



Thesis Report of the: Ongoing experimental research on seismo-electromagnetic fields generated at saturated porous media interfaces

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Overview

Introduction

Experiments: What has been done

Open questions I will focus

Known questions

Questions we have ourselves

Experiments to be conducted

Where am I at?

General view

Automation

Validation of set-up

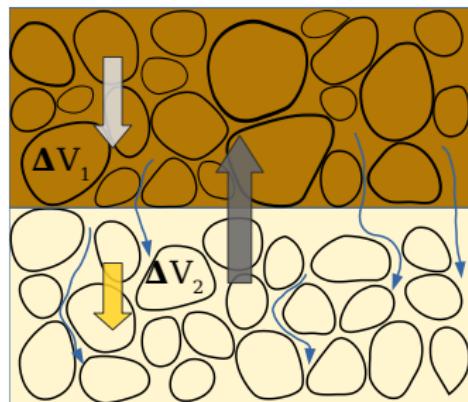
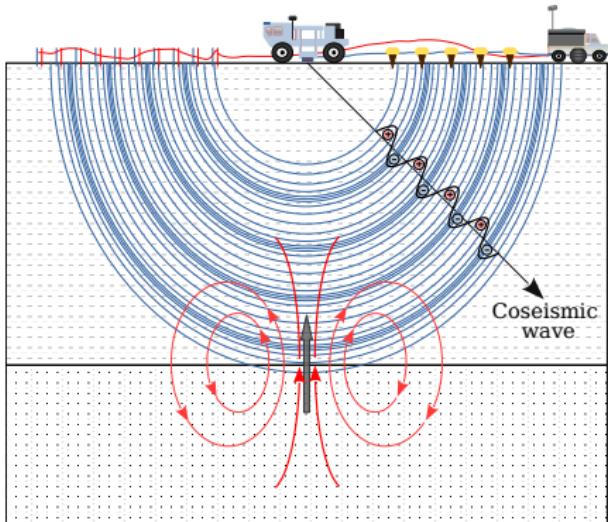
Planning validation and automation

Perspectives

Planning

Introduction

Seismo-electromagnetic phenomena



Introduction

Interface response :

- ▶ Synchronous
- ▶ Arrival time is equal to travel time of P-wave to the interface
- ▶ Max amplitude in receivers whose offset is equal to half the interface depth
- ▶ Different polarity in source sides

Physical properties : Porosity (ϕ), Permeability (k_0), Bulk modulus (K_s, K_f, K_{fr}), frame's Shear modulus, densities (ρ_s, ρ_f), fluid's electrical conductivity (σ), fluid's viscosity (η), molarity, temperature, solid and fluid's relative permittivity and tortuosity.

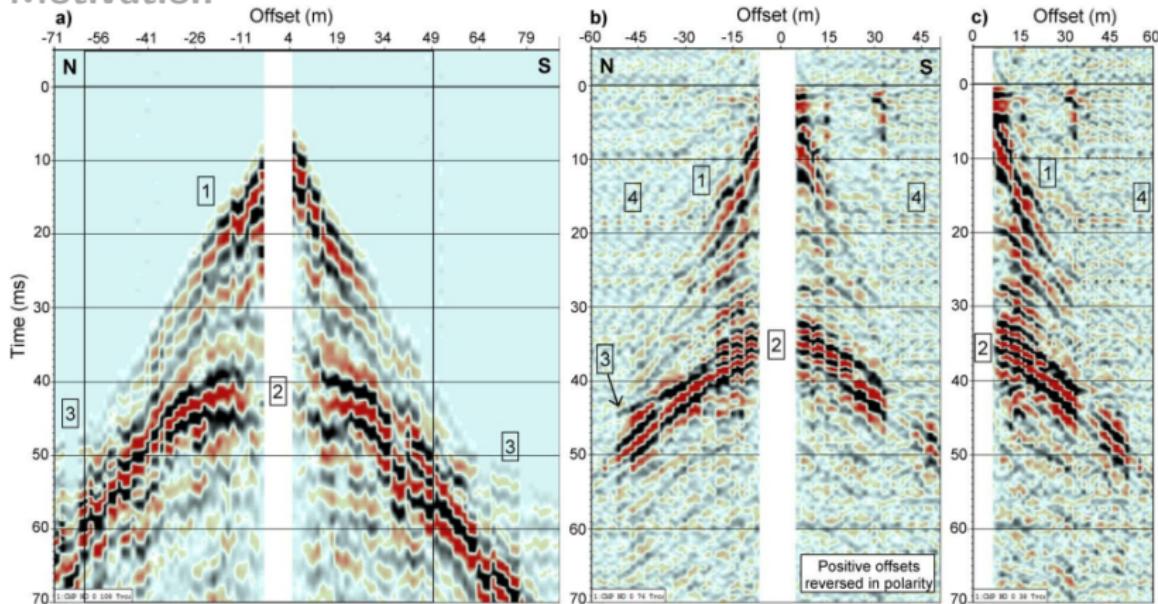
Introduction

Motivation

- ▶ Hydrocarbon
- ▶ Bedrock
- ▶ Water
- ▶ Water table
- ▶ CO₂ storage
- ▶ Borehole and surface

