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# Coils or capacitors?

## How should we measure motion?

Michael S. Hons, Robert R. Stewart,
Don C. Lawton, Malcolm B. Bertram
and Eric V. Gallant

November 29, 2007

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# Outline

- Sensor response
  - Accelerometer
  - Comparison to geophones
  - Noise floors
- Field Data (Violet Grove CO2 injection project)
  - Introduction
  - Noise floors
  - Gabor TVS
- Conclusions

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# How geophones work

- Magnetic induction
  - Seismic Data = Sensitivity x Proof mass velocity
  - Resonance within seismic band: complicated response

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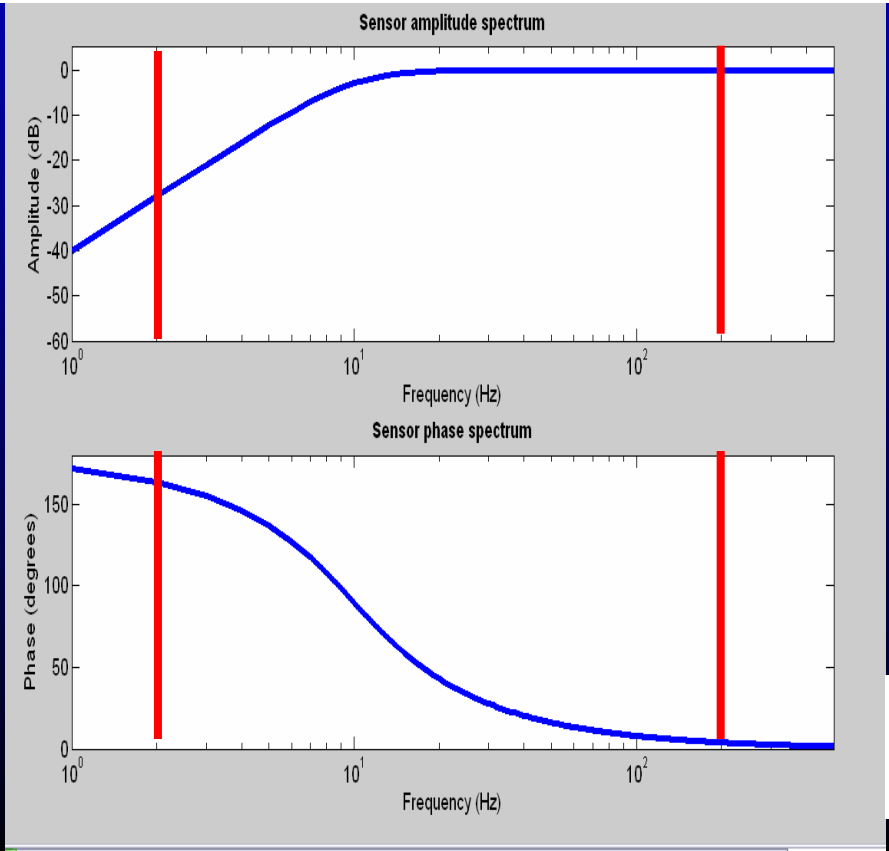
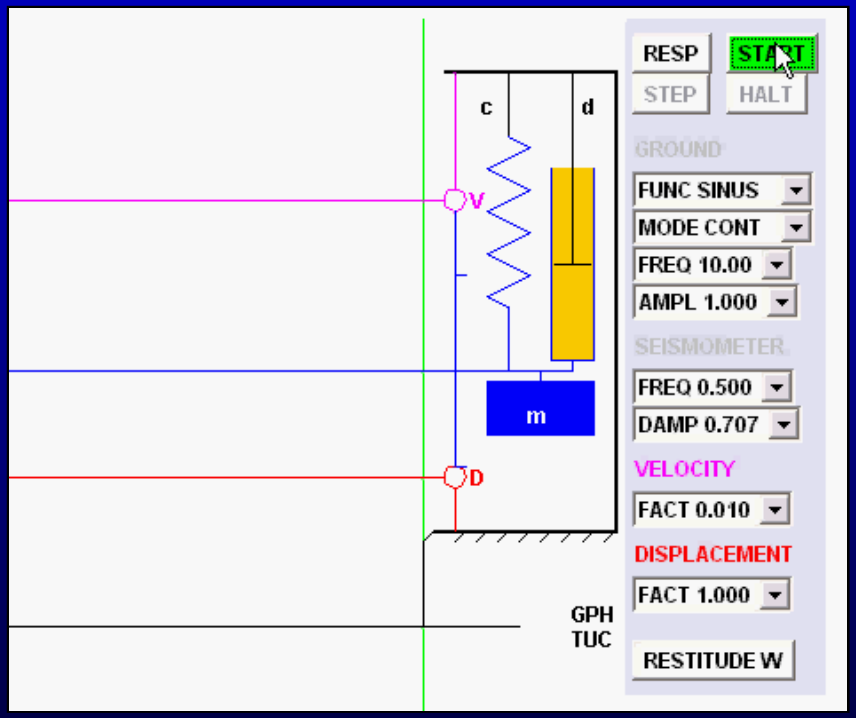
# Geophone response to velocity

Ground displacement

Proof mass displacement relative to case

Proof mass displacement relative to fixed reference




Animation by Helga Meier-Cortes and Fritz Keller, Technical University of Clausthal, Germany

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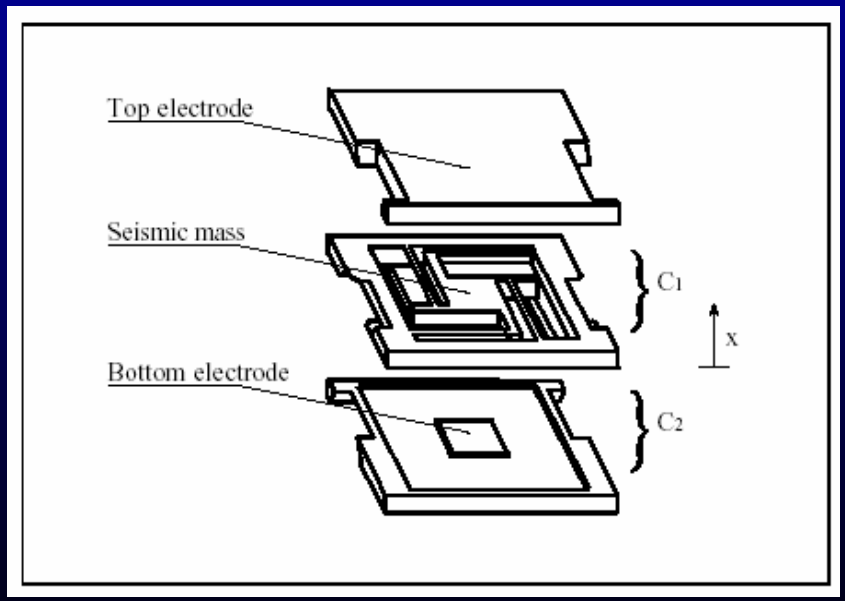
# How MEMS work

- Capacitive detection
  - Seismic Data = Sensitivity x Proof mass displacement
  - Resonance well above seismic band: simple response

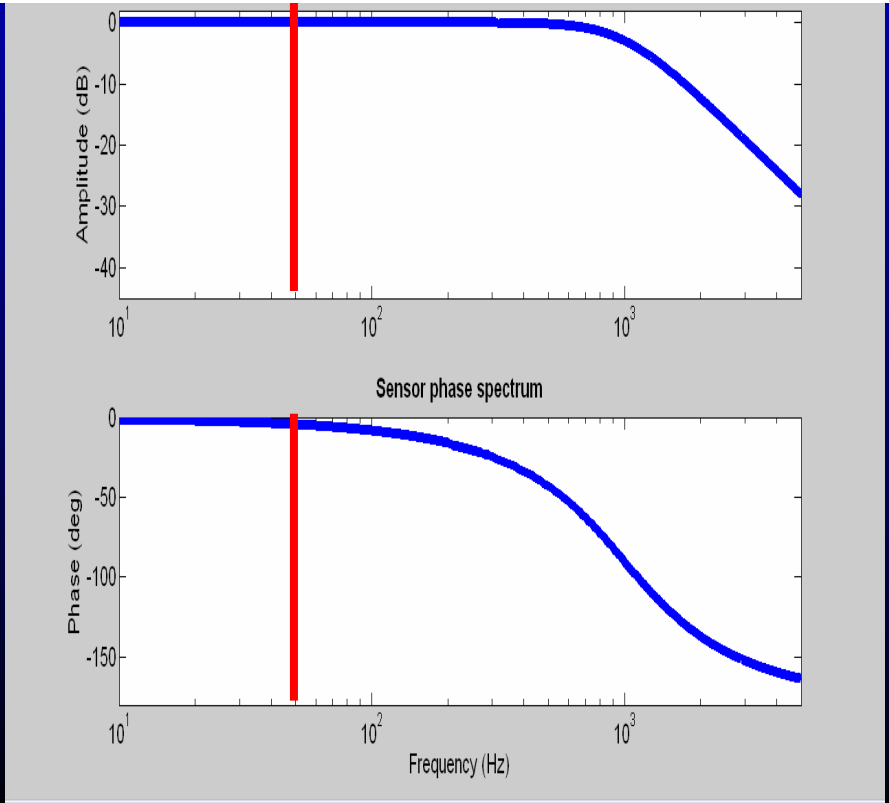


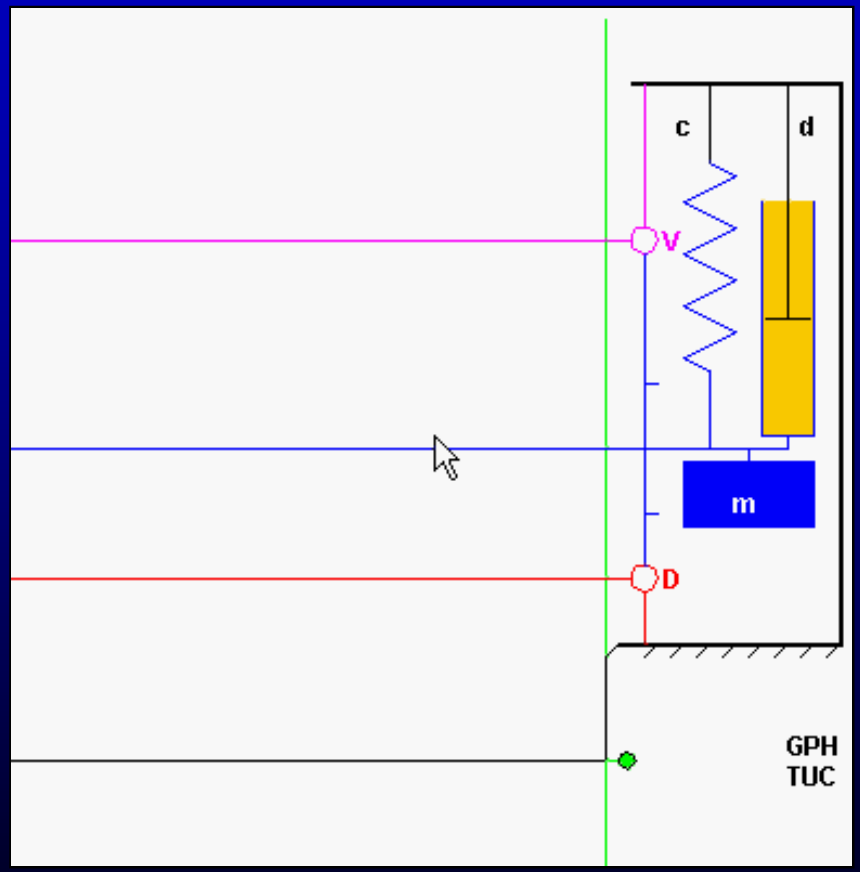
# Accelerometer response to acceleration

