Implementation of Down-Hole Geophysical Testing for Rock Sockets

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FDOT GRIP

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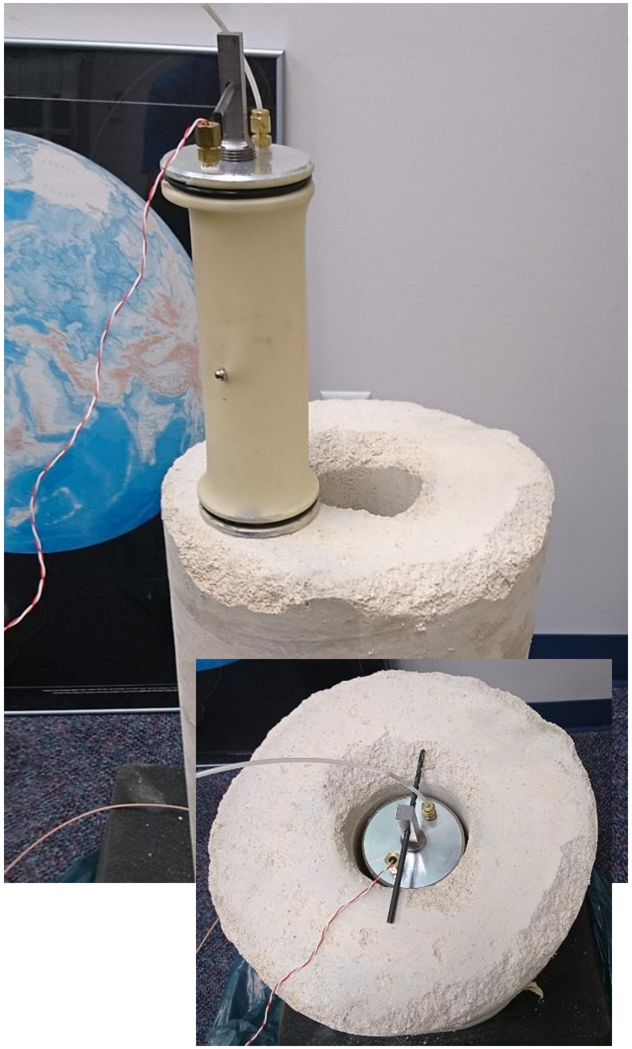
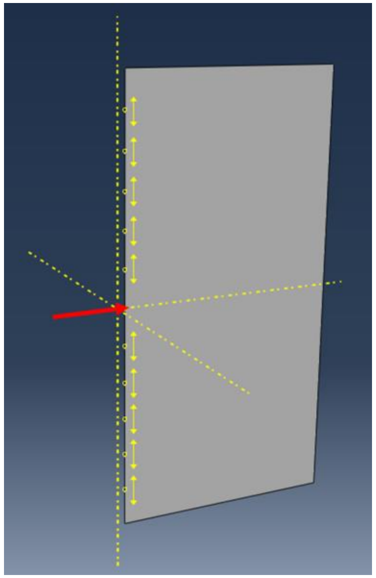


Workplan

- Task 1: Borehole Instrument
  - Source for generating seismic (mechanical) waves
  - Receiver array for capturing the wavefield
- Task 2: Inversion Software
  - ABAQUS forward model
  - Stand-alone forward model for borehole geometry
  - Artificial neural network (ANN) trained by ABAQUS
- Task 3: Validation Experiments
  - Large laboratory block of synthetic limerock
  - Newberry and Kanapaha test sites
- Task 4: Report

Inversion Software

- ABAQUS 2.5D FEM and regularized Gauss-Newton method
- Improved FEM element and mesh and streamlined inversion code
- Looked at open-source FEM, FD solution, and ANN
- Implemented 2.5D borehole model in Student Version of ABAQUS (free)
- Inversion shell in MATLAB

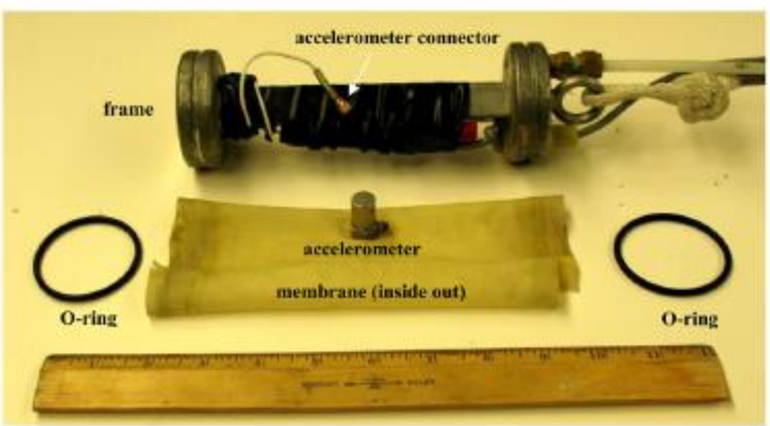


- Residual wave field: $\Delta\mathbf{d} = \mathbf{F}(\mathbf{m}) - \mathbf{d}$
- Least-squares error: $\mathrm{E}(\mathbf{m}) = \frac{1}{2}\Delta\mathbf{d}^t\,\Delta\mathbf{d}$
- Model updating: $\mathbf{m}^{n+1} = \mathbf{m}^n - \alpha^n[\mathbf{J}^t\mathbf{J} + \lambda_1\mathbf{P}^t\mathbf{P} + \lambda_2\mathbf{I}^t\mathbf{I}]^{-1}\mathbf{J}^t\,\Delta\mathbf{d},$
- Gradient matrix J: $\mathbf{J} = \frac{\partial\,\mathbf{F}(\mathbf{m})}{\partial m_p}$
- Step length: $\alpha^n \cong \frac{[\mathbf{J}^t g^n]^t[\mathbf{F}(\mathbf{m}^n) - \mathbf{d}]}{[\mathbf{J}^t g^n]^t[\mathbf{J}^t g^n]},$

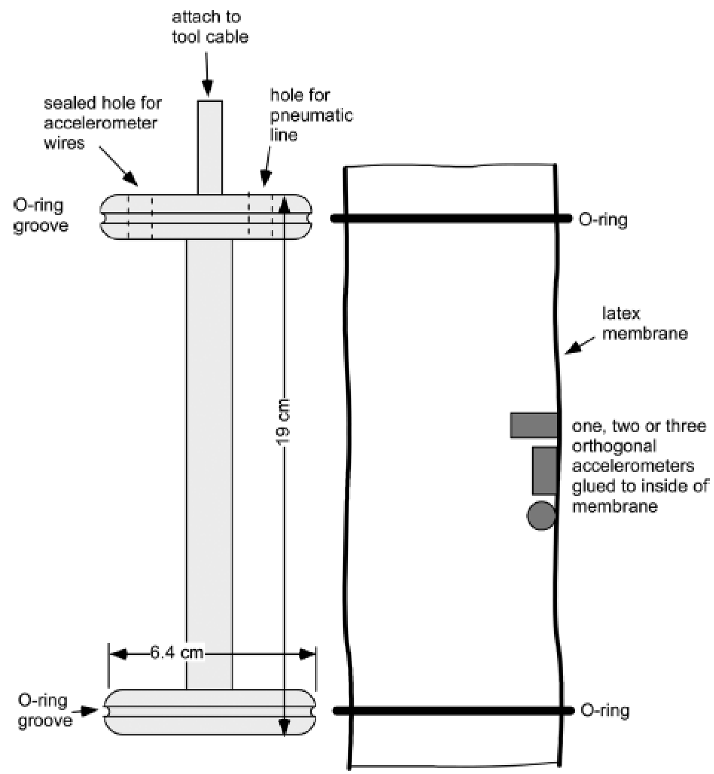
  $g^n = [\mathbf{J}^t\mathbf{J} + \lambda_1\mathbf{P}^t\mathbf{P} + \lambda_2\mathbf{I}^t\mathbf{I}]^{-1}\mathbf{J}^t[\mathbf{F}(\mathbf{m}^n) - \mathbf{d}].$