Introduction

Motivation



Butler et al., 2018

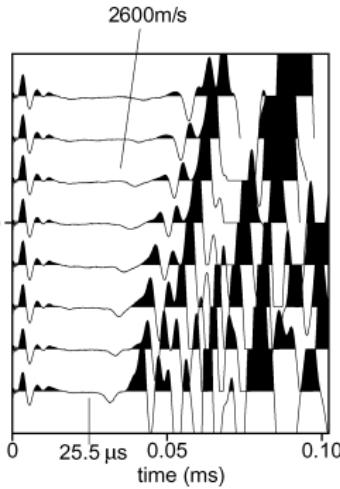
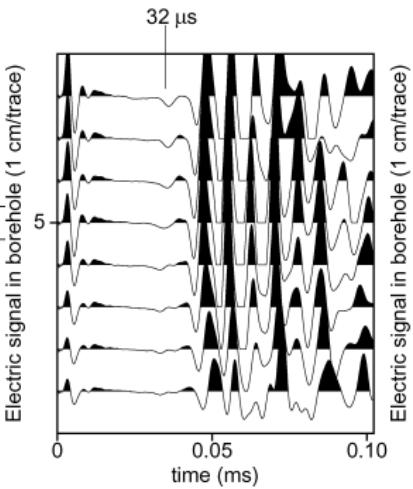
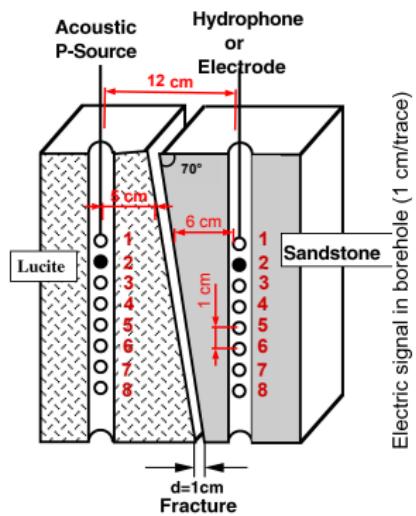
Experiments: What has been done

Summary

1. Zhu and Toksöz (2003)
2. Chen and Mu (2005)
3. Zu et al. (2008)
4. Schakel et al. (2011)
5. Peng et al. (2017)
6. Ellouz (2017)

Experiments: What has been done

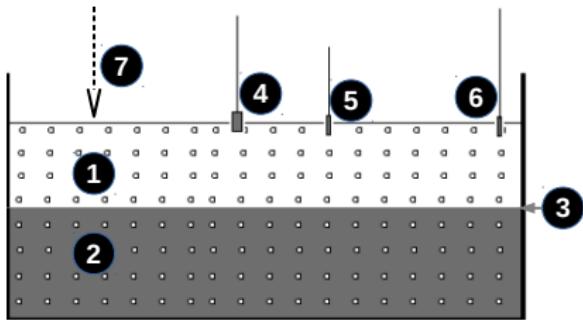
Zhu and Toksöz (2003)



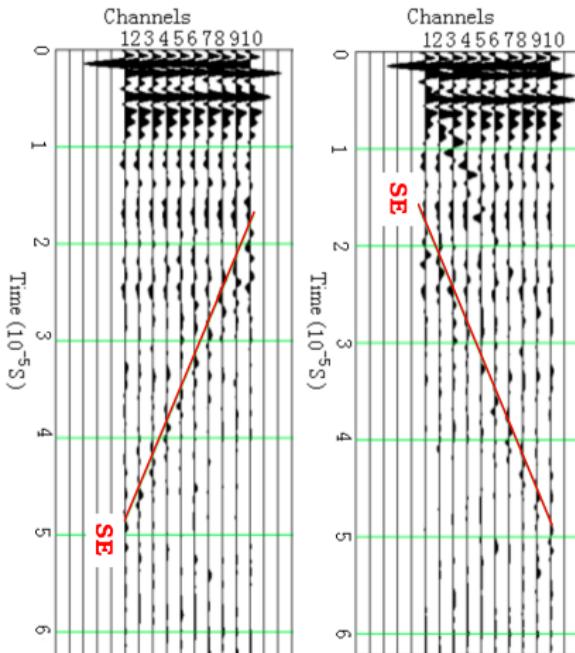
- ▶ Crosshole w/ water filled fracture
- ▶ Study fracture aperture vs amplitude
- ▶ Geometrical parameters of dipping fractures

Experiments: What has been done

Chen and Mu (2005)

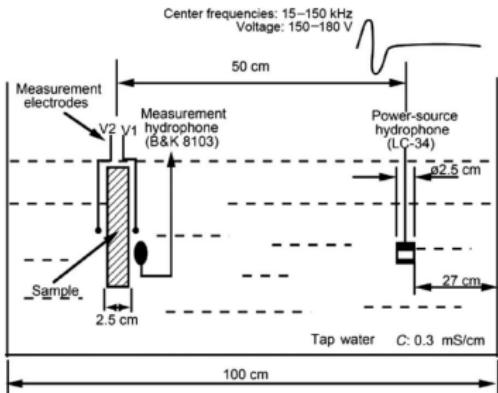


- ▶ NaCl-saturated sand
- ▶ Salt-water/Water/Oil saturated layers
- ▶ Conductivity behaviour
- ▶ converted EM is sensitive to Oil/salt-water

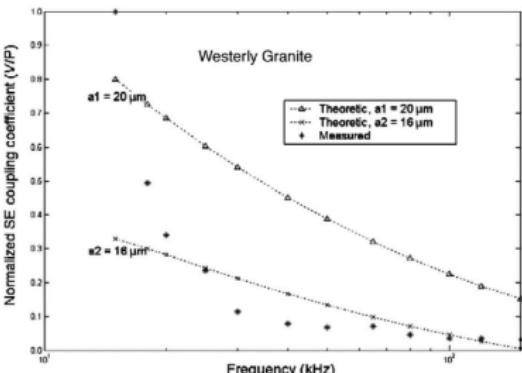
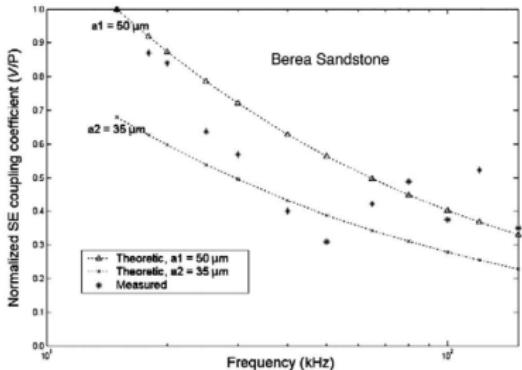


