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Sandia National Laboratories

Infrasound Sensor Evaluations Performed at the Facility for Acceptance, Calibration and Testing (FACT) site

June 15, 2012

CEA - France

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CEA Visit

- Infrasound Minimum Station Requirements
- Sensors
- Analysis and Evaluation Summary
- New sensor designs
- Discussion

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I.2. Minimum Requirements for Infrasound Station Specifications

Characteristics	Minimum Requirements
Sensor type	Microbarometer
Number of sensors	Four element array[a]
Geometry	Triangle with a component at the centre
Spacing	Triangle basis: 1 to 3 km[b]
Station location accuracy	≤100 m
Relative sensor location	≤1 m
Measured parameter	Absolute[c] or differential pressure
Passband	0.02 to 4 Hz
Sensor response	Flat to pressure over the passband
Sensor noise	≤18 dB below minimum acoustic noise[d]
Calibration	≤5% in absolute amplitude[e]
State of health	Status data transmitted to the International Data Centre
Sampling rate	≥10 samples per second
Resolution	≥1 count per 1 mPa
Dynamic range	≥108 dB
Timing accuracy	≤1 ms[f]
Standard temperature range	−10°C to +45°C[g]
Buffer at the station or National Data Centre	≥7 days
Data format	Group of Scientific Experts format
Data frame length	≤30 s
Data transmission	Continuous
Data availability	≥98%
Timely data availability	≥97%
Mission capable array	≥3 elements operational
Acoustic filtering	Noise reduction pipes (site dependent)
Auxiliary data	Meteorological data[h]

[a] In the case of noisy sites or when increased capability is required, the number of components could be increased.
[b] 3 km is the recommended spacing.
[c] Used for daily state of health.
[d] Minimum noise level at 1 Hz ~5 mPa.
[e] Periodicity: once per year (minimum).
[f] Better than or equal to 1 ms.
[g] Temperature range to be adapted for some specific sites.
[h] Once per minute.

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Summary of IMS requirements:

1. Passband 0.02 – 4 Hz
   - (flat over passband +/- ?)

2. Sensor (System) Noise ≤18 dB below minimum noise model
   - [d] Minimum sensor noise at 1 Hz is 5 mPa (-46 dB)
   - critical review is needed for any noise model produced

3. Calibration 5% absolute amplitude

4. Resolution ≥ 1 count per mPa
   - Review current definition of CALIB ()

5. Dynamic Range ≥ 108 dB
   - RMS of Full-Scale Output Pa for tonal signal
   - Noise is estimated using RMS of passband
   - 20*log10 (FS/Noise)

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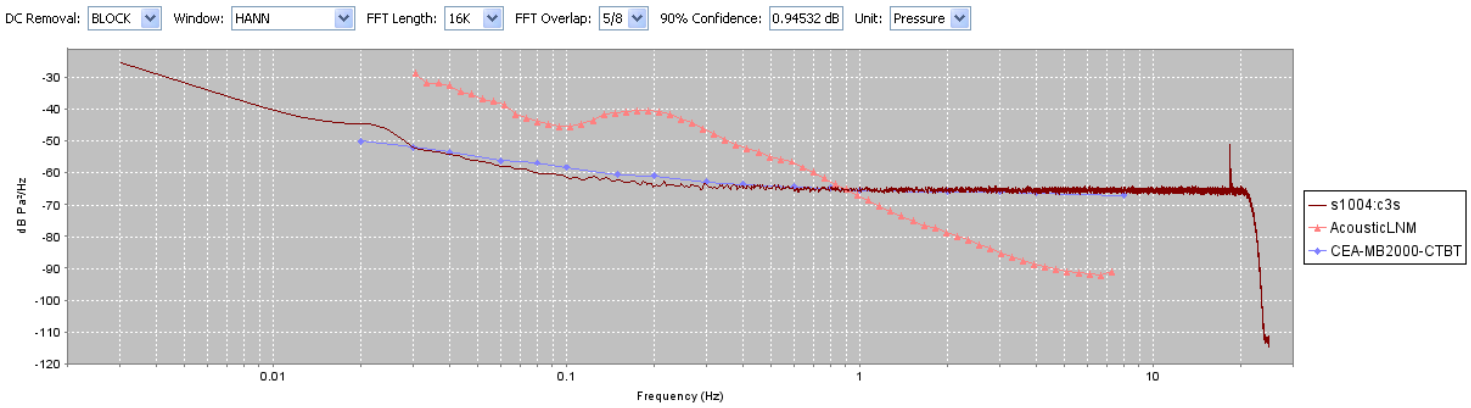
Martec RM2000/MB2000/MB2005

Power: MB2000 =4 watts and MB2005 =1.6 watts @ 12V
Sensitivity: MB2005 96.3 mV/Pa
Noise: -64 dB rel 1 Pa^2/Hz ~ 0.7 mPa rms (0.5-2 Hz)
Full-scale Pressure: 107 Pa (zero to peak)
Dynamic Range: 104 dB
Passband:0.02 – 10 Hz
Seismic coupling: Yes

