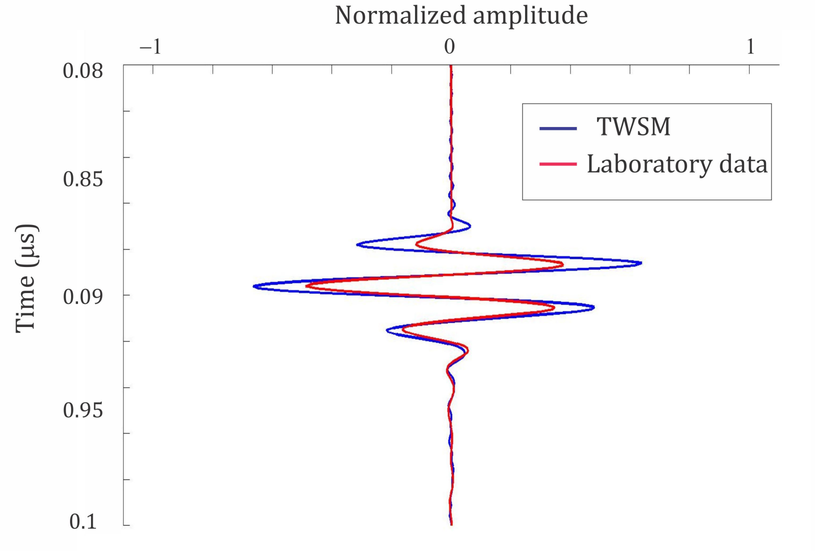
Comparison of seismograms, Line 2



Comparison of traces, trace 15



Comparison of traces, trace 53



Numerical comparison

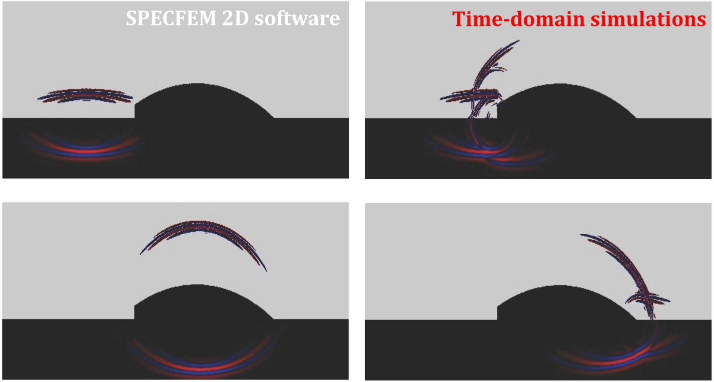
Similarity factor $F = 2 \cdot \frac{\sum_t s_1(t) \cdot s_2(t)}{\sum_t s_1^2(t) + \sum_t s_2^2(t)}$.

	Source 1	**Source 2**
Line 1	0.9775	0.9366
Line 2	0.9667	0.9050

Spectral-Element Method

- Based upon a high-order piecewise polynomial approximation of the weak formulation of the wave equation.
- Combines the accuracy of the pseudo-spectral method with the flexibility of the finite-element method.
- Well suited to complex media and to HPC.

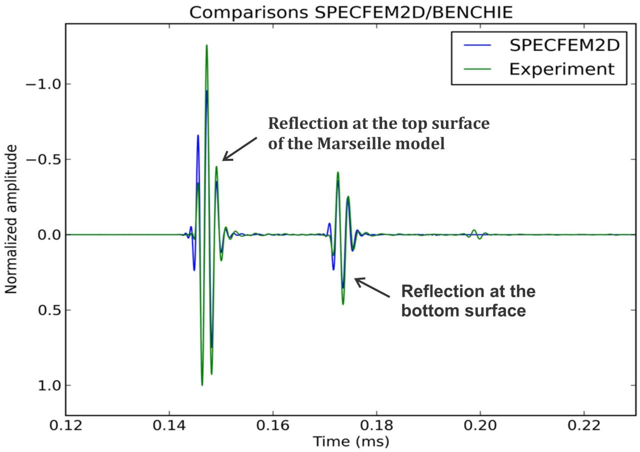
Simulations using SEM



Modeling using SEM

- Primary reflection at the top and at the bottom of the Marseille model.
- Distance source-flat surface of the Marseille model = 10.5 cm.
- Ultrasonic transducer with 500 kHz frequency.
- Focused directivity performed using a set of 51 equidistant omindirectional sources (amplitude weighted by a Hamming window).

Comparisons SEM/BENCHIE



Conclusions and future work

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  - Measurements of reflected ultrasonic waves.
  - Numerical simulations of wave propagation (SEM and TWSM).
- Multi-offset seismic experiments using sources with unfocused beam and different receivers.

Acknowledgements

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VISTA Project

ROSE Project