Experiments: What has been done

Zhu et al. (2008)

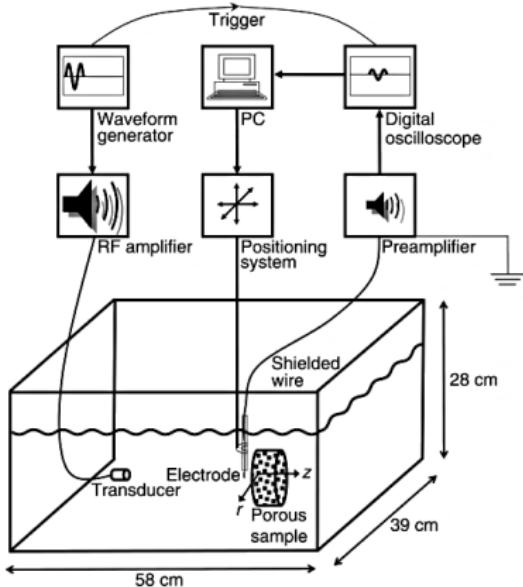


- ▶ Sandstone and Granite
- ▶ Coup Coef for 15 – 150 kHz
- ▶ Coup Coef for Capillary model
- ▶ Similar in frequency
- ▶ Converted energy \propto Permeability and Porosity

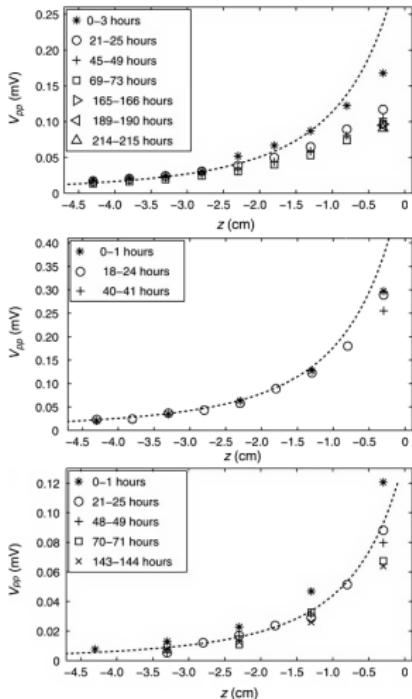


Experiments: What has been done

Schakel et al. (2011)

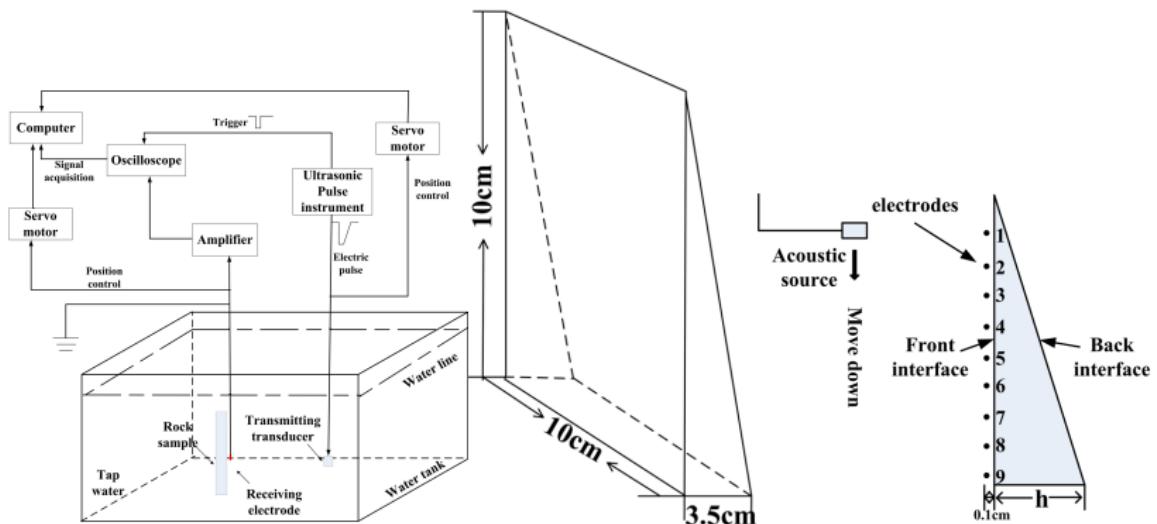


- ▶ Amp vs. Conductivity
- ▶ $\sigma = 1.27\text{e-}3$ (up), $1.20\text{e-}2$ (middle), $1.01\text{e-}1$ (bottom)



Experiments: What has been done

Peng et al. (2017)

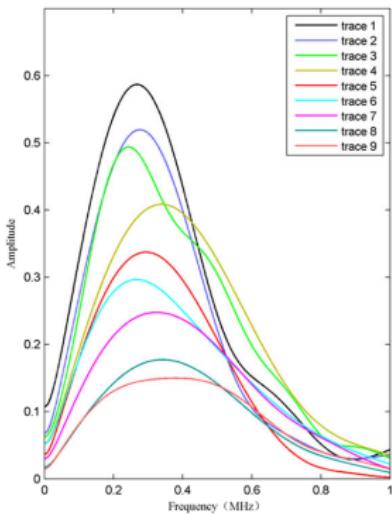
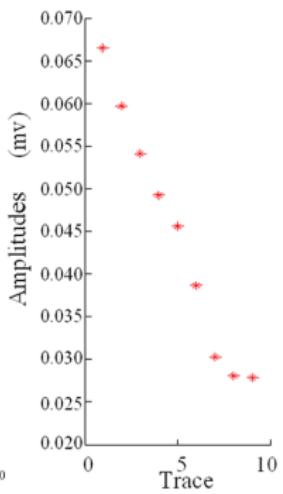
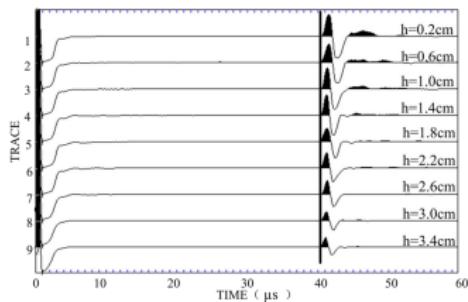