Ground displacement

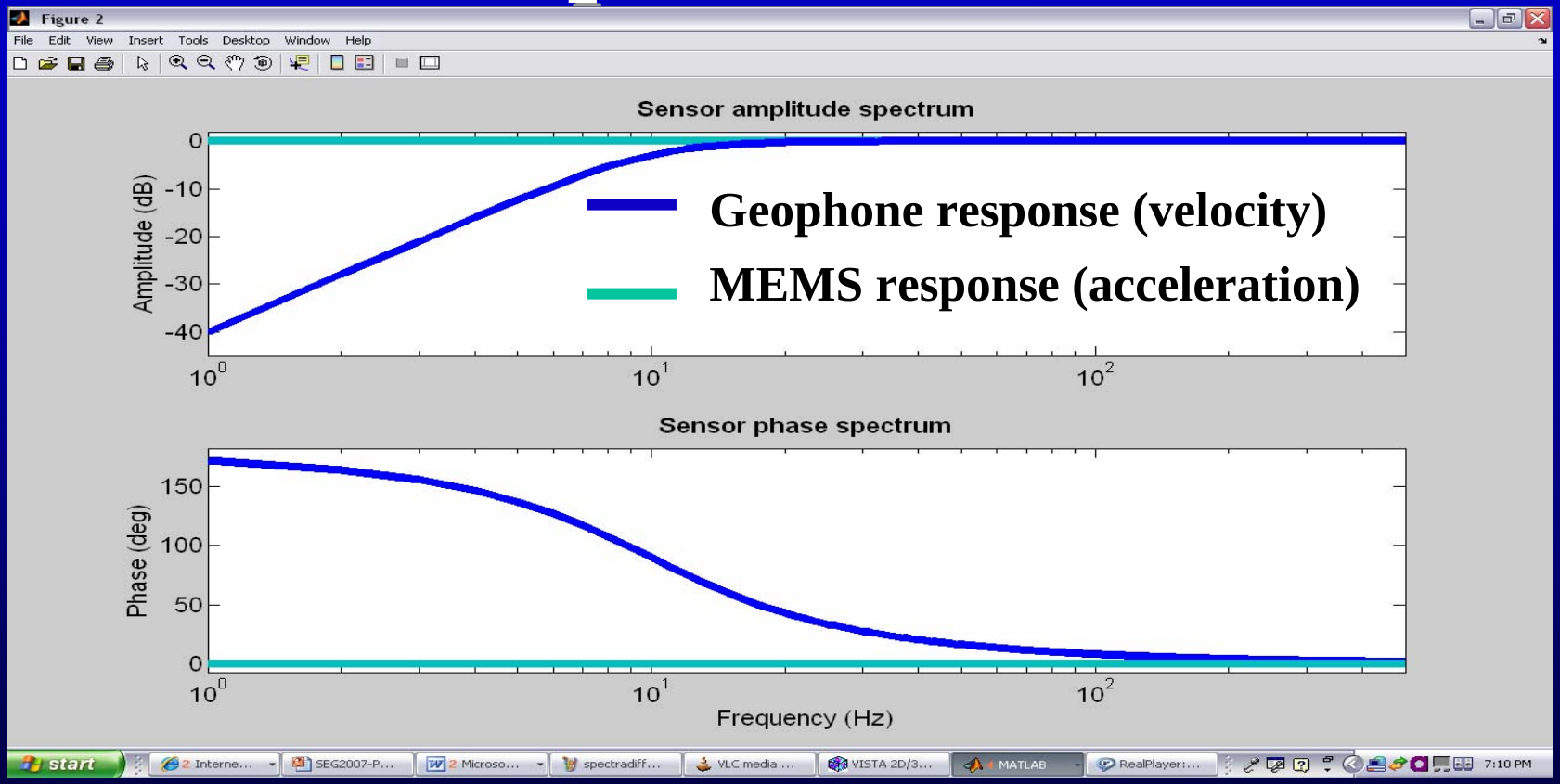
Proof mass displacement relative to case

Proof mass displacement relative to fixed reference



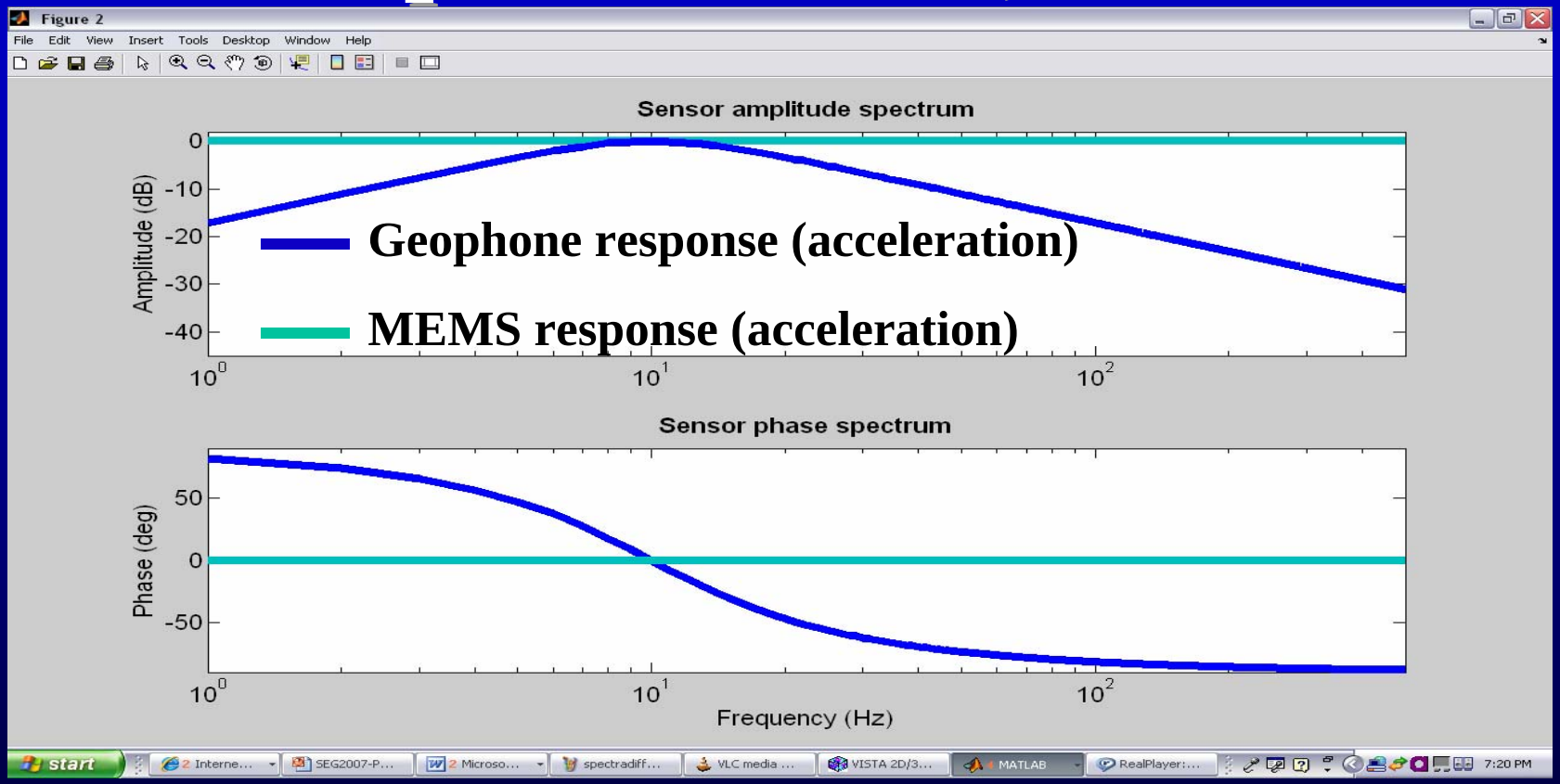



# Response curves




$$V_G = S_G \frac{\partial X}{\partial t} = S_G \frac{\omega^2}{-\omega^2 + 2i\lambda\omega\omega_0 + \omega_0^2} \frac{\partial U}{\partial t}$$

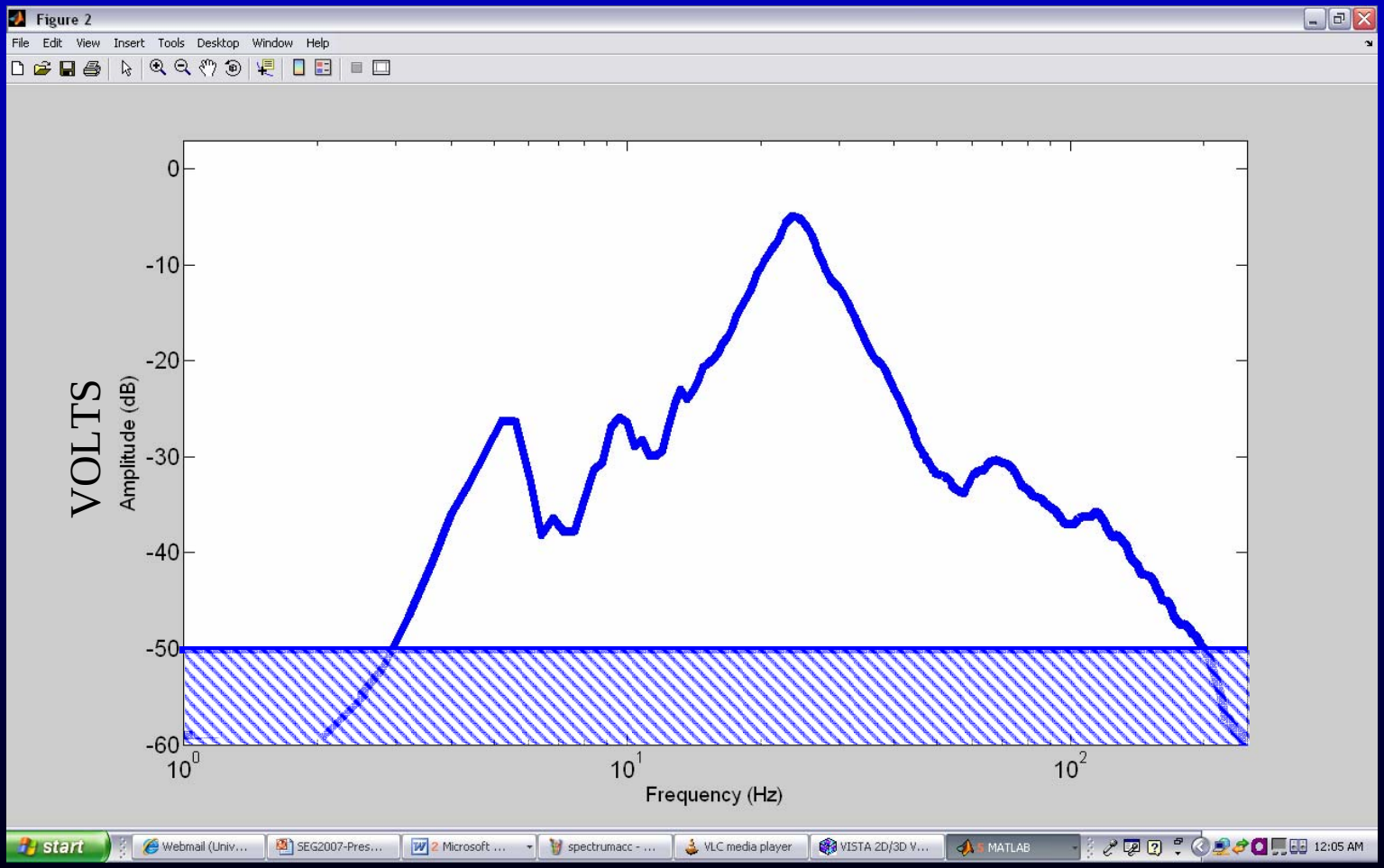
# Response curves, redux




$$V_G = S_G \frac{\partial X}{\partial t} = S_G \frac{-i\omega}{-\omega^2 + 2i\lambda\omega\omega_0 + \omega_0^2} \frac{\partial^2 U}{\partial t^2}$$