Kalinski Borehole Receiver

a. assembled view

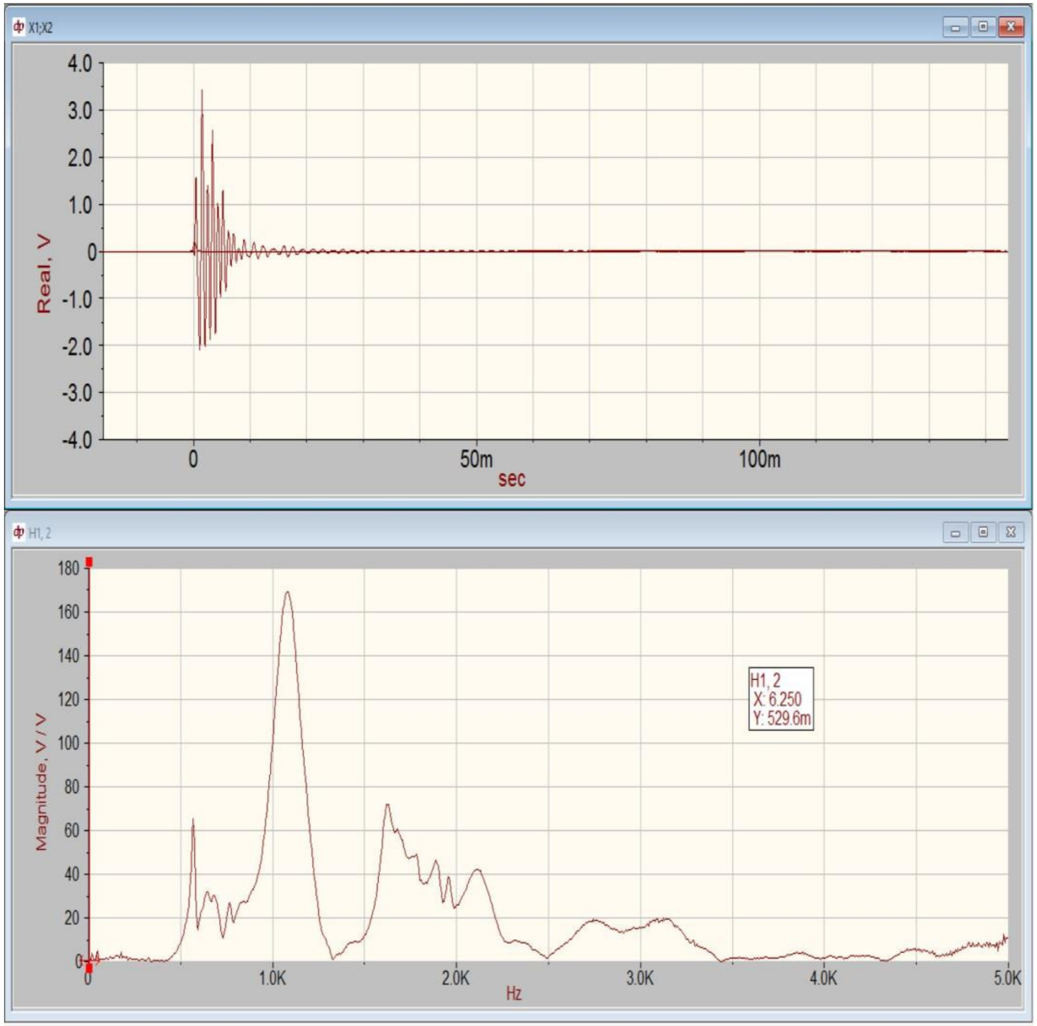


b. exploded view

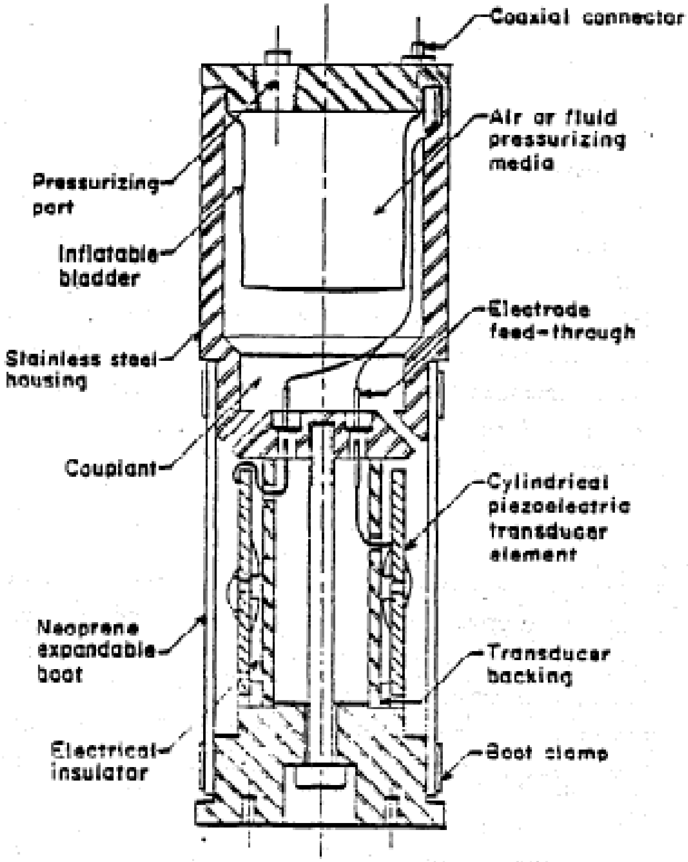


a. support frame b. inflatable membrane

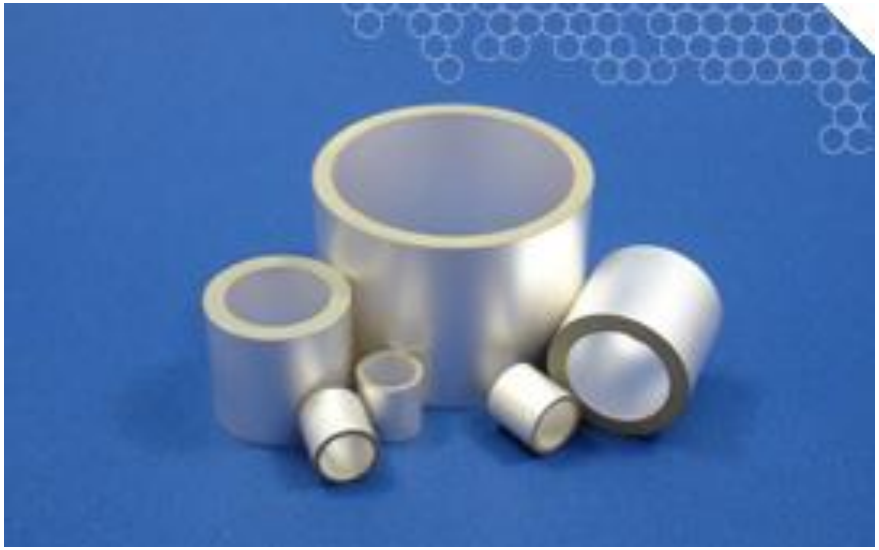
Borehole Receiver



Piezoelectric Borehole Source



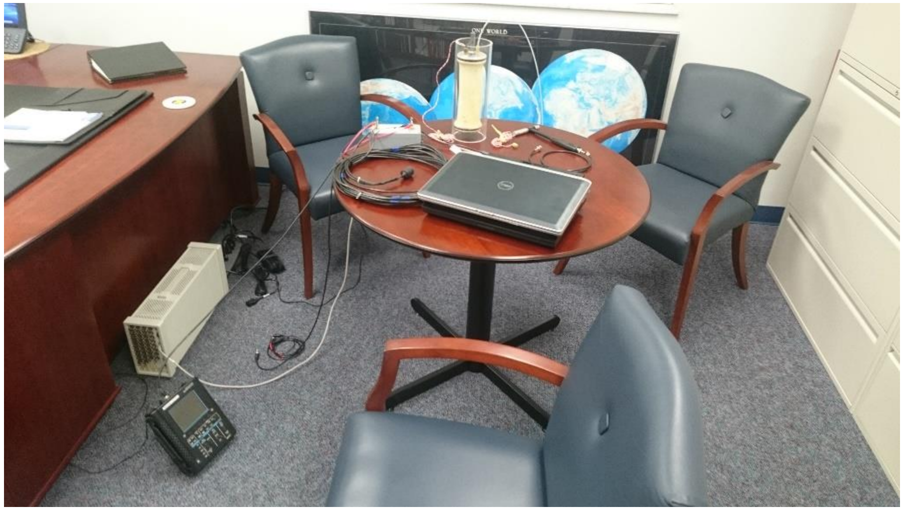
Thill (1978)