► $\lambda=0.9\text{cm}$

Experiments: What has been done

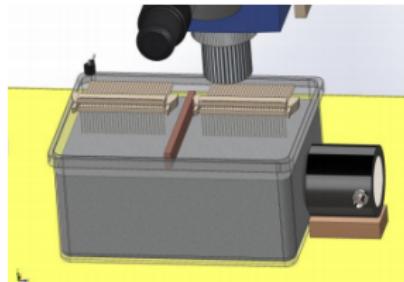
Peng et al. (2017)

Continue :



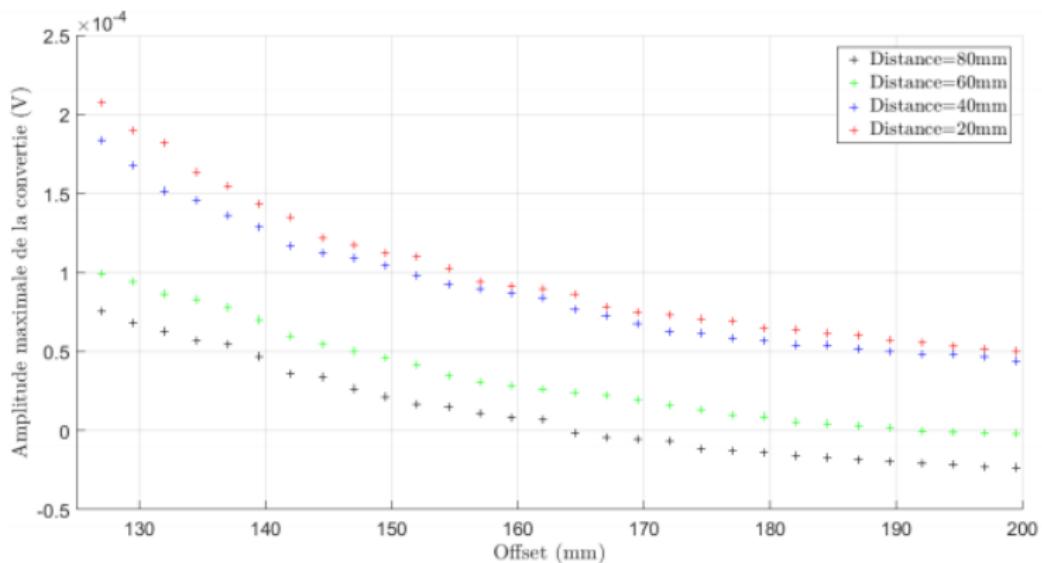
- ▶ Experimentally confirmed that thin-layers can enhance the interface response.

- ▶ Investigated the effect of various acquisition and geometry-related model parameters to amplitude of converted-EM:
 - ▶ Thickness
 - ▶ Electrode distance to layer
 - ▶ Excitation frequency
- ▶ Layer with widths as small as $\lambda/6$ could be identified



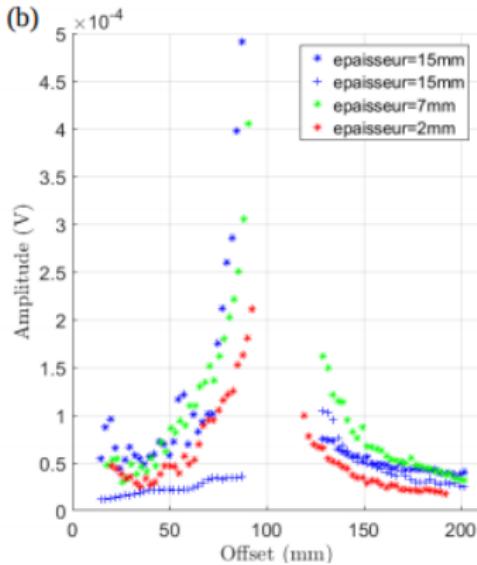
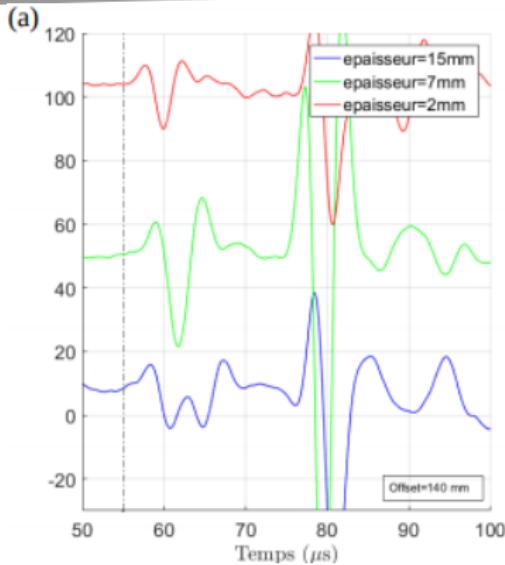
Experiments: What has been done

Ellouz (2017)



Experiments: What has been done

Ellouz (2017)



- ▶ $\lambda \approx 7\text{mm}$
- ▶ Thin-layer amplitude enhancement was not seen for 2mm thickness