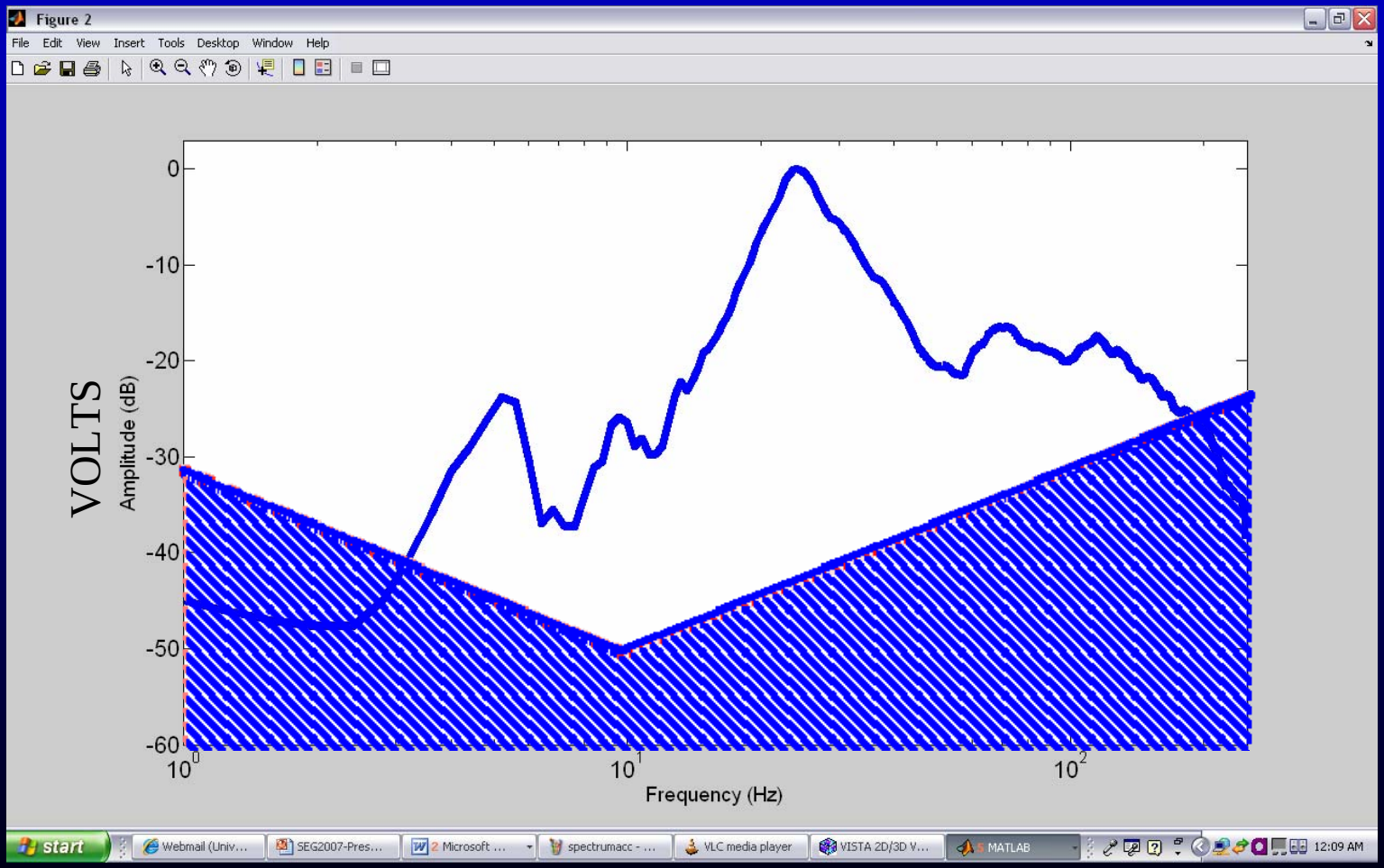
# Noise floors

- Geophone data (noise floor: ~0.7 μV)



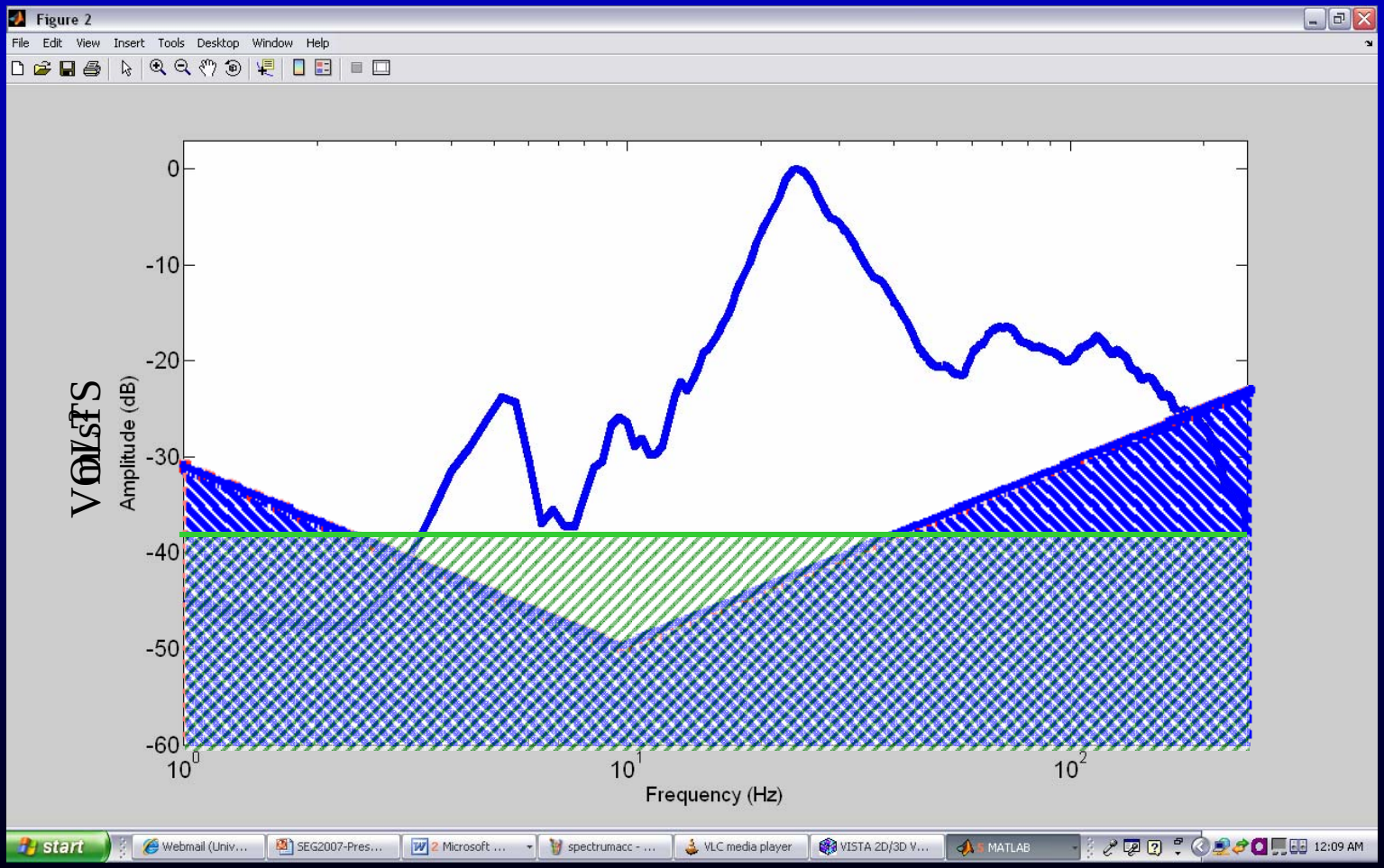
# Noise floors

- Correct to acceleration (noise ~215 ng at 10 Hz)

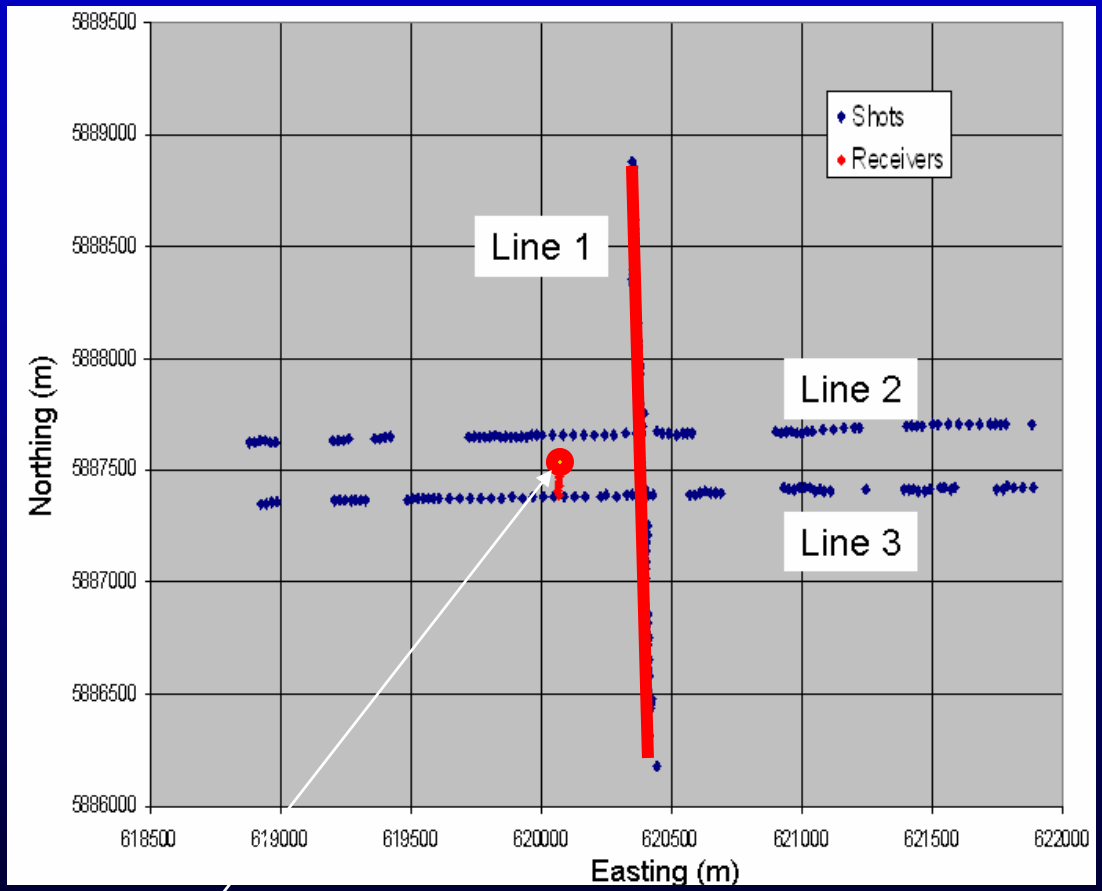


# Noise floors

- Compare to MEMS (noise floor ~806 ng)