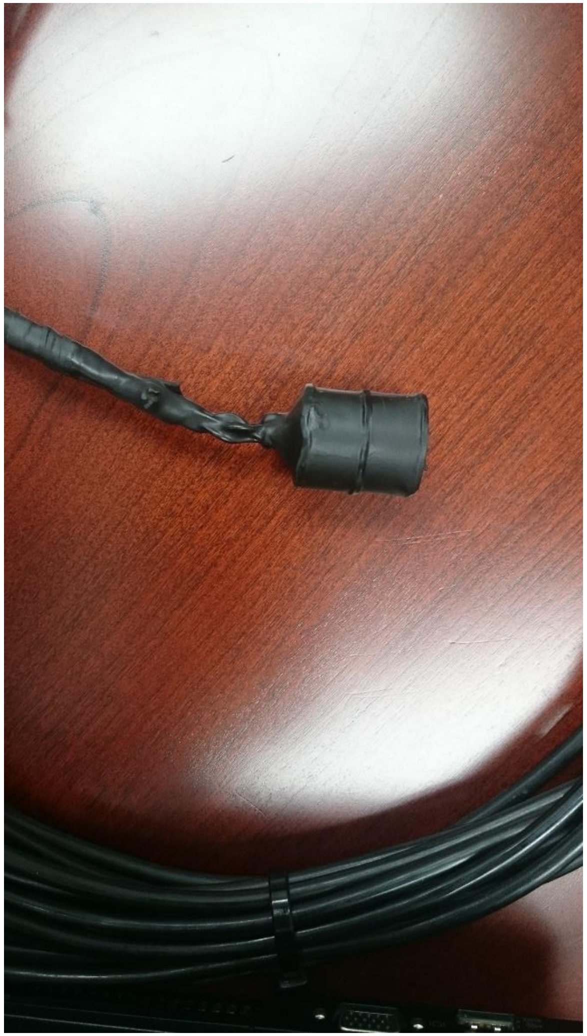


Piezoelectric Cylinders

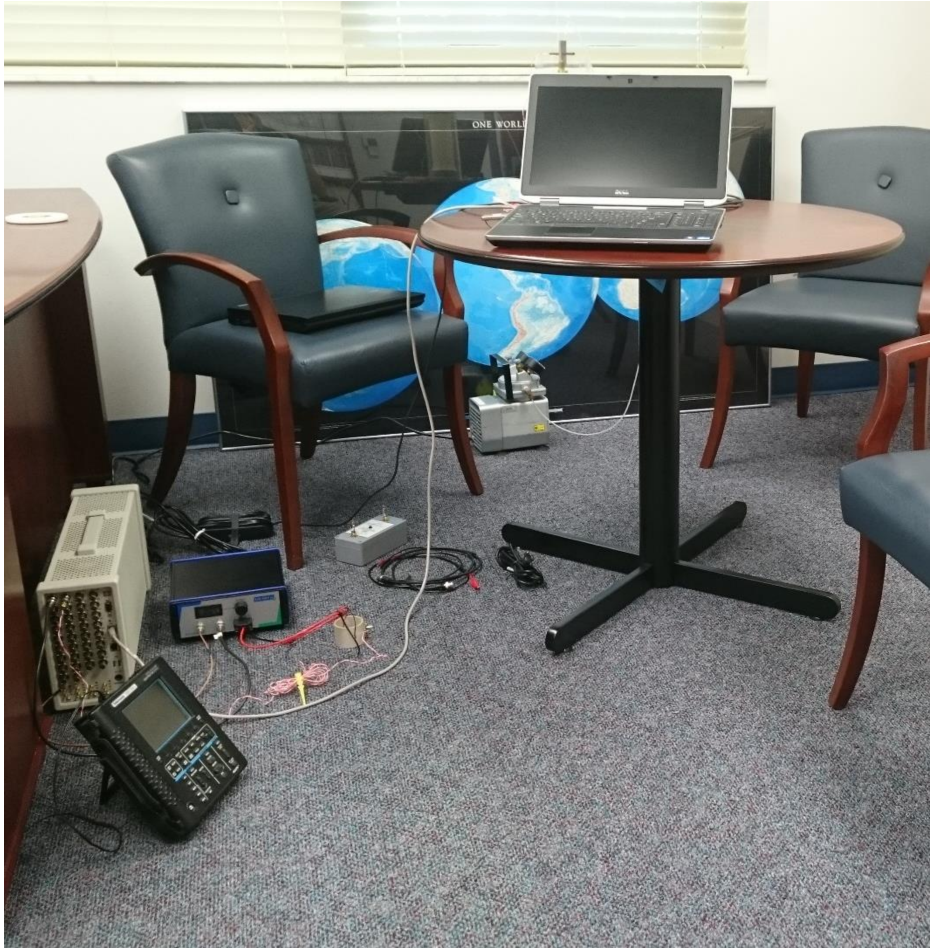
CSL Sensor

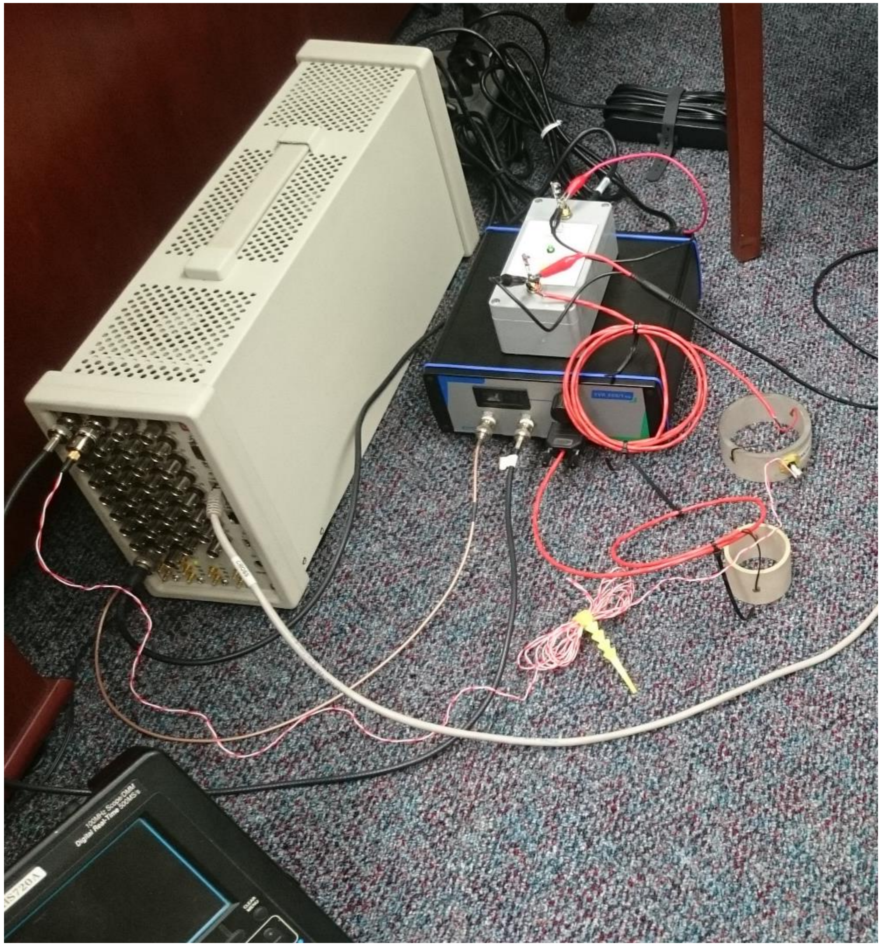
Cylinder and Amplifier: First Draft



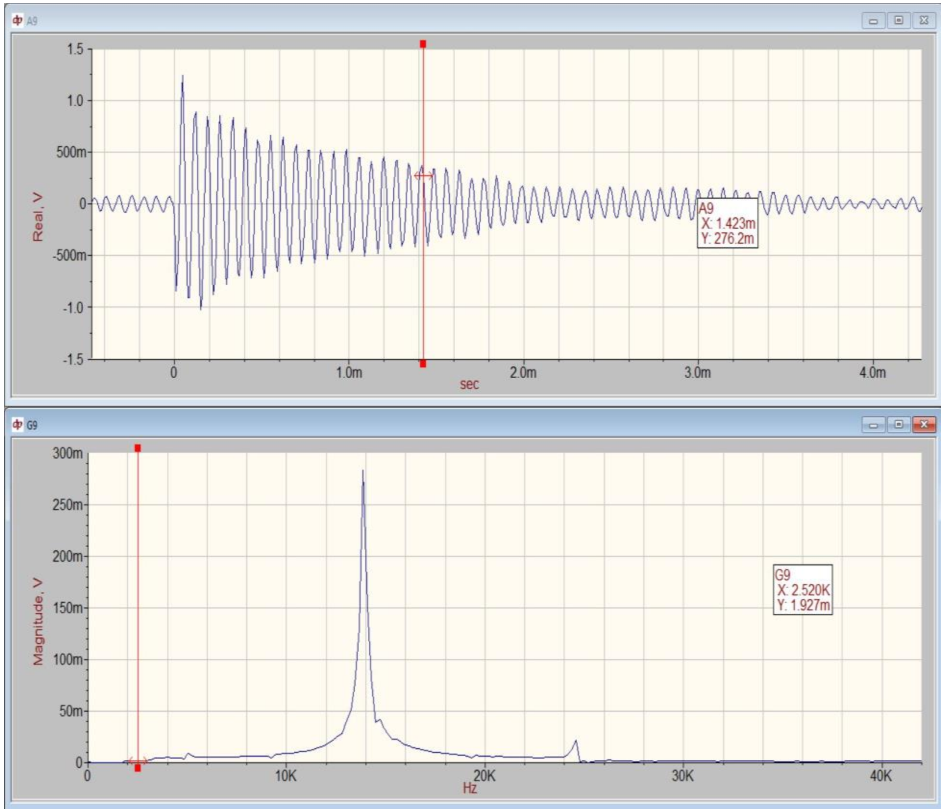


Cylinder and Amplifier: 2nd Generation

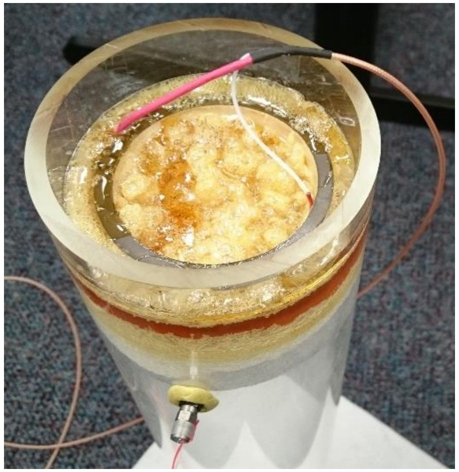