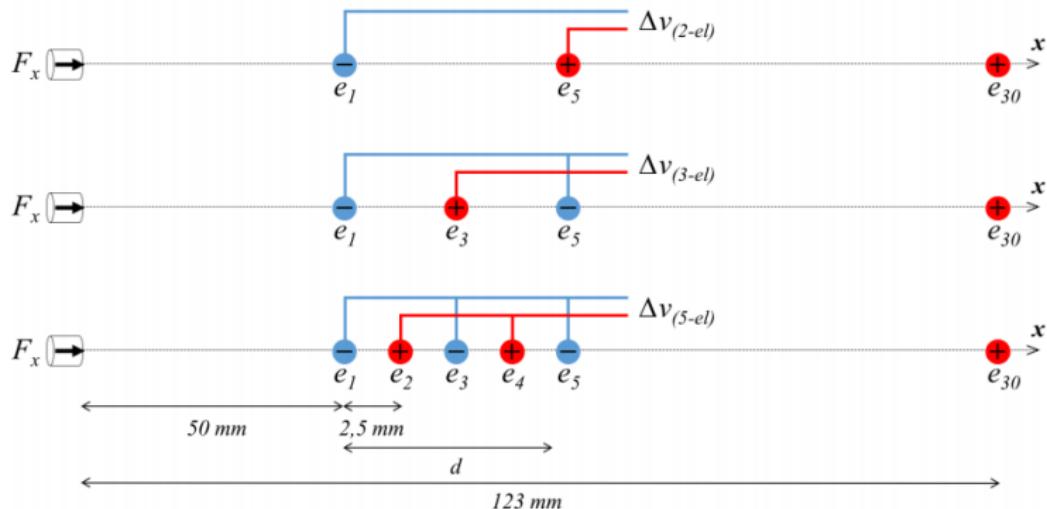
- ▶ Extend what was experimentally done in Schakel et al. (2012), Peng et al. (2017) and Ellouz (2017)
- ▶ Change in thickness and physical properties:
 - ▶ Wetting fluid/Salinity
 - ▶ Permeability/Porosity
- ▶ Try to keep up with numerical studies (Grobbe et al., 2016)

Thin-layers : those smaller than the wavelength

Open questions

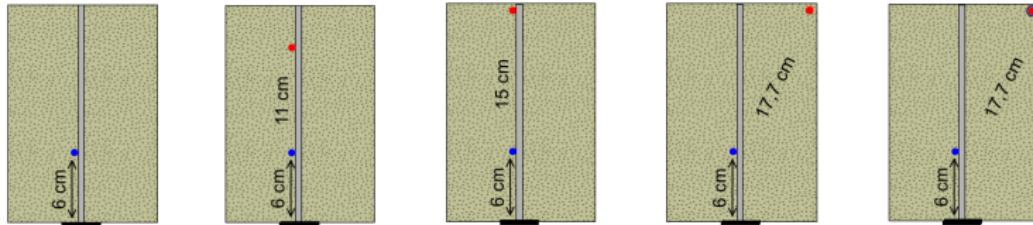
Multi-electrode arrangement

- ▶ Devi (2017)
- ▶ 3 and 5-electrodes configuration to reduce noise and amplify EM-waves



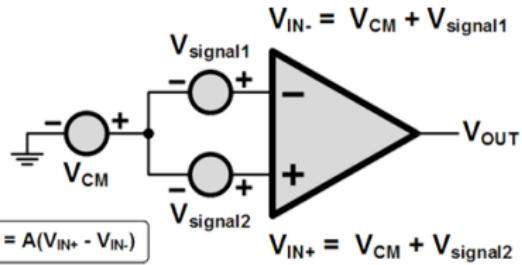
Questions we have ourselves

Reference electrode



Ellouz (2017)

Differential amplifier – Common mode rejection ratio

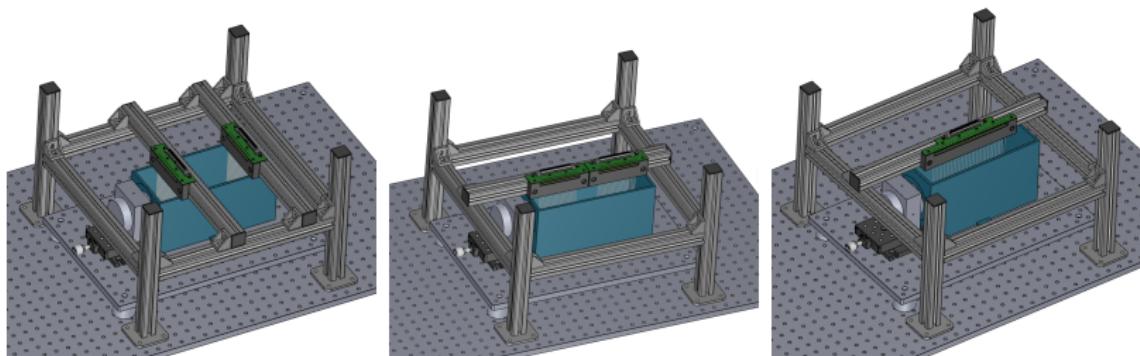


Experiments to be conducted

- ▶ Test:
 - ▶ Reference electrode (which configuration, are there improvements?, etc.)
 - ▶ Common mode rejection (does it improve our signal? Is it worthy to use it?)
 - ▶ Multi-electrode configuration
- ▶ Parallel and perpendicular (to layer) measurements
- ▶ Change rocks /rock properties (heating to change porosity?)
- ▶ Change wetting fluid (μ m plastic to seal fluid in?)