# Data acquisition




Station 183

- 8 stations
  - Single sensor stations
  - 2 geophones, 1 DSU
    - 3 geophones at stations 183 and 184
  - 1 m spacing xline, 20 m receiver spacing
- 3 shot lines
  - Dynamite
  - Line 1
    - 75 shots
    - Minimum offset ~300 m

# Sensor types

| Manufacturer | Model | Element | Stations |
|---|---|---|---|
| Input/Output | IO-Spike | SM24 (coil) | 5183-5190 |
| OyoGeospace | GS-3C | GS-20DM (coil) | 5183-5190 |
| Sercel | DSU3 | MEMS | 5183-5190 |
| OyoGeospace | OG-Nail | GS-32CT (coil) | 5183-5184 |

| Geophone recorder | MEMS recorder |
|---|---|
| ARAM Aries | Sercel 408XL |
| 0.8 f(nyq) zero-phase AAF | 0.82 f(nyq) minimum-phase AAF |
| 2 ms sampling | 2 ms sampling |

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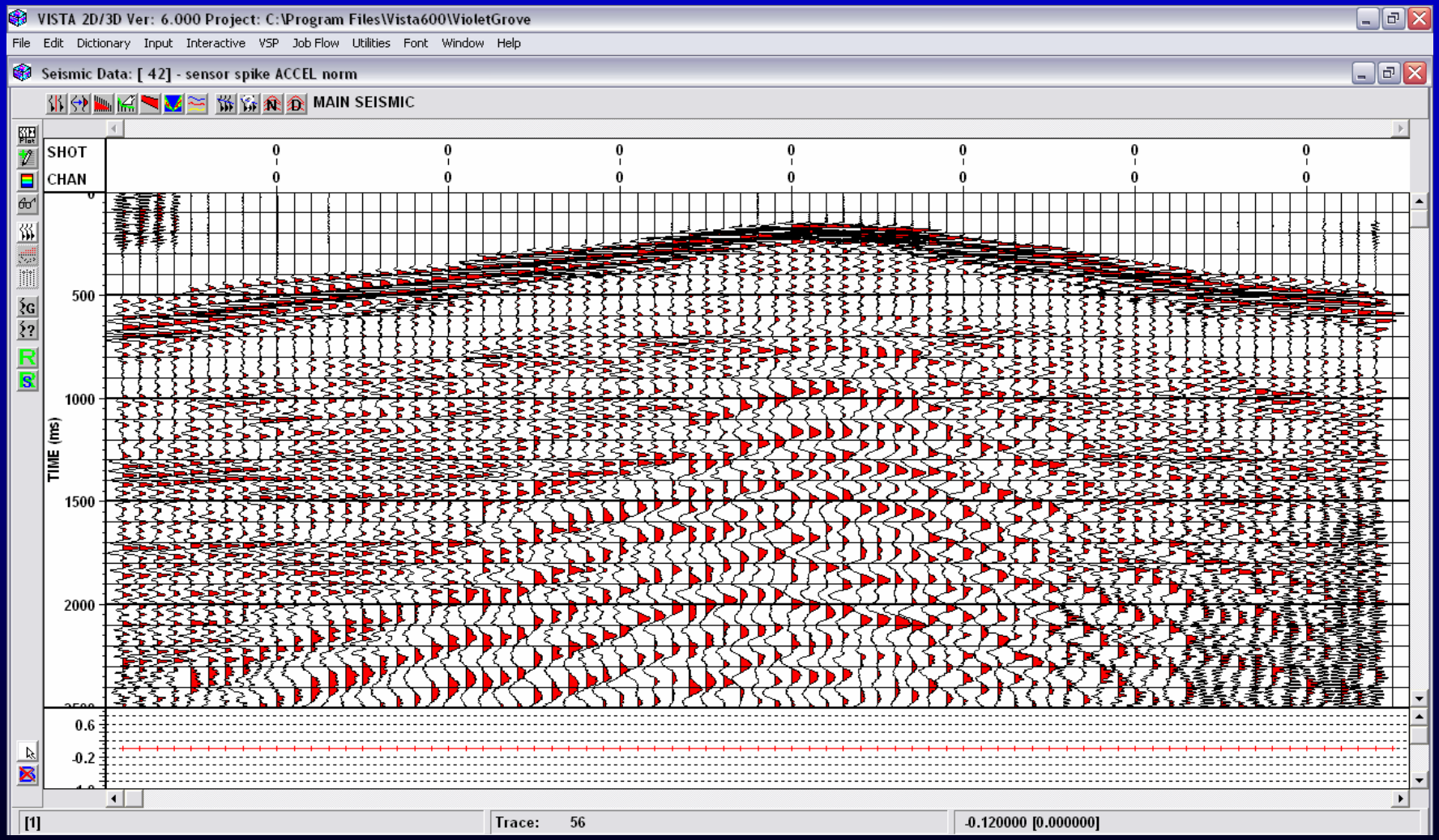
# Geophone accel



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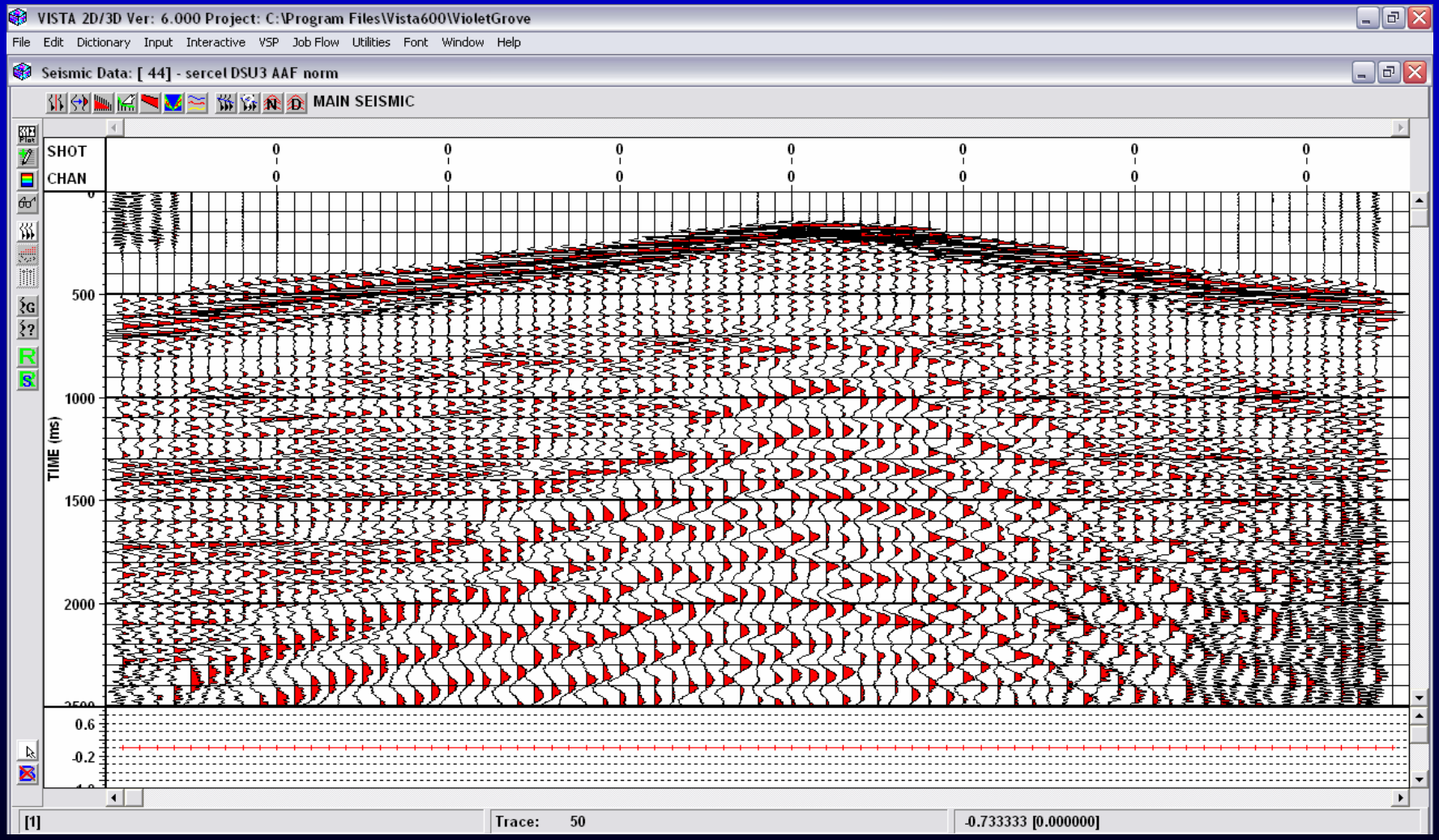
# MEMS


VISTA 2D/3D Ver: 6.000 Project: C:\Program Files\Vista600\VioletGrove
File Edit Dictionary Input Interactive VSP Job Flow Utilities Font Window Help
Seismic Data: [ 44] - sercel DSU3 AAF norm
MAIN SEISMIC
SHOT
CHAN
TIME (ms)
500
1000
1500
2000
0.6
-0.2
[1]
Trace: 50
-0.733333 [0.000000]