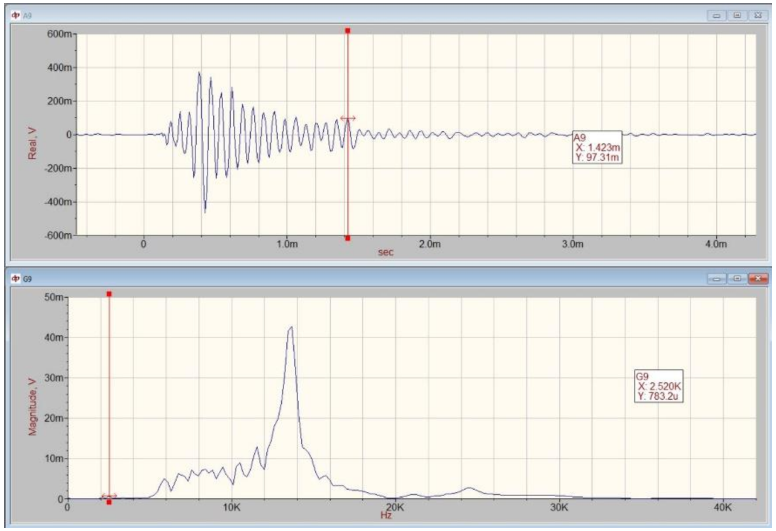


Cylinder and Amplifier: 3rd Generation

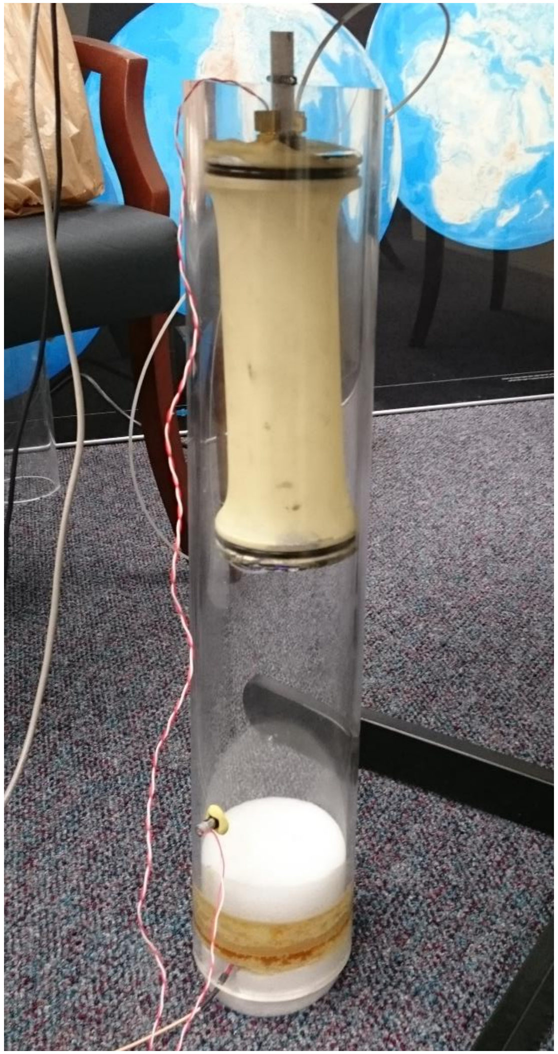


Acrylic Tube

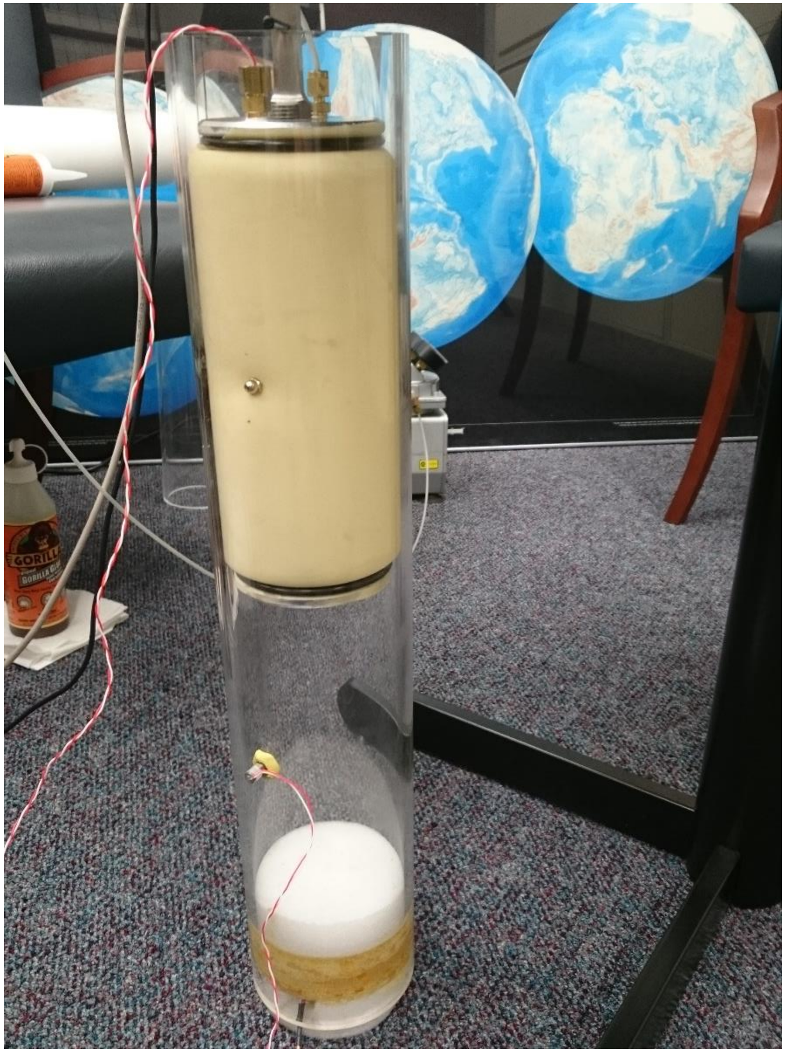


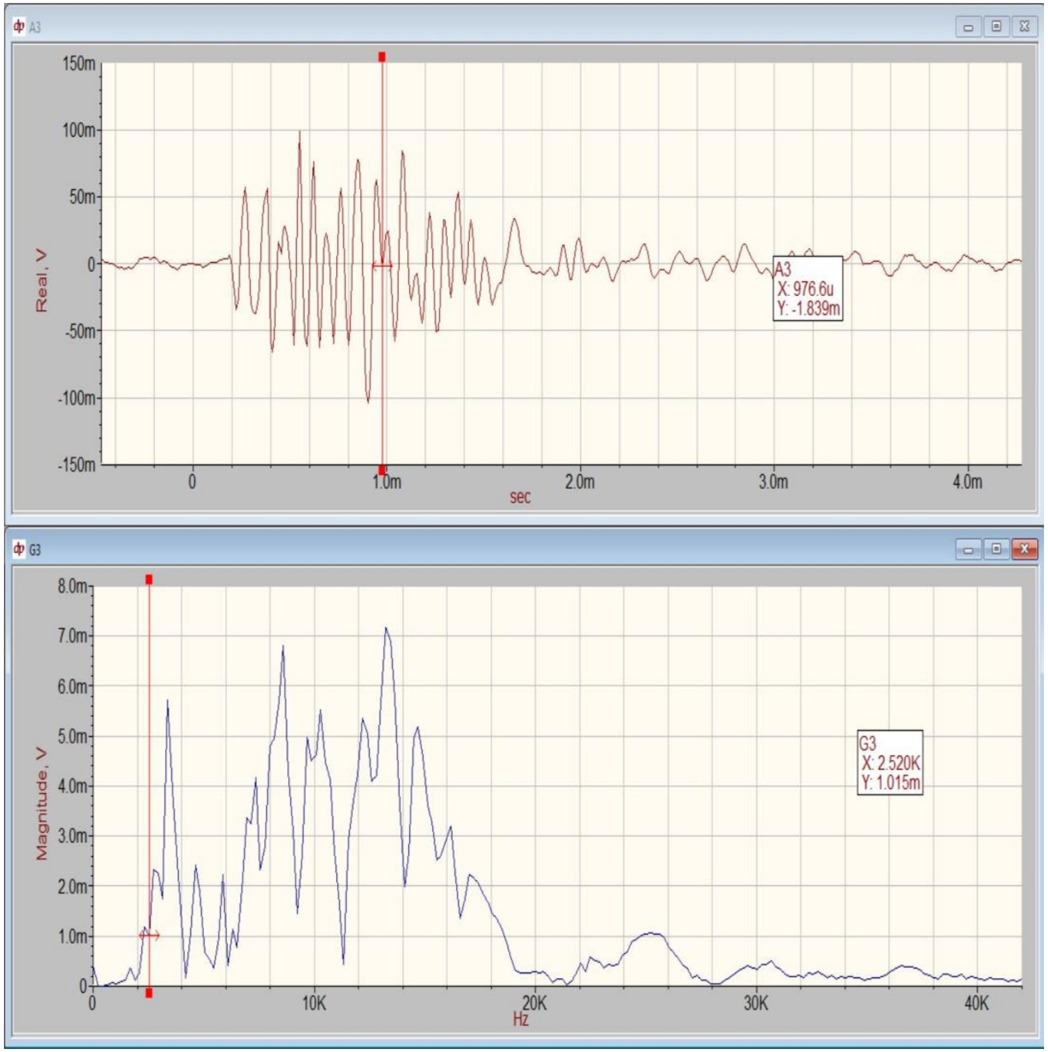


Combined Source/Receiver Concept



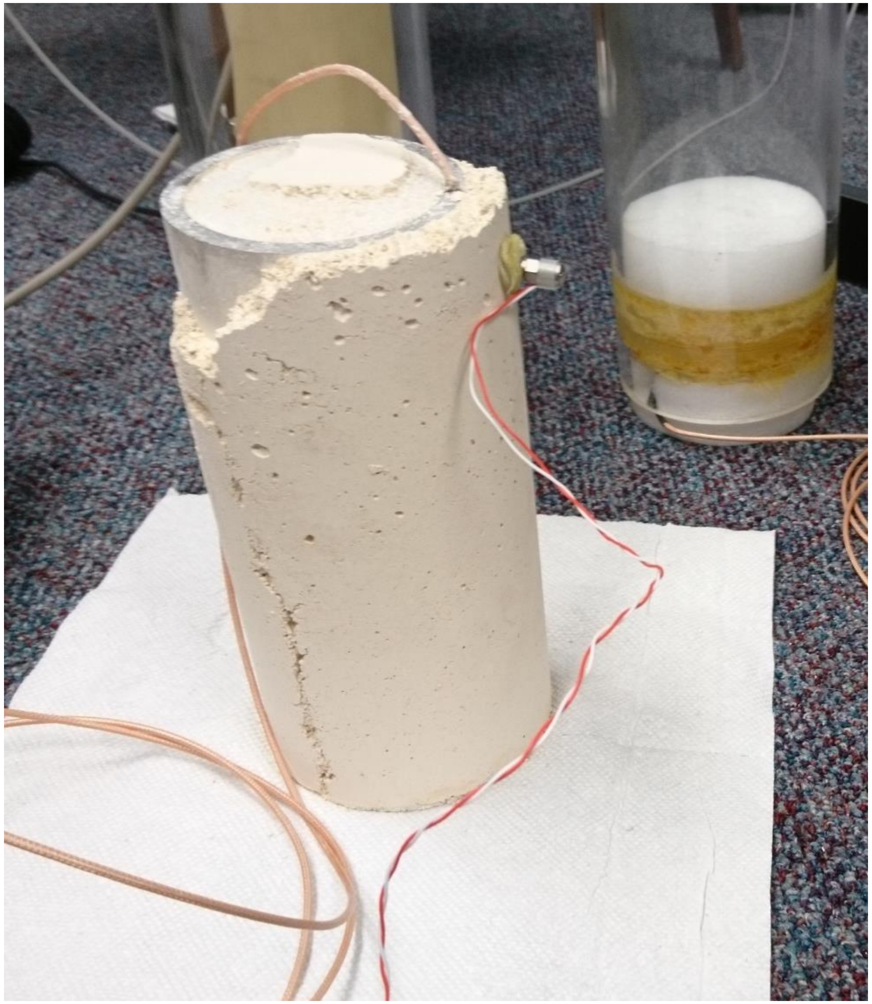