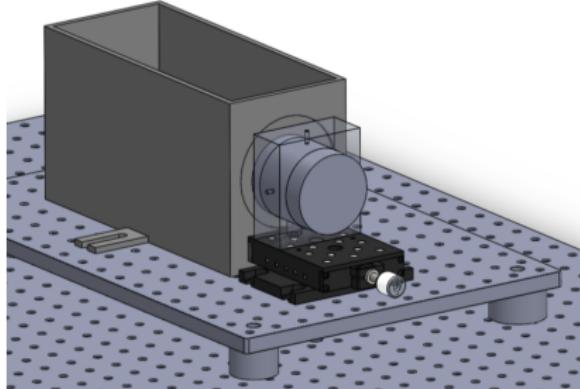
New experimental set-up

- ▶ Conceived thanks to Federico
- ▶ With the help of Clarice and Daniel



New experimental set-up

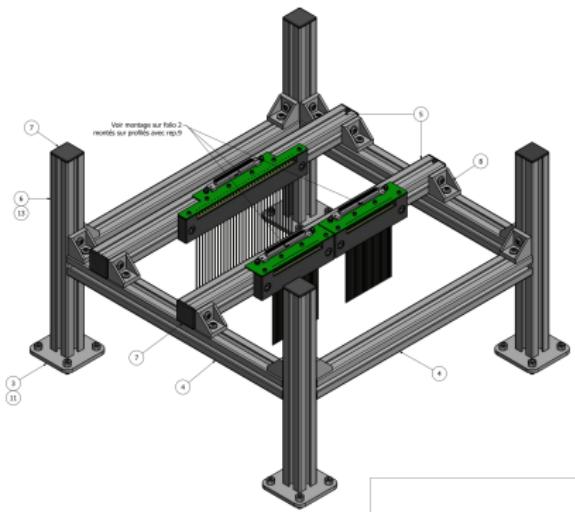
Acoustic-related



- ▶ Thorlabs equipments
- ▶ Support for Piezo
- ▶ Sandbox

New experimental set-up

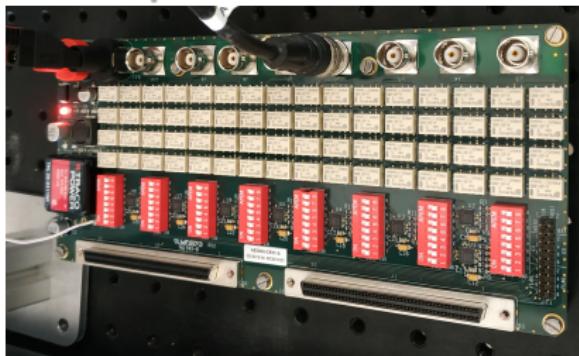
EM-related



- ▶ Thicker and longer electrodes
- ▶ More rigid -> Better positioning
- ▶ Metallic support for moving

New experimental set-up

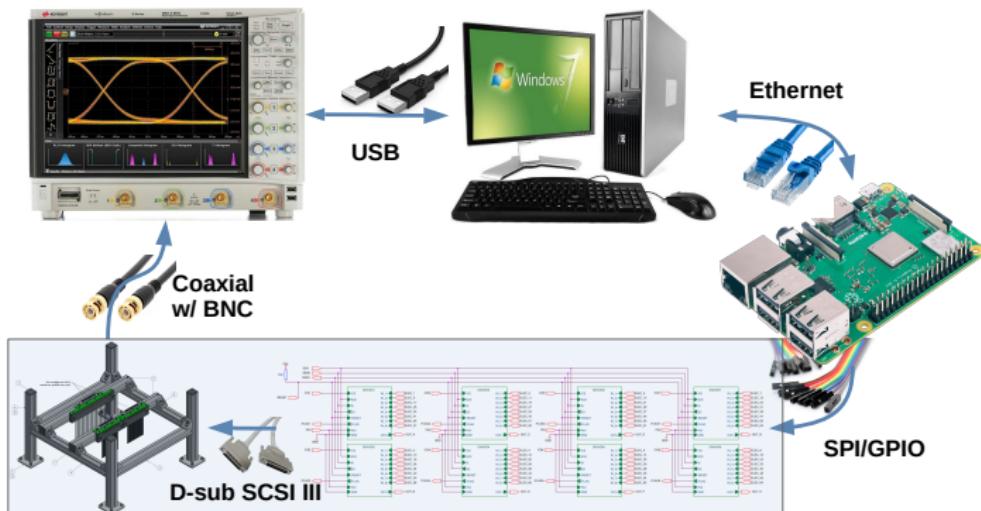
EM Acquisition-related



- ▶ Easily make measurements manually or in an automated way using SPI
- ▶ Faster acquisitions
- ▶ Less human influence

Automation – general view

Schema

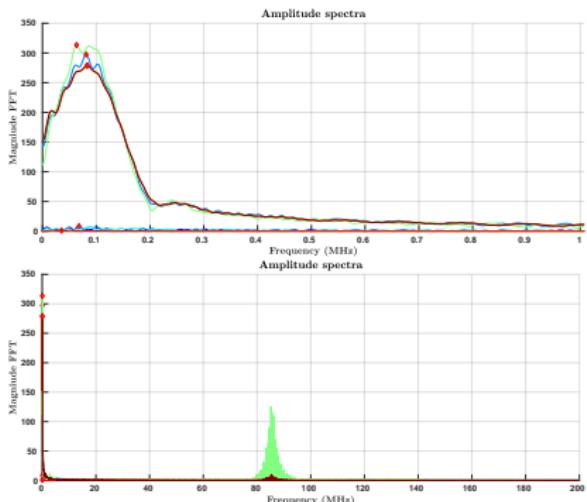
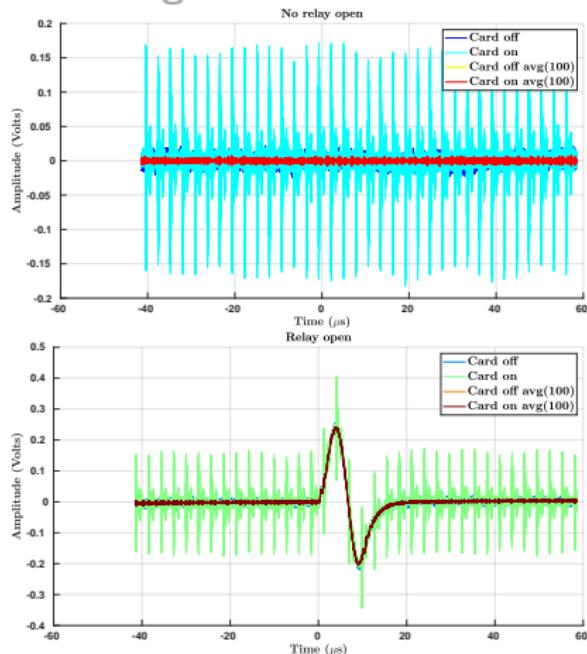