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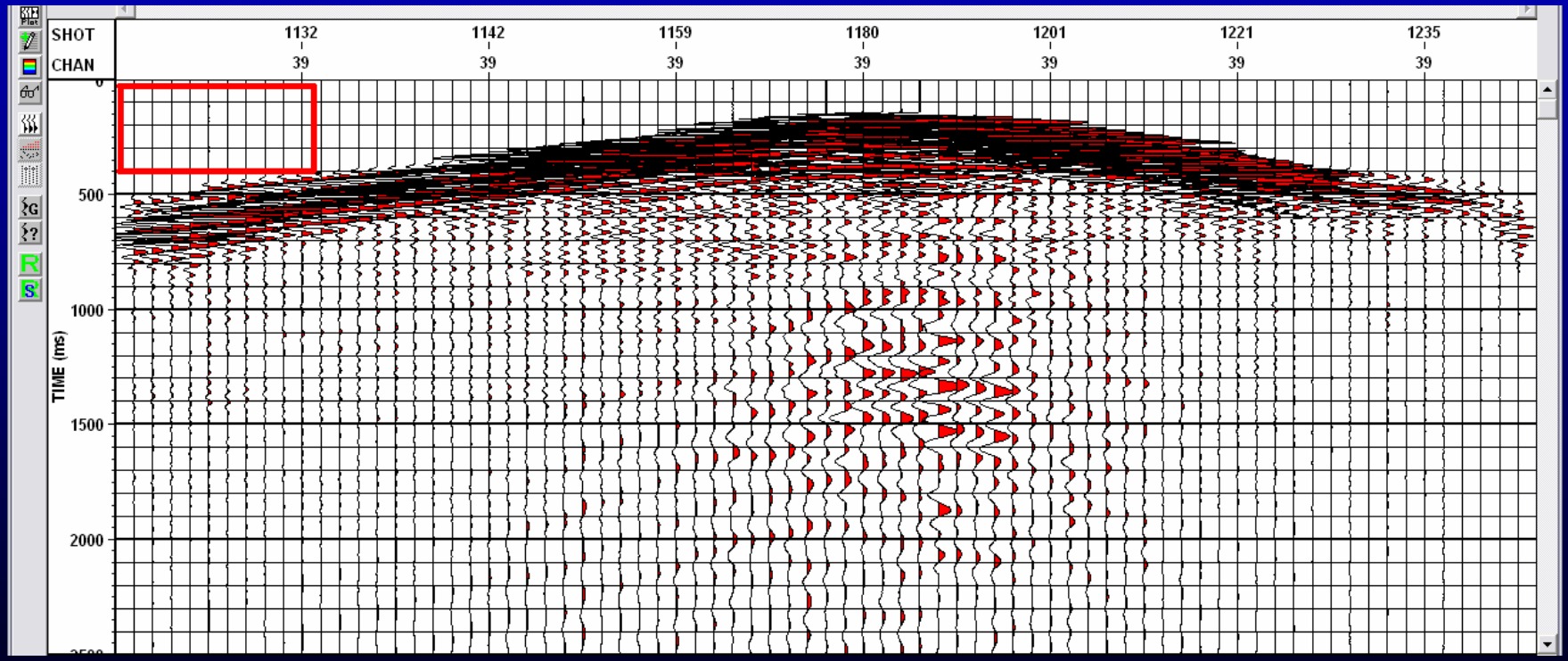
# Field Data

- All data shown in acceleration domain
- Before first breaks



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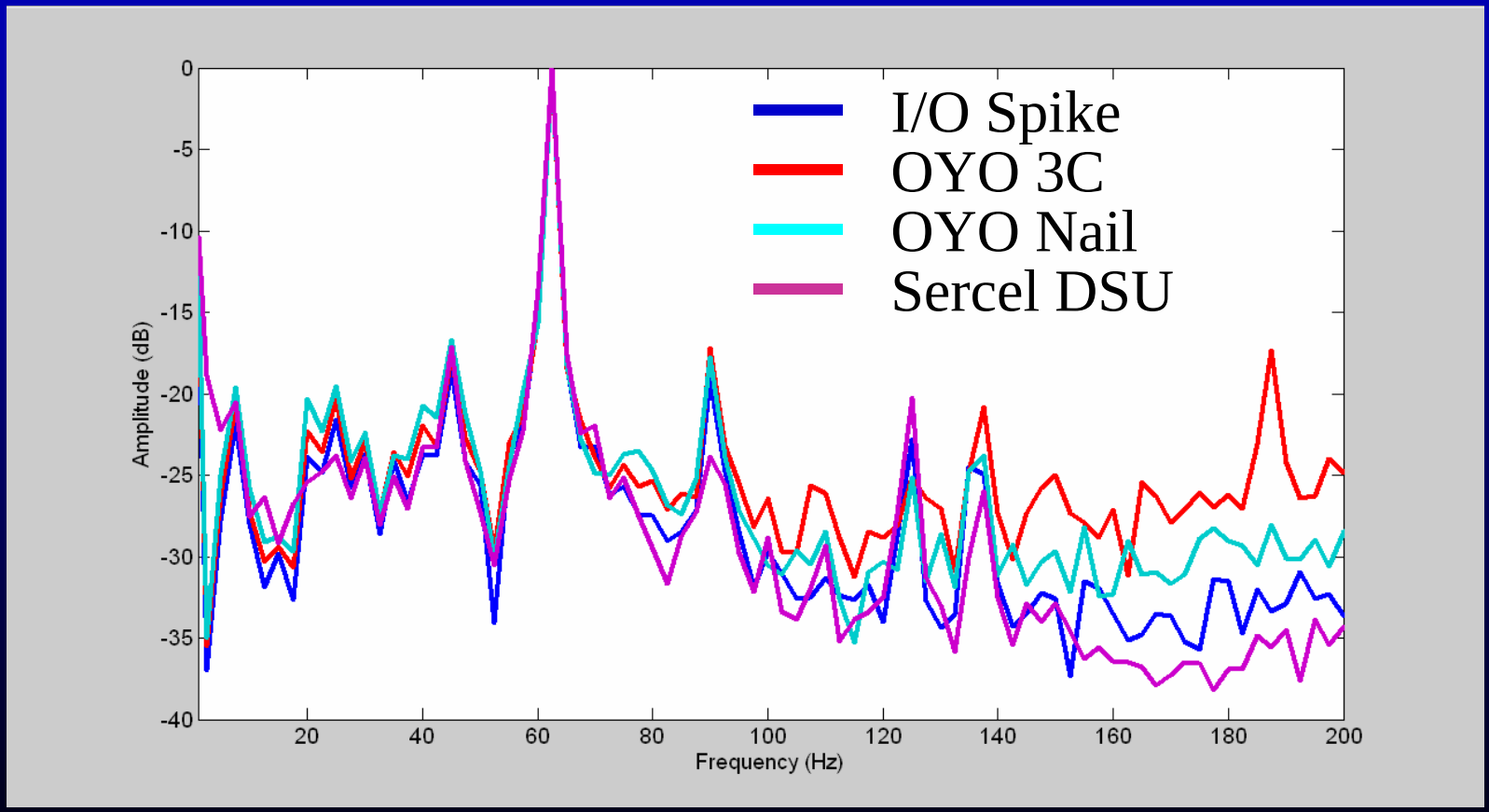
# Field Data

- Before first breaks



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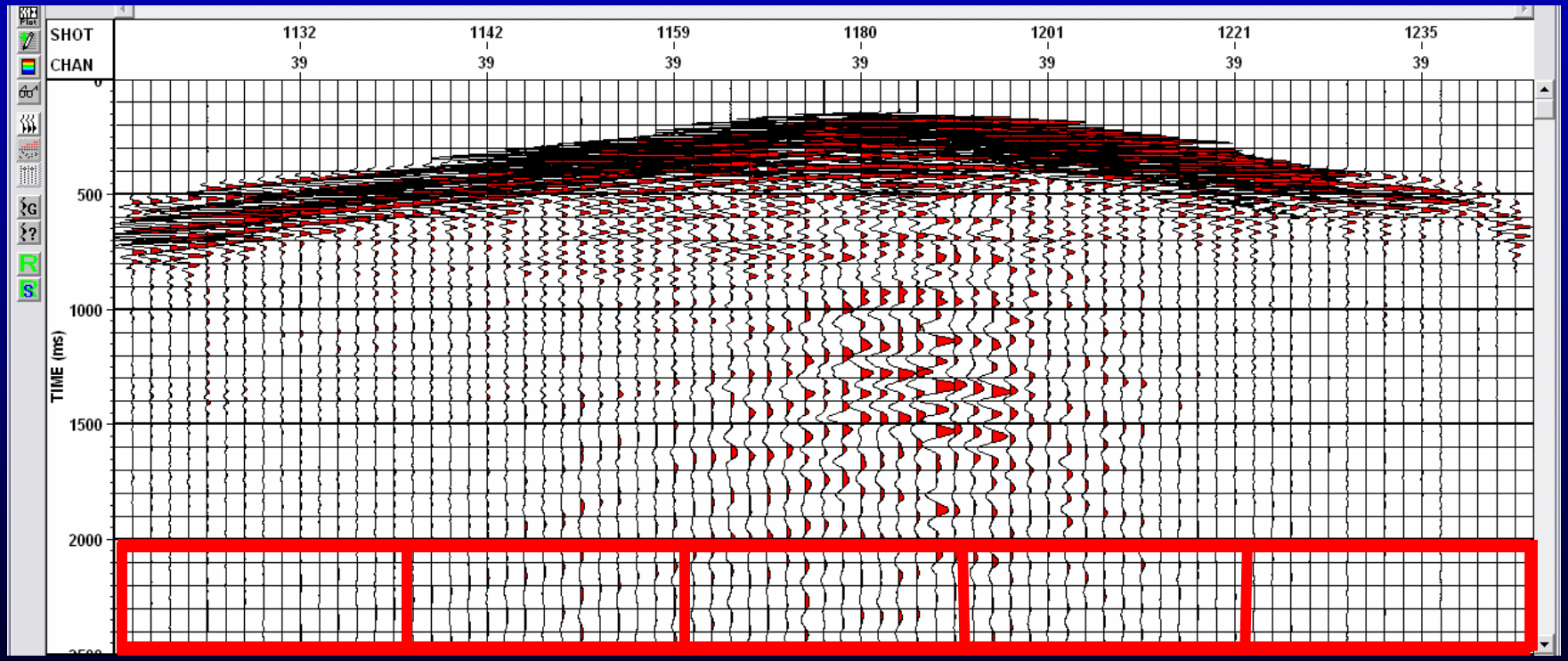
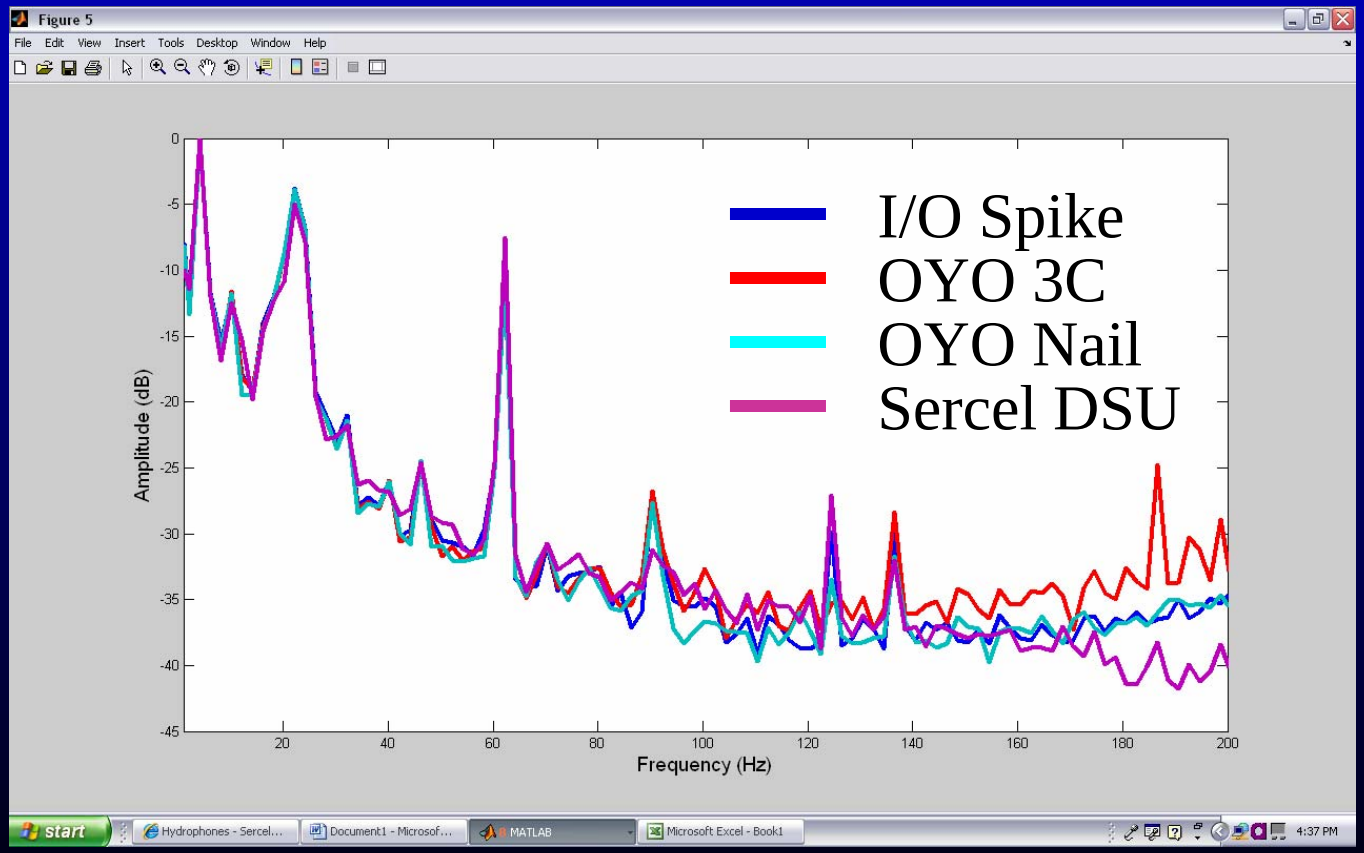
# Field Data