Receiver Improvements

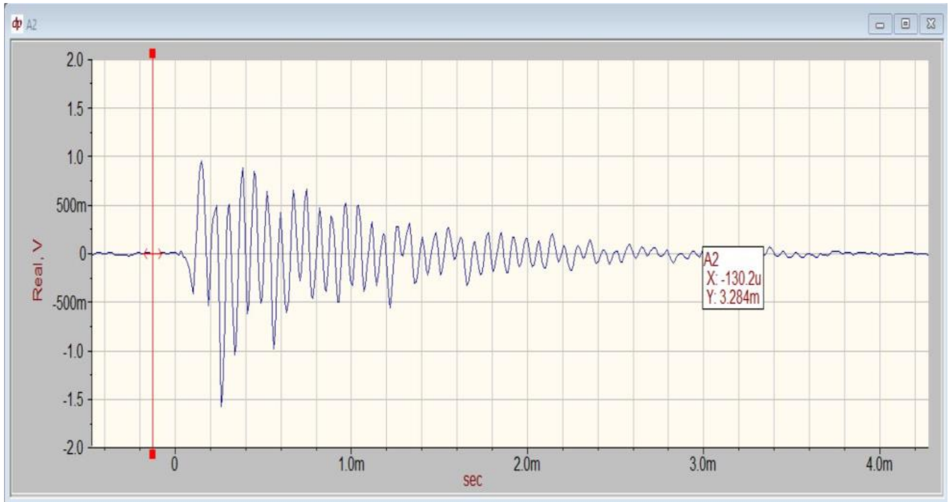




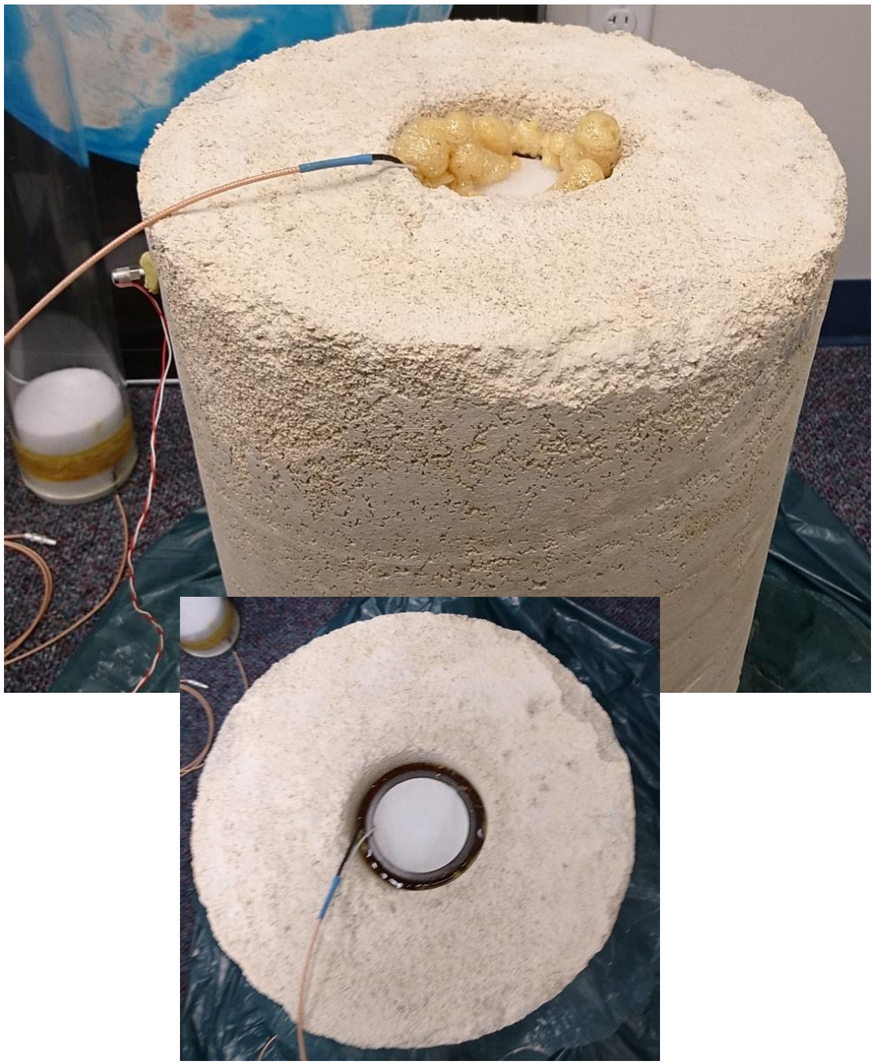
Synthetic Limerock Specimens

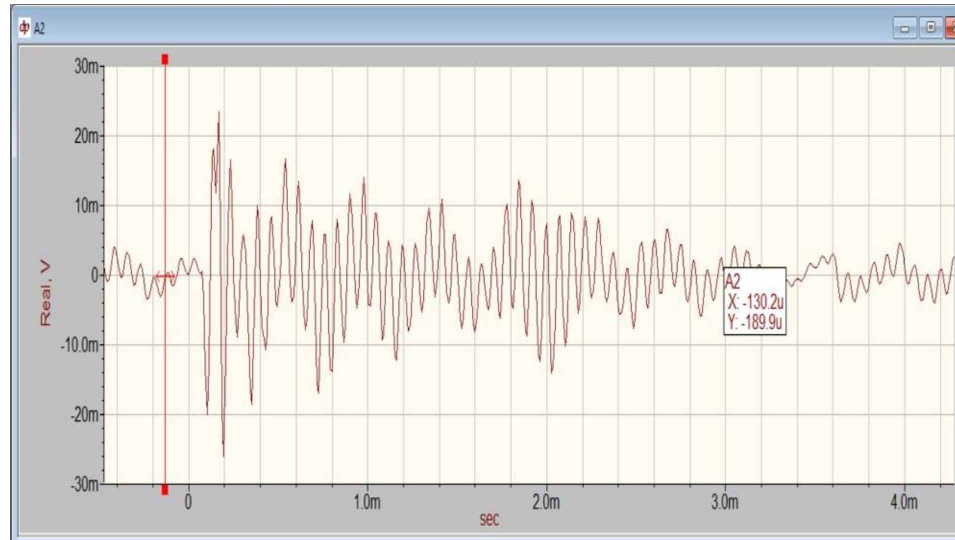
Synthetic Limerock Cylinder



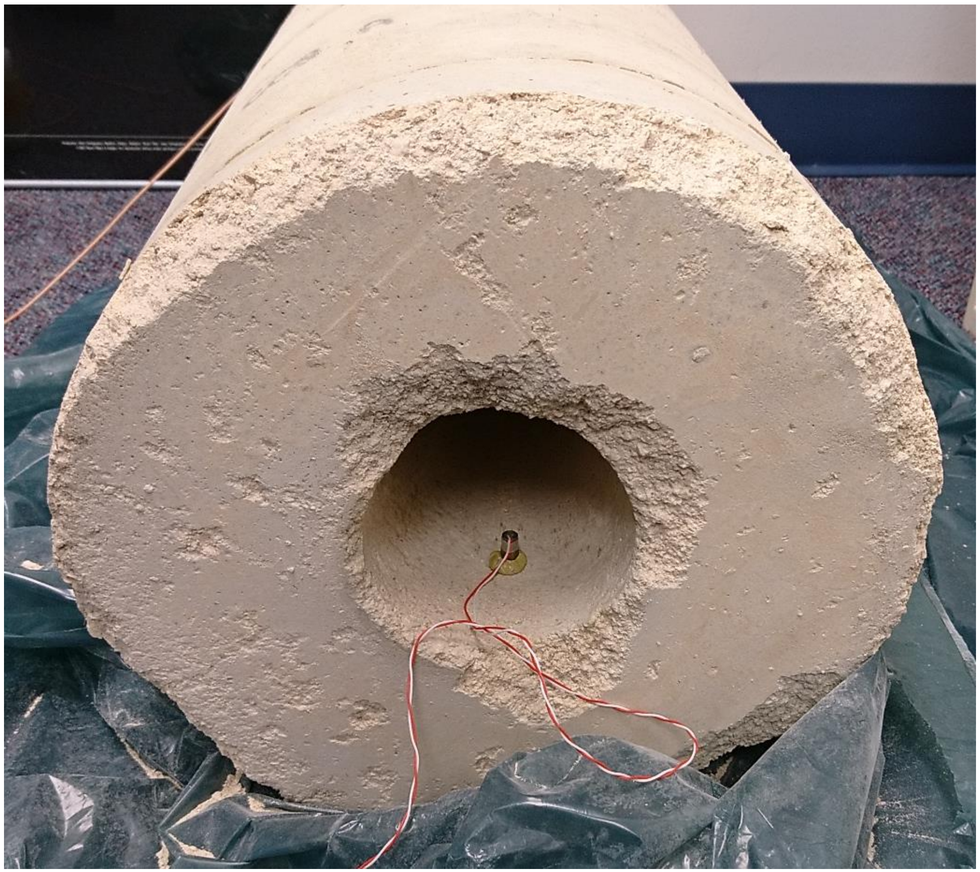


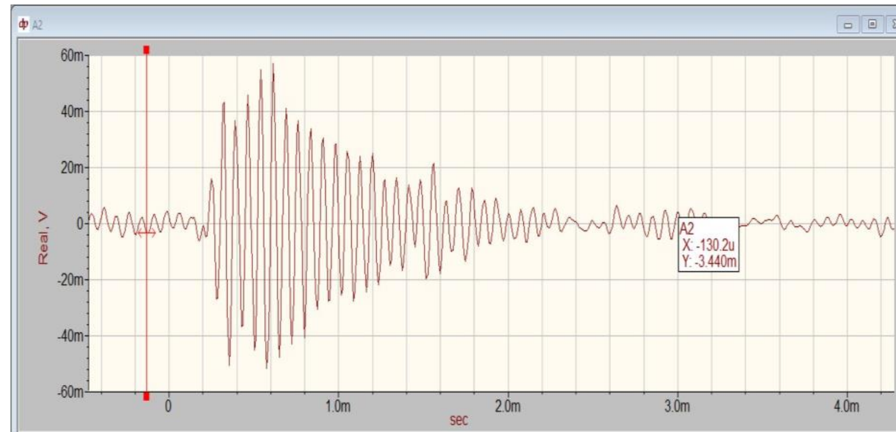