Automation – general view

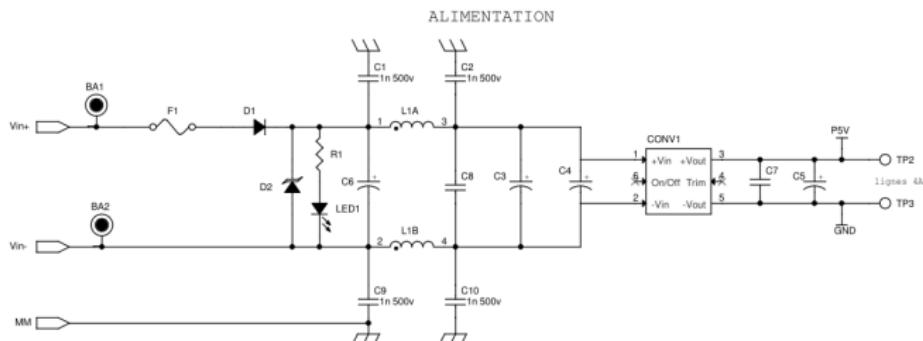
Main points

- ▶ Python-based routines and interface to control the electric acquisition
- ▶ Quicker and simpler acquisition
- ▶ Less human interaction
- ▶ Towards reproductibility

Testing the card

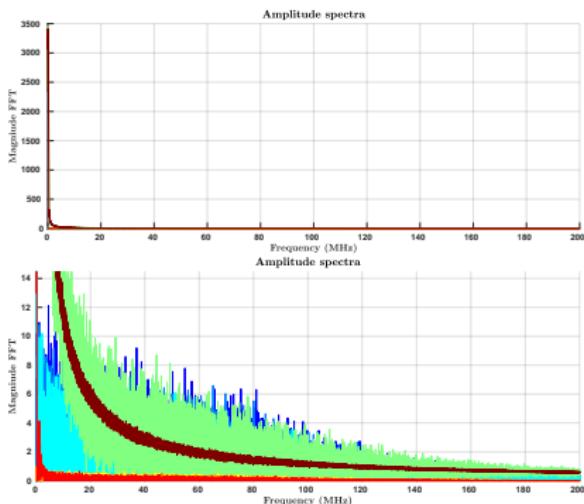
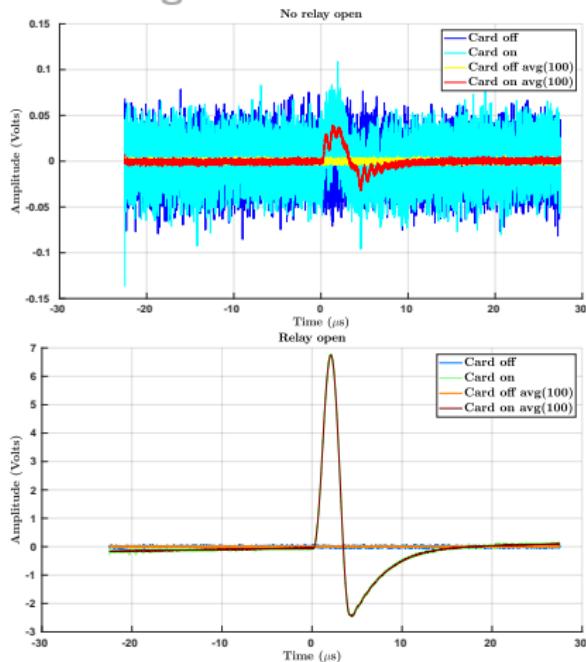


Testing the card

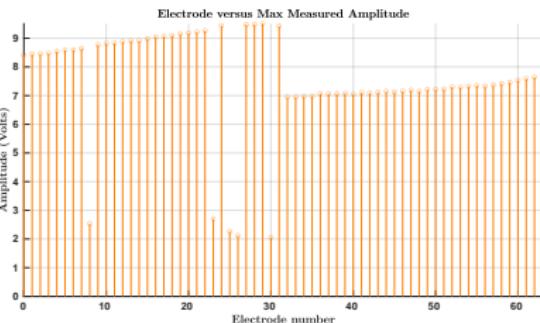
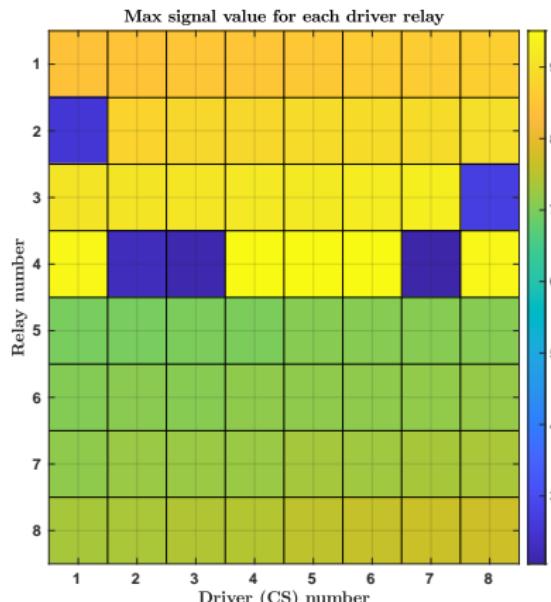