- > 2 seconds TWTT



# Field Data

- > 2 seconds TWTT



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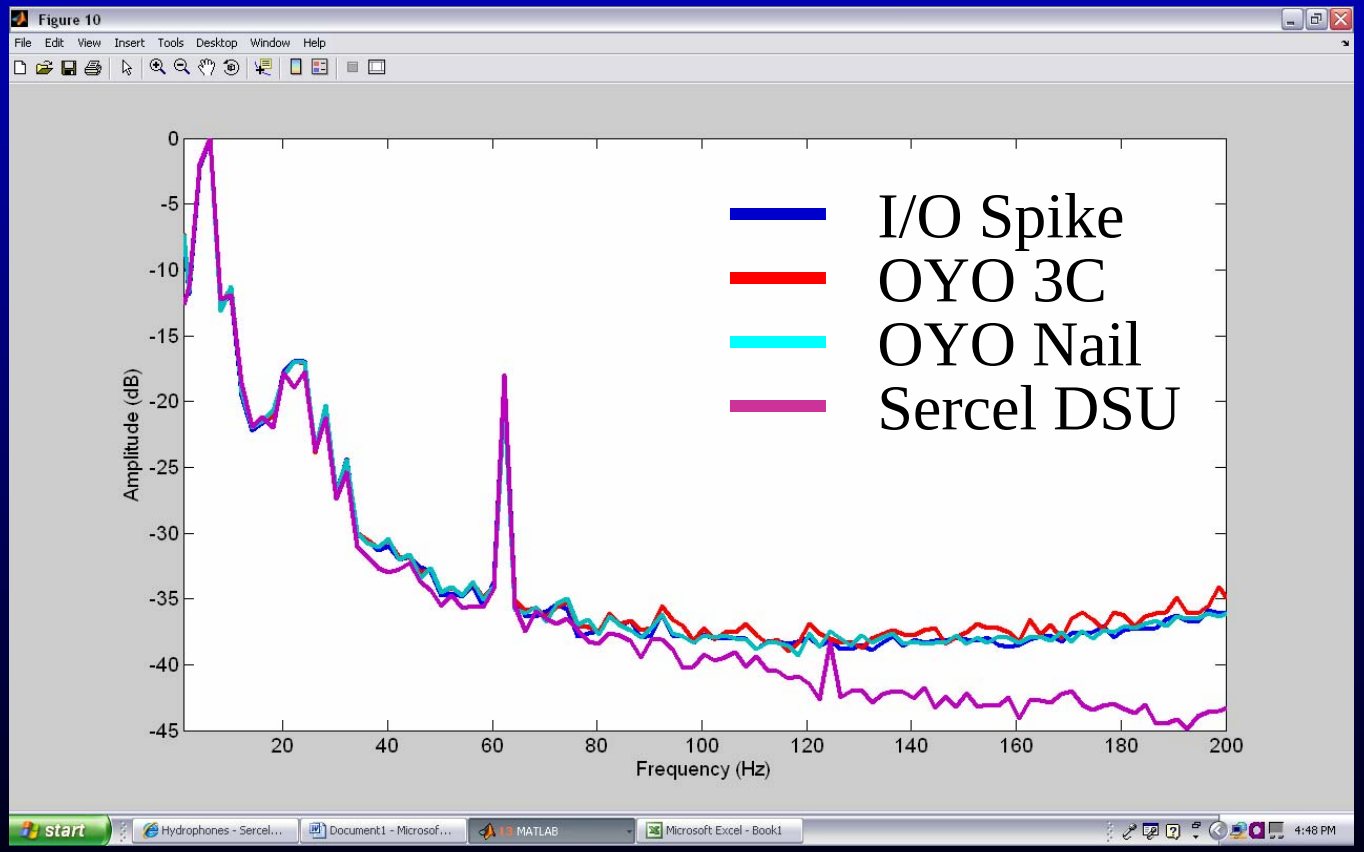
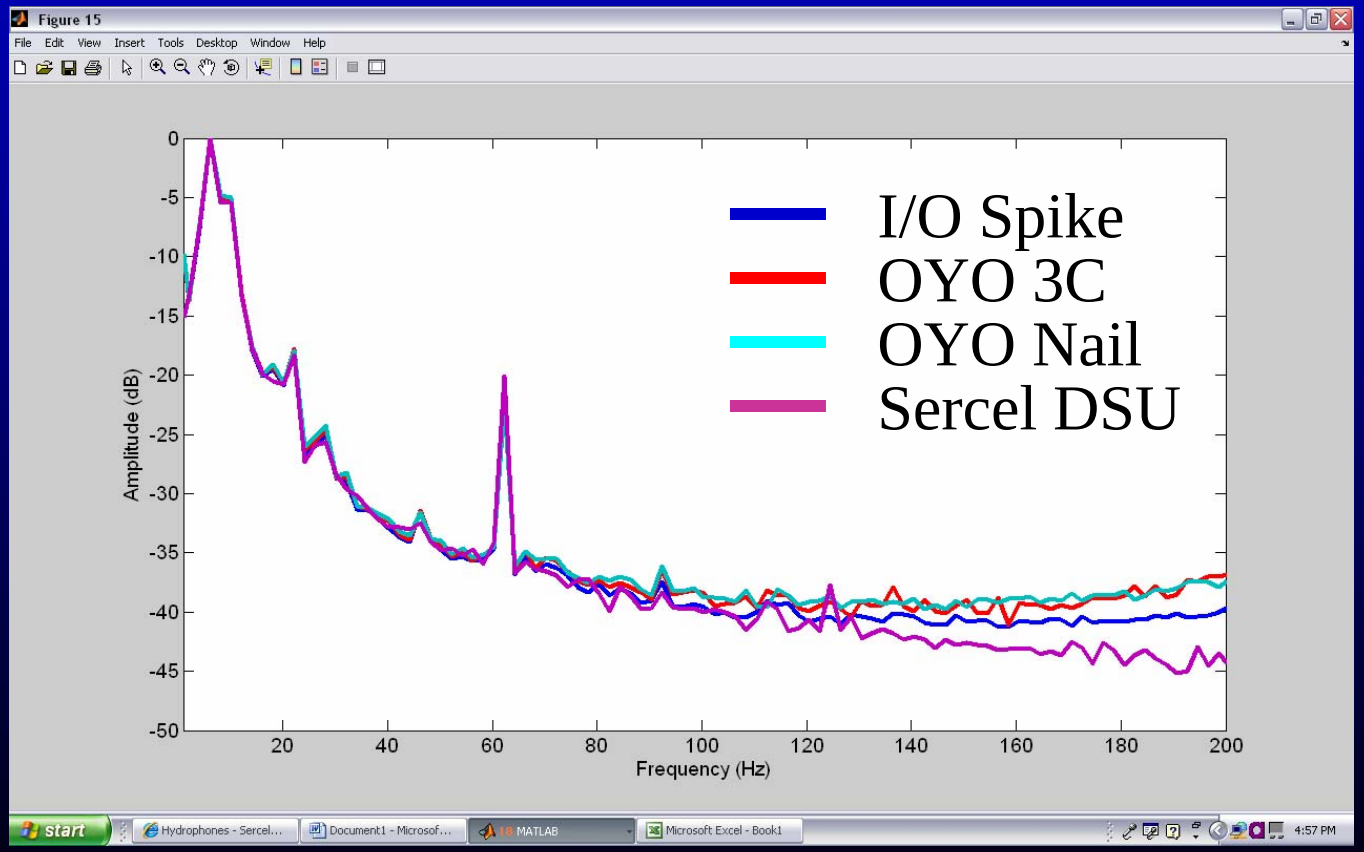
# Field Data