Synthetic Limerock Borehole Model

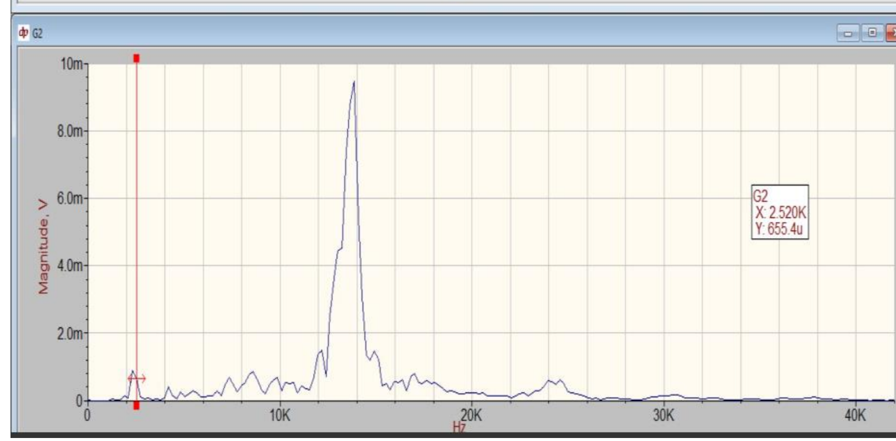




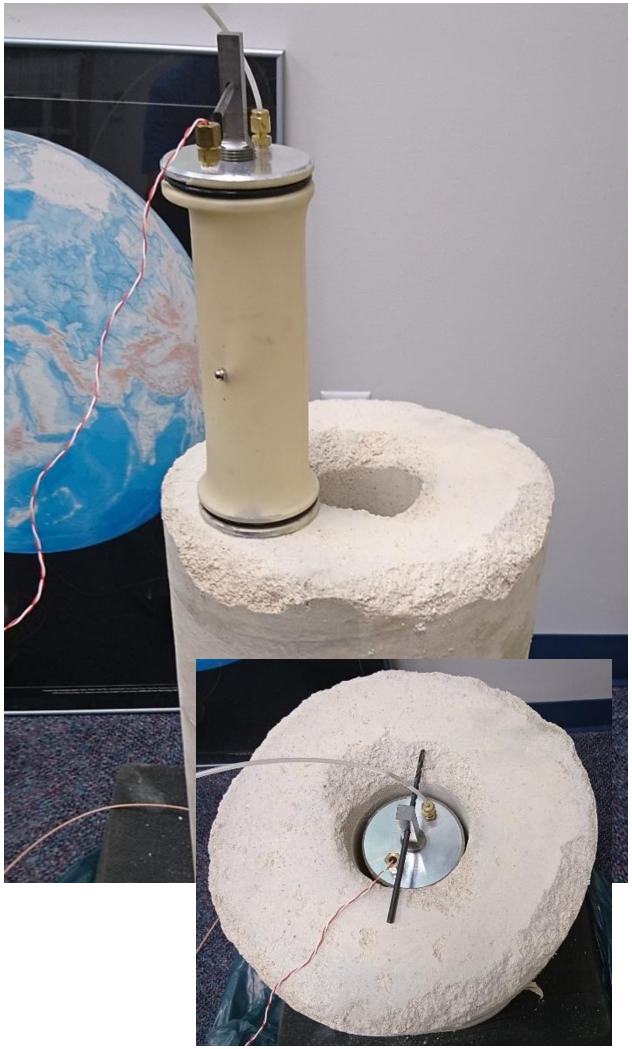
Synthetic Limerock Borehole Model

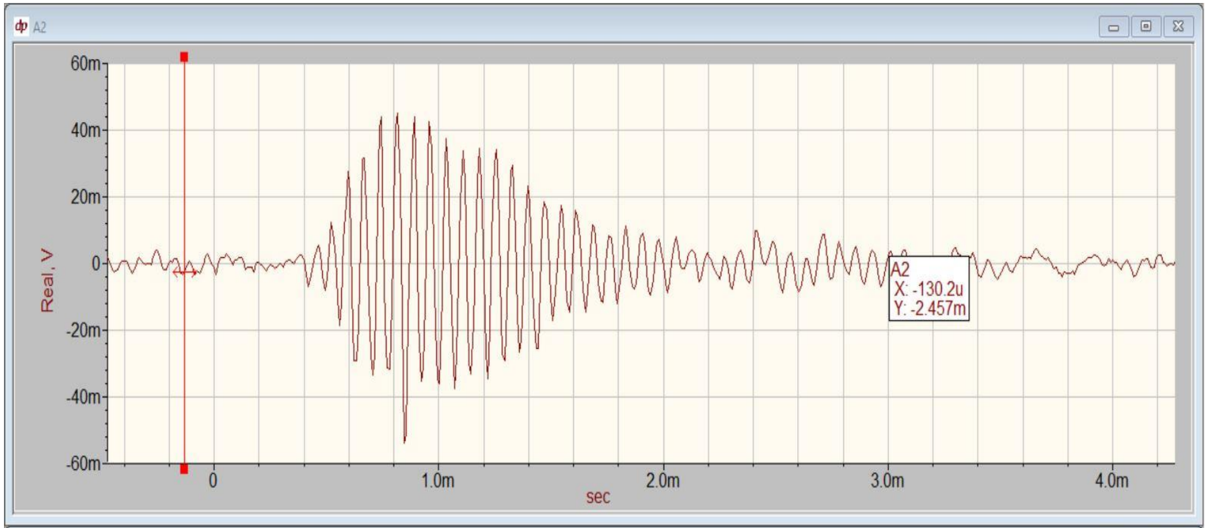


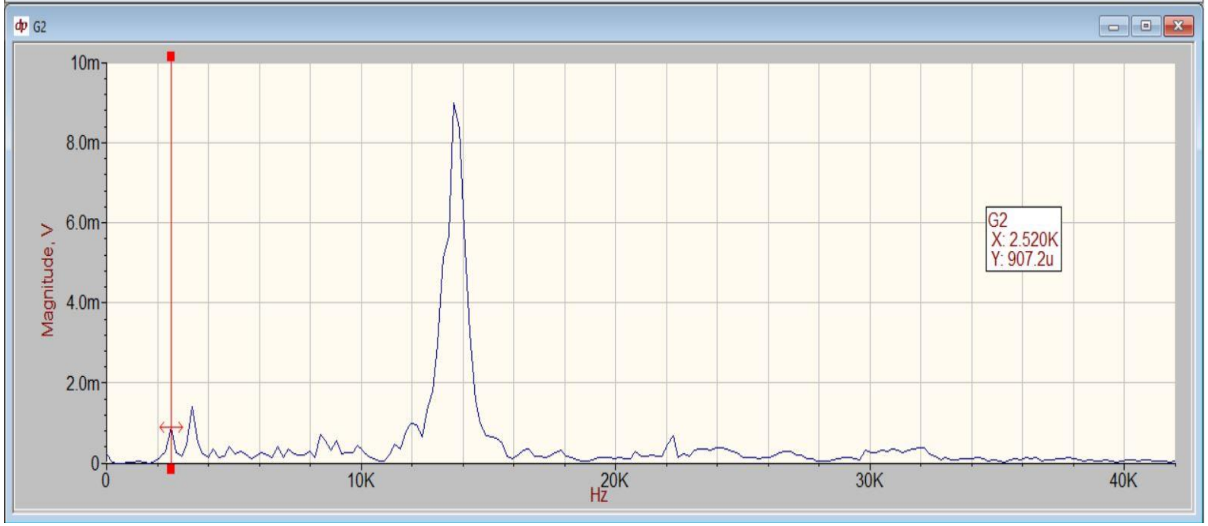




Synthetic Limerock Borehole Model



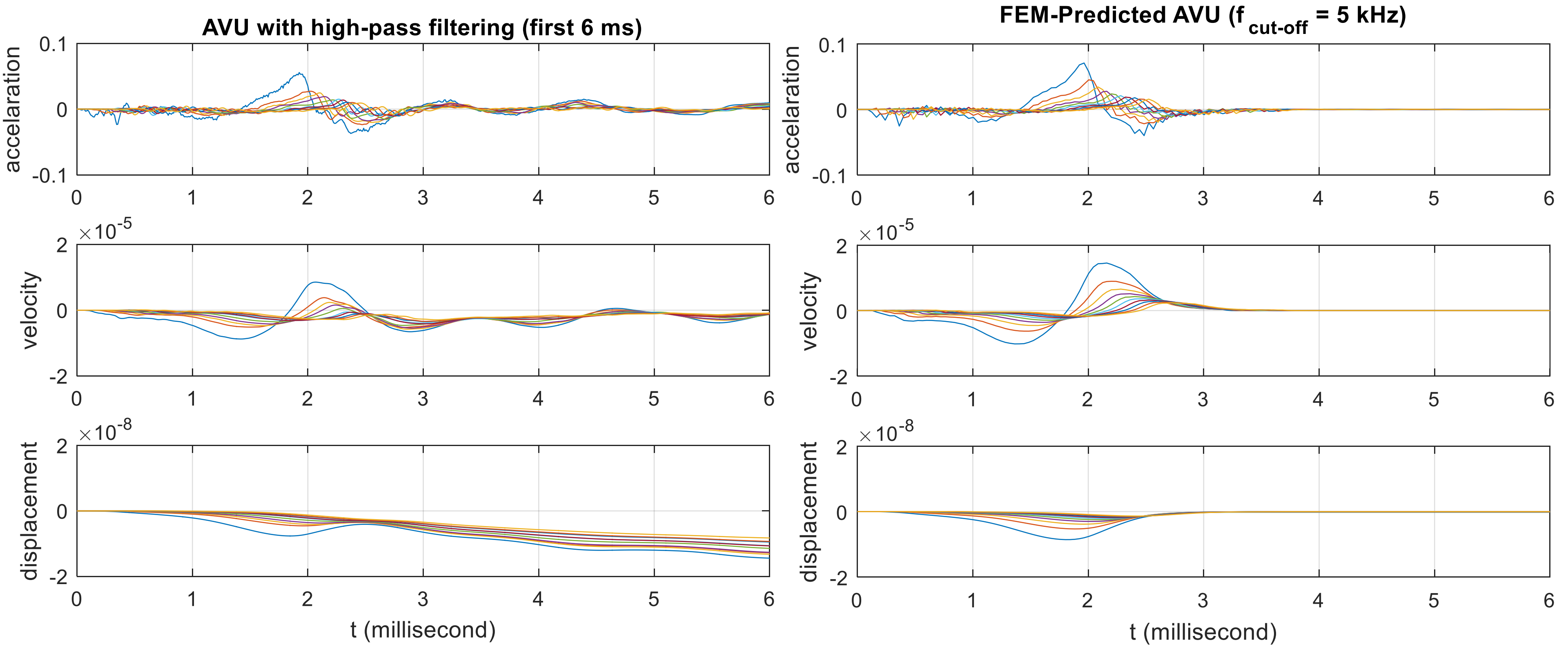