- ▶ Problem in switching regulator
- ▶ Solution: remove it

Testing the card

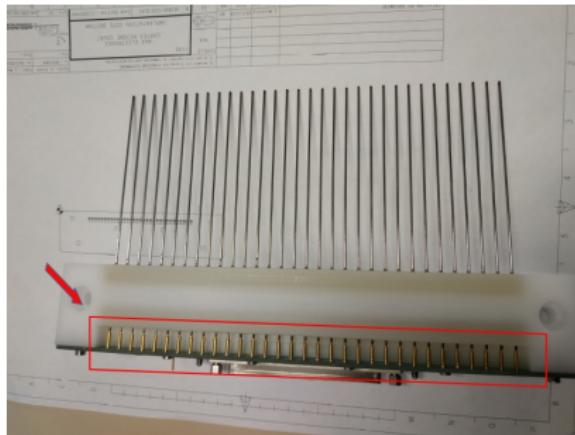


Testing electrodes



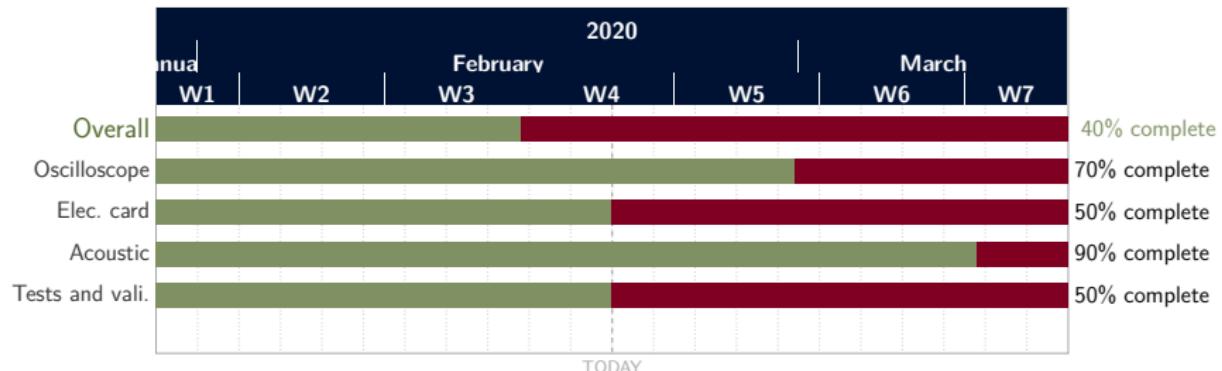
Testing electrodes

- ▶ Some defectuous electrodes in two combs
- ▶ Long comb (2,5,7,18 and 24)
- ▶ Short comb (9,24,26,27 and 31)
- ▶ Not yet solved



Automation and validation Planning

From : 2020-01-30 until 2020-03-13



► **Proposed at 2020-02-20**

Automation and validation Planning

Today



Tests yet to be performed

- ▶ Test box attenuation/plastic velocity/etc **ONGOING**
 - ▶ Better characterize measurements
 - ▶ More measurements
- ▶ Sand-filled box
- ▶ Sensitivity to the Layer response
- ▶ Check for improvements (acoustic and electric-wise) from previous experiment

Perspectives to new experimentl setup

General :

1. Greater SNR
2. Faster acquisition
3. Greater spatial precision of electric measurements due to more rigid electrodes
4. Ensure repeatability
5. More precision when studying the converted wave

Perspectives to new experimentl setup

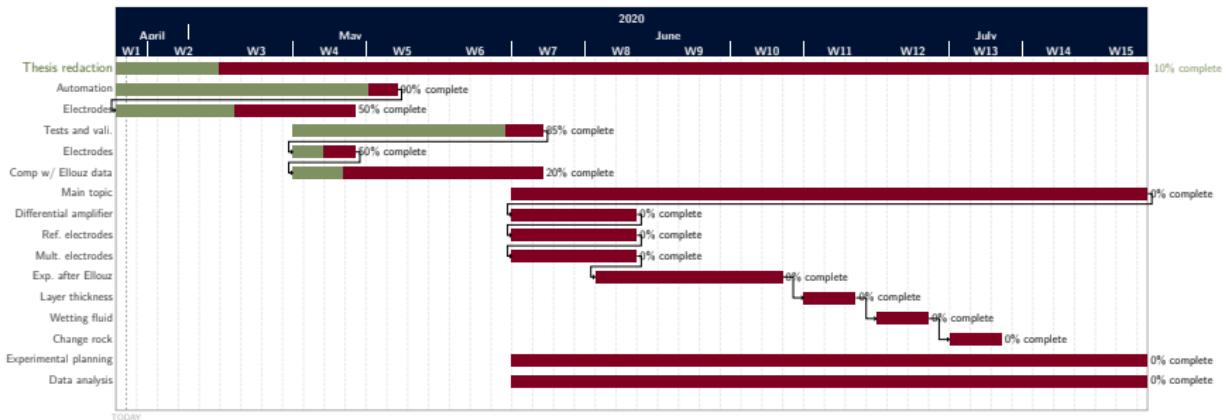
General :

1. Greater SNR
2. Faster acquisition
3. Greater spatial precision of electric measurements due to more rigid electrodes
4. Ensure repeatability
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In the end : A robust and easily reproducible seismoelectric experiment.

Final Planning

Today



Thank you for your attention!