- > 2 seconds TWTT



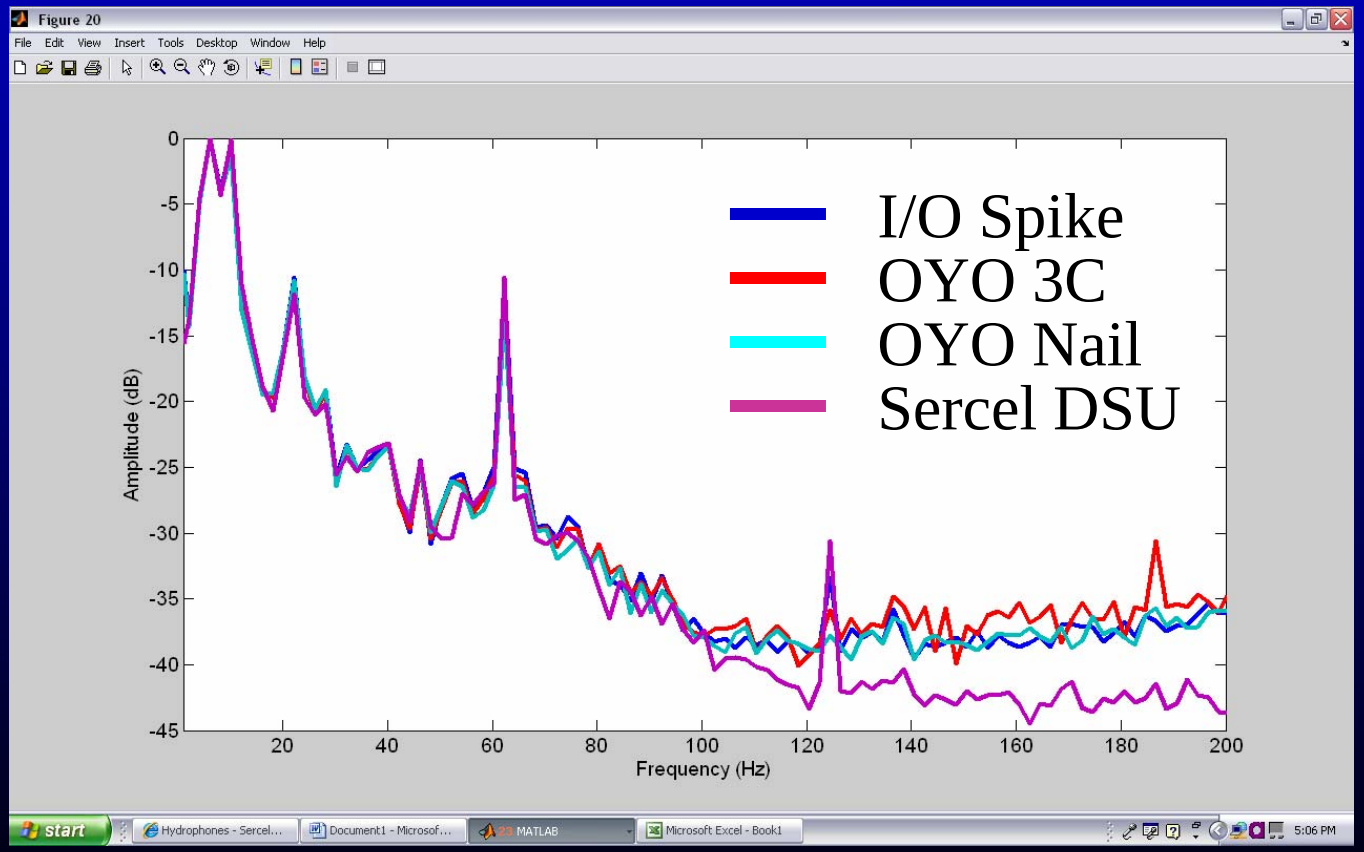
# Field Data

- > 2 seconds TWTT



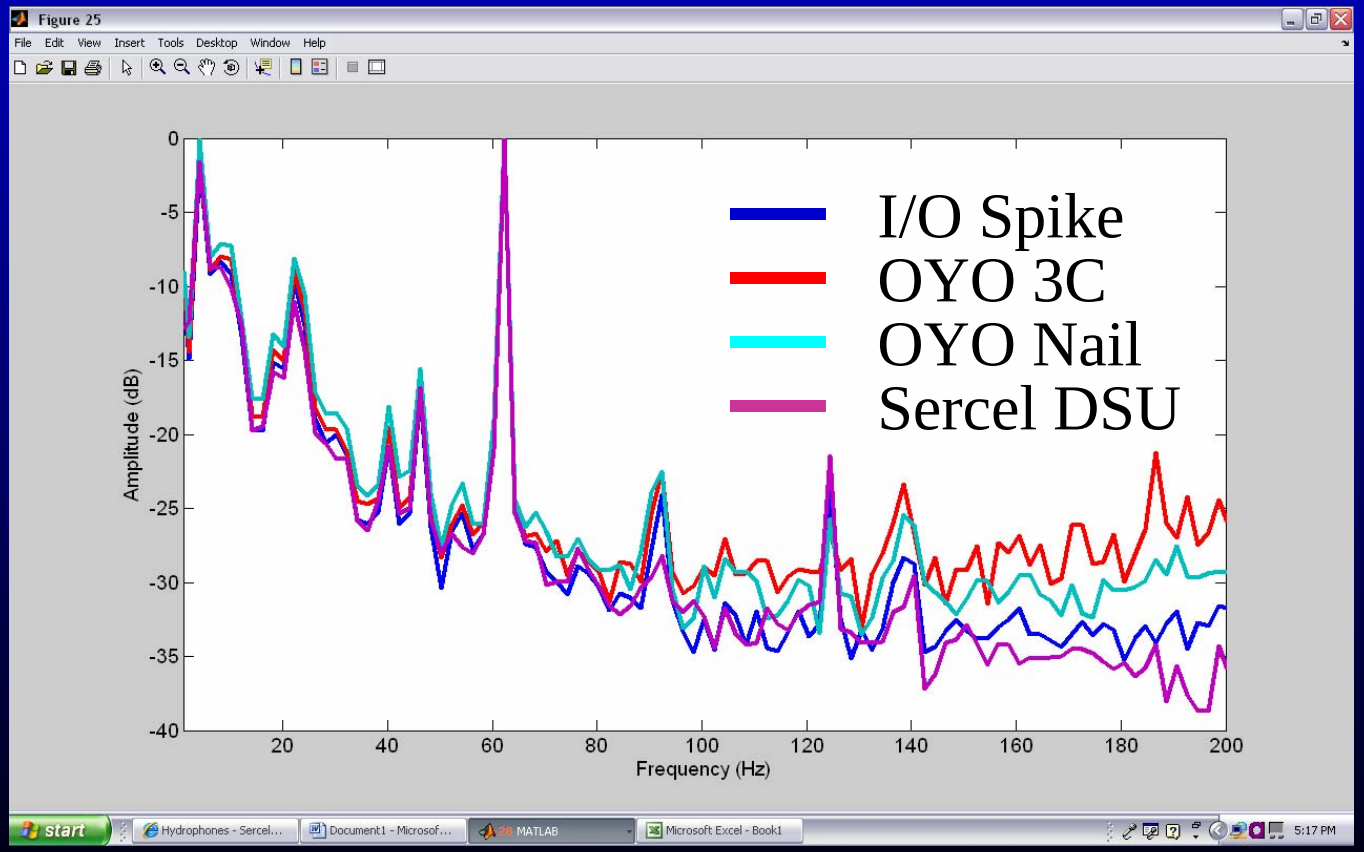
# Field Data

- > 2 seconds TWTT



# Field Data

- > 2 seconds TWTT



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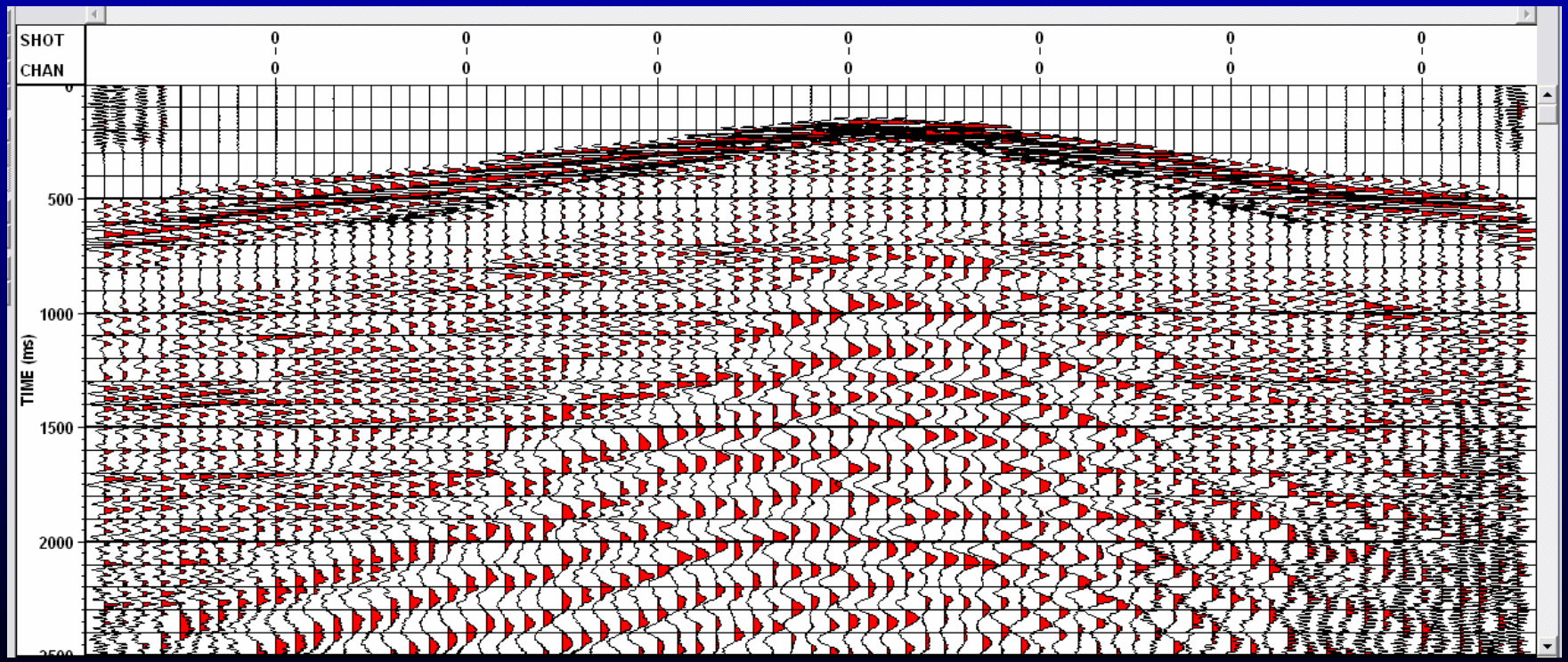
# 60 Hz Noise?

- Fairly equal on geophone and MEMS records
- More pronounced towards right (later shots)



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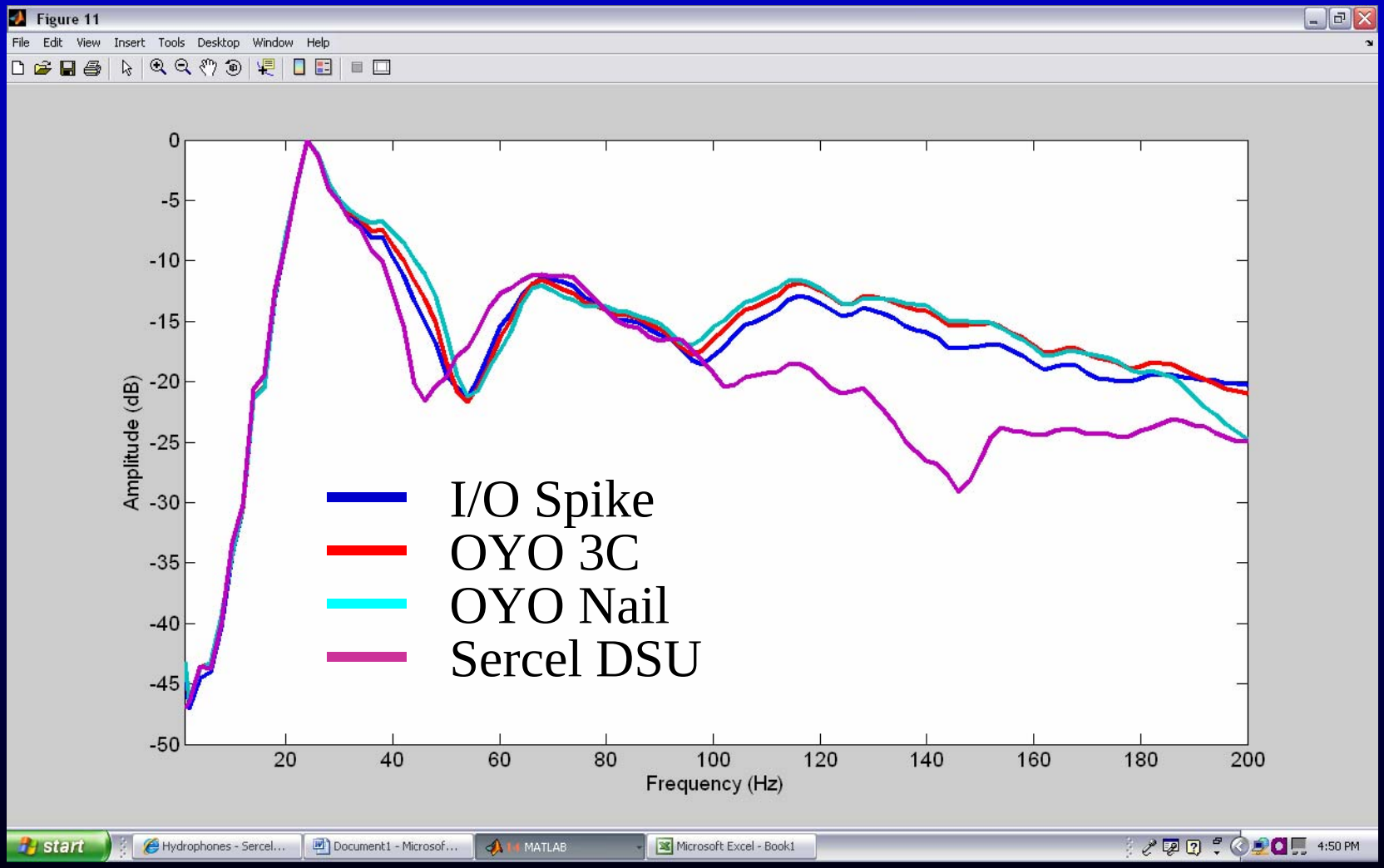
# Trouble at High Amplitudes