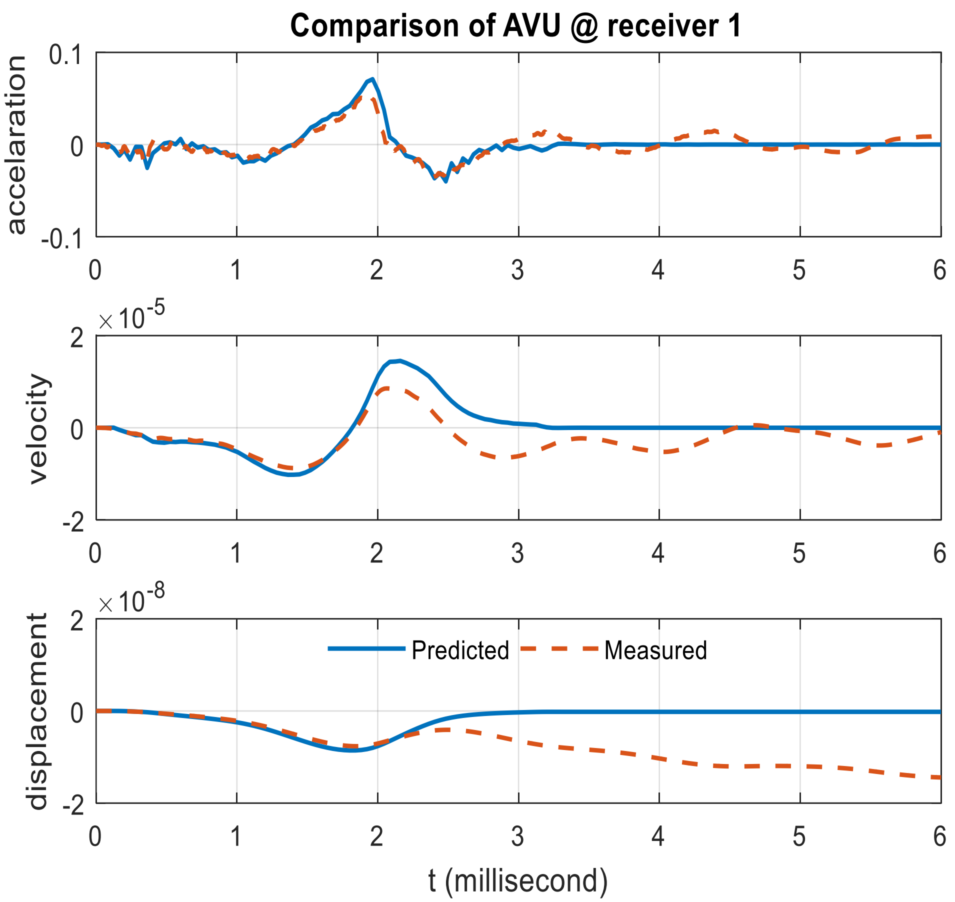
Synthetic Limerock Block

- Full waveform tests on top surface
- Free-free resonant column tests on companion cylinder
  - Vp = 1500 m/s
  - Poisson's ratio = 0.2
  - Thus Vs = 890 m/s

Synthetic Limerock Block

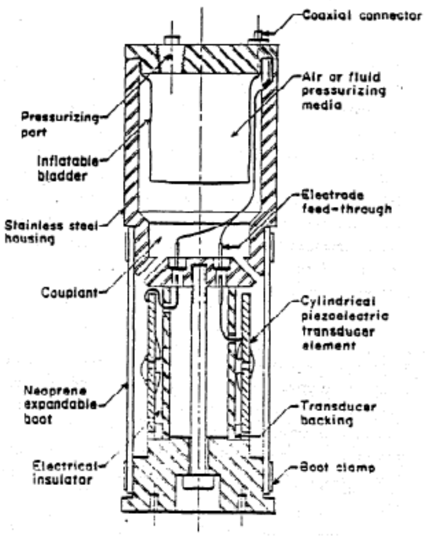


Synthetic Limerock Block

