





QuietSeis™

An Ultra-low noise MEMS accelerometer for Seismology

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Introduction



// SERCEL

- French company founded in 1956, subsidiary of CGG
- More than 1500 employees in 8 countries and 14 sites
- Market leader in seismic instrumentation for O&G exploration in marine, land and transition zones
- Longstanding culture of technological innovation





Introduction



// Context

- Sensors for low frequency seismic applications (<2Hz):
 - Geophones (10Hz, ~5Hz)
 - Seismometers (1-2Hz)
 - Force Balance Accelerometers (FBA)

 \rightarrow bulky, costly, power consuming, not deemed industrial..

→phase rotation at low frequency, manufacturing tolerances, aging, environmental conditions: amplitude & phase distortions detrimental to the fidelity of the signal





Introduction



// Context

- MEMS accelerometers often perceived as too noisy at low frequency because of 1/f noise
 - True for most of the seismic MEMS on the market
- Latest generation of digital closed-loop MEMS accelerometer, initially designed for seismic imaging, exhibits very good noise performances at low frequency.





MEMS accelerometer



// Some benefits of MEMS accelerometer

- No sensor leveling required, can be used in any orientation
- Measures its own tilt (DC response)
- Compact and very low power
- Digital closed-loop architecture:
 - Frequency response flat and highly stable in amplitude and phase (down to DC):
 - » Perfect time synchronization of events between sensors
 - Very low distortion
 - Very fast clip recovery time





- Noise measured above 1Hz in LSBB (France)
- <15ng/sqrt(Hz) above 10Hz</p>
- 1/f noise at low frequency not characterized





// Low frequency noise measurement

- Basement of office building in periurban area
- Vibration isolation platform ($f_0 \sim 2,7$ Hz)
- Soundproof acoustic chamber
- Data acquired at night over the course of several months
- Raw data processed using ANSS/USGS Matlab script: ANSS_noise_rms_rev4.m







// Low frequency noise measurement

- 2 QS-DB boards: Vertical and horizontal
 - QuietSeis MEMS accelerometer
 - UART serial data transmission to external device
- 10 Hz and 5Hz geophone channels
 - low noise 24 bits / ADC
 - Velocity data converted in acceleration











- 10Hz-geophone noise below ~2Hz
- 5Hz-geophone noise below ~0,1Hz
- NHNM down to ~0,1Hz



(†)

// Low frequency Dynamic Range



// Full scale @ +/-13m/s² pk :

• Vertical MEMS Dyn. Range ~131dB



(†)

// Comparative testing vs. Trillium Compact broadband seismometer in a low noise test site is being scheduled with a French seismology institution.





Test site Noise PPSD (vertical)



Trillium Compact

QS-DB



Earthquake detection

// IRAN-IRAK border M7.4 earthquake

- Nov 12th,2017
- 18:18:19 (UTC)





Earthquake detection





 (\mathbf{i})

Earthquake detection





Conclusion



// A new MEMS accelerometer with improved noise floor and reduced 1/f noise contribution has been evaluated for very weak signals and very low frequency measurements. A noise floor below NHNM down to 0.1 Hz has been demonstrated.

// New possibilities for low frequency, weak signal applications:

- Ambient seismic noise imaging and monitoring
- Seismology
 - Replacement of Force Balance Accelerometer seismometers,...
- Structural Health Monitoring of large structures
 - Operational Modal Analysis using ambient vibrations
- Active stabilization platforms in low noise or low-g environments







Bibliography



// References

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Ahead of the Curvesm