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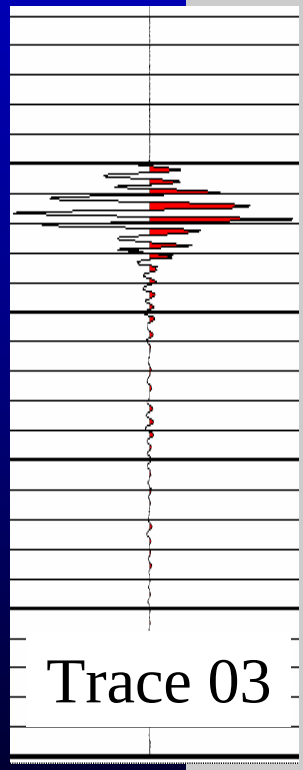
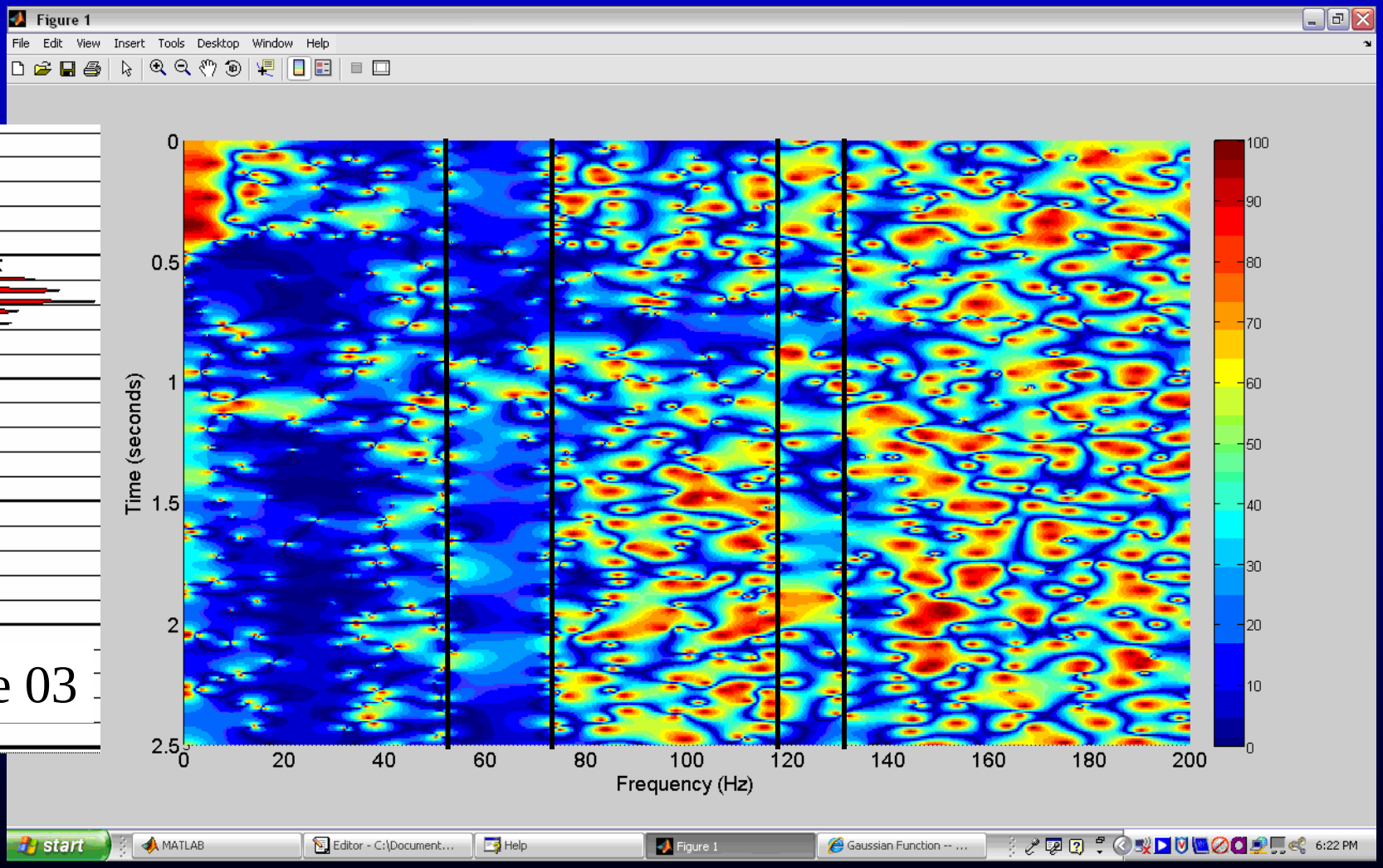
# Normalized Spectral Difference



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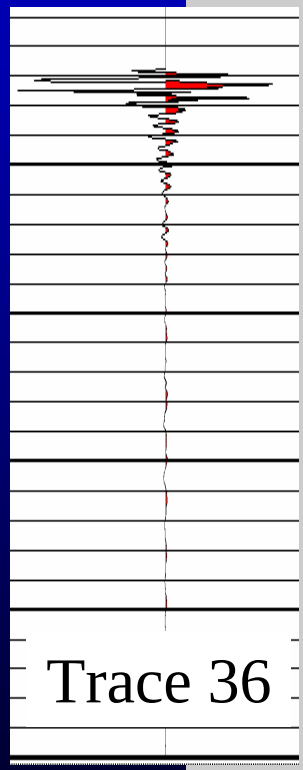
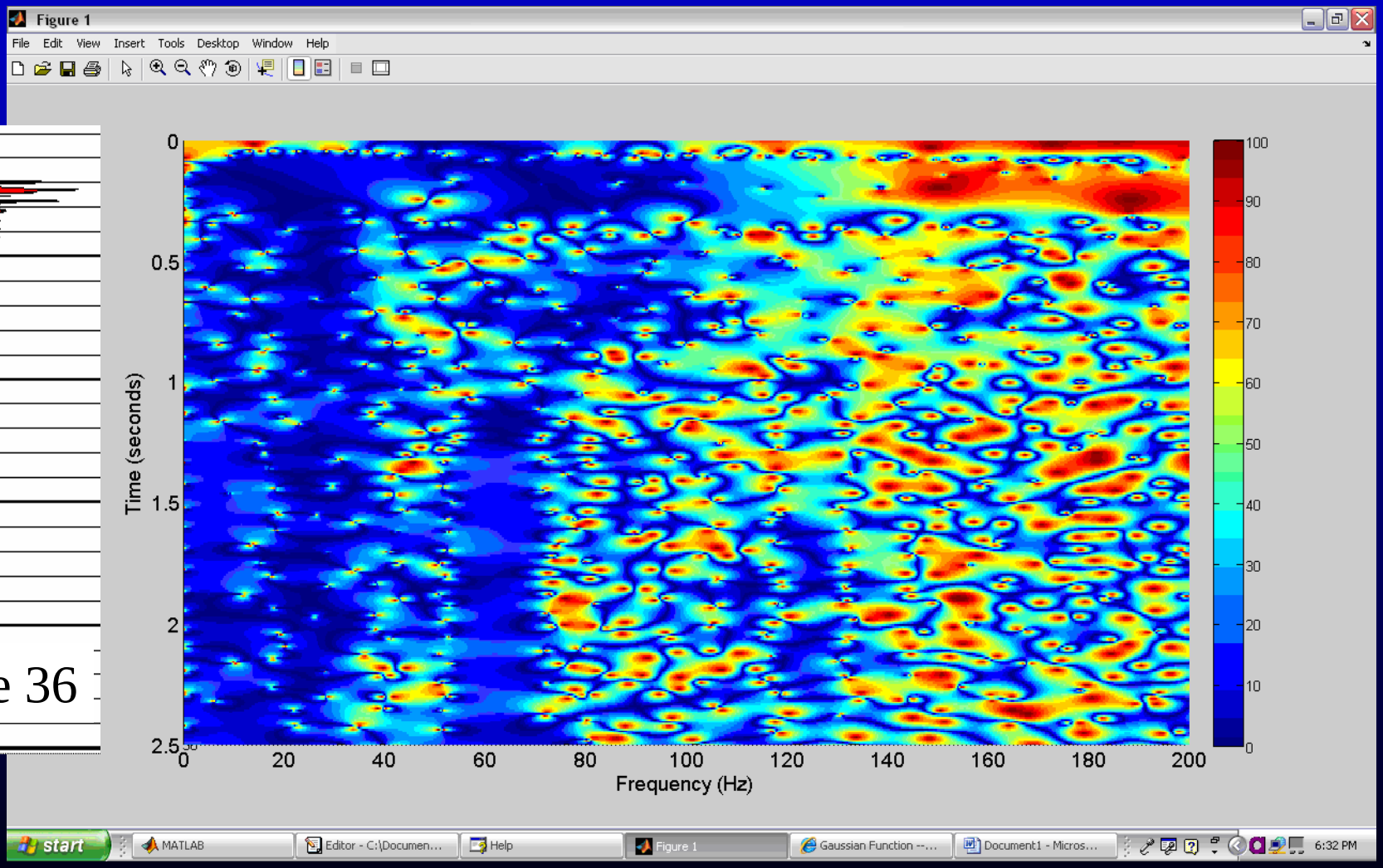
# Normalized Spectral Difference



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# Conclusions

- Frequency content with both sensors is very similar
  - Especially 3 to 70 Hz range
- Separation of signal and noise essential
- Accelerometers should have a lower noise floor at high frequencies
  - Depending on ambient noise strength
- Both sensors record line noise at this location
- Significant difference also observed at high frequencies under strong motion
- Further studies at West Castle, Violet Grove pod test, and Spring Coulee

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# Acknowledgements


- Thanks to Glenn Hauer of ARAM for constructive comments, and all the CREWES sponsors


# References


*Cooper, N. M., 2002, Seismic Instruments-What's new? What's true? CSEG Recorder, Dec., 36-45*

*Lawton, D. C., Bertram, M. B., Margrave, G. F., and Gallant, E. V., 2006, Comparisons between data recorded by several 3-component coil geophones and a MEMS sensor at the Violet Grove monitor seismic survey, CREWES research report, 18, 2.1-2.24*

*http://www.ifg.tu-clausthal.de/java/seis/seis_doc-e.html*