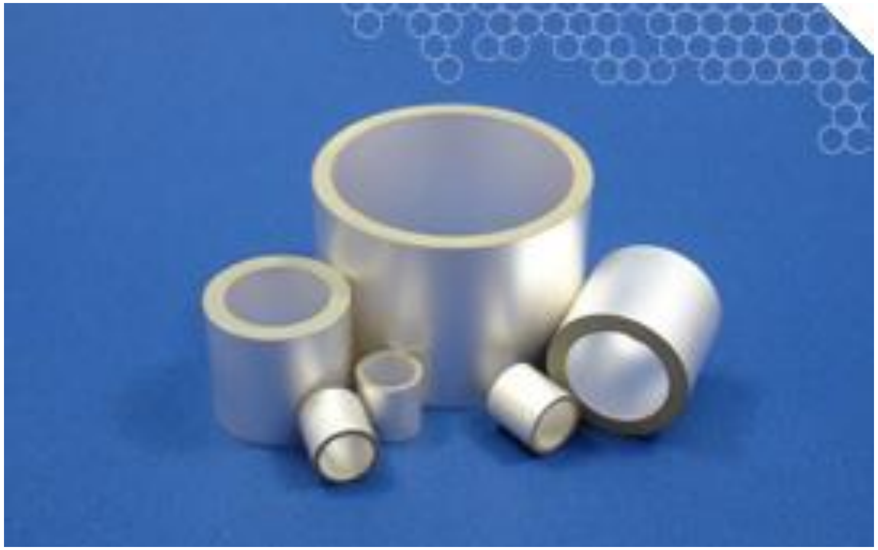


Next Activities

- 3-component accelerometers
- Repeatable, reusable coupling of borehole source
- Continue development of processing and inversion techniques on data from field experiments



Thank You!



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