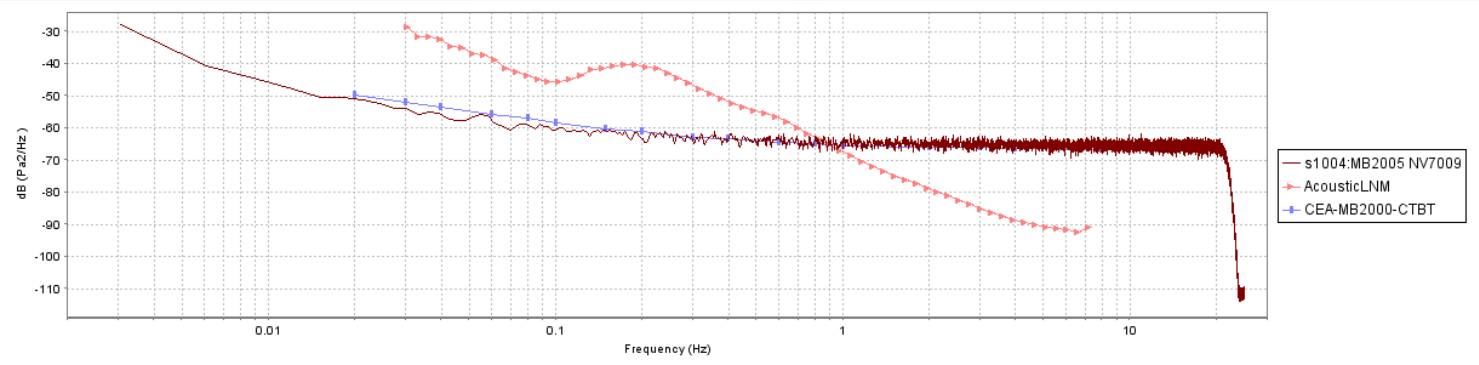
Observations for MB2005:
- TP9 output to re-center LVDT
- Reduced power consumption
- Differential outputs
- Increased input voltage range (9-36V)

General Comments
- Is the seismic sensitivity too large?

Martec MB2000 1380 and MB2005 NV7009 Isolation Self-Noise (static)



2-Channel Coherence – Distributed model Self-Noise (dynamic)



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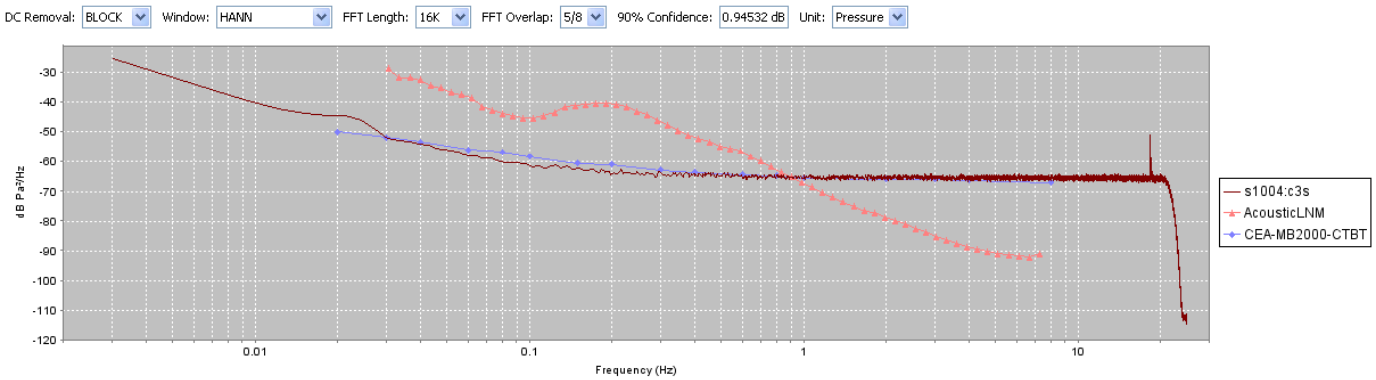

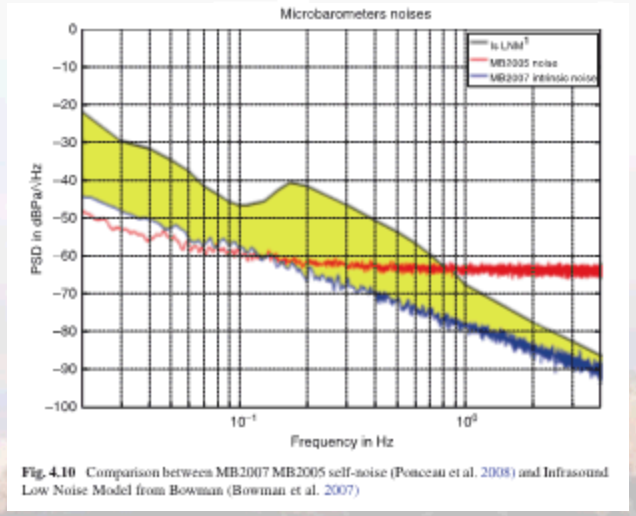

Fig. 4.10 Comparison between MB2007 MB2005 self-noise (Ponceau et al. 2008) and Infrasound Low Noise Model from Bowman (Bowman et al. 2007)

Figure taken from: Infrasound Monitoring for Atmospheric Studies, p.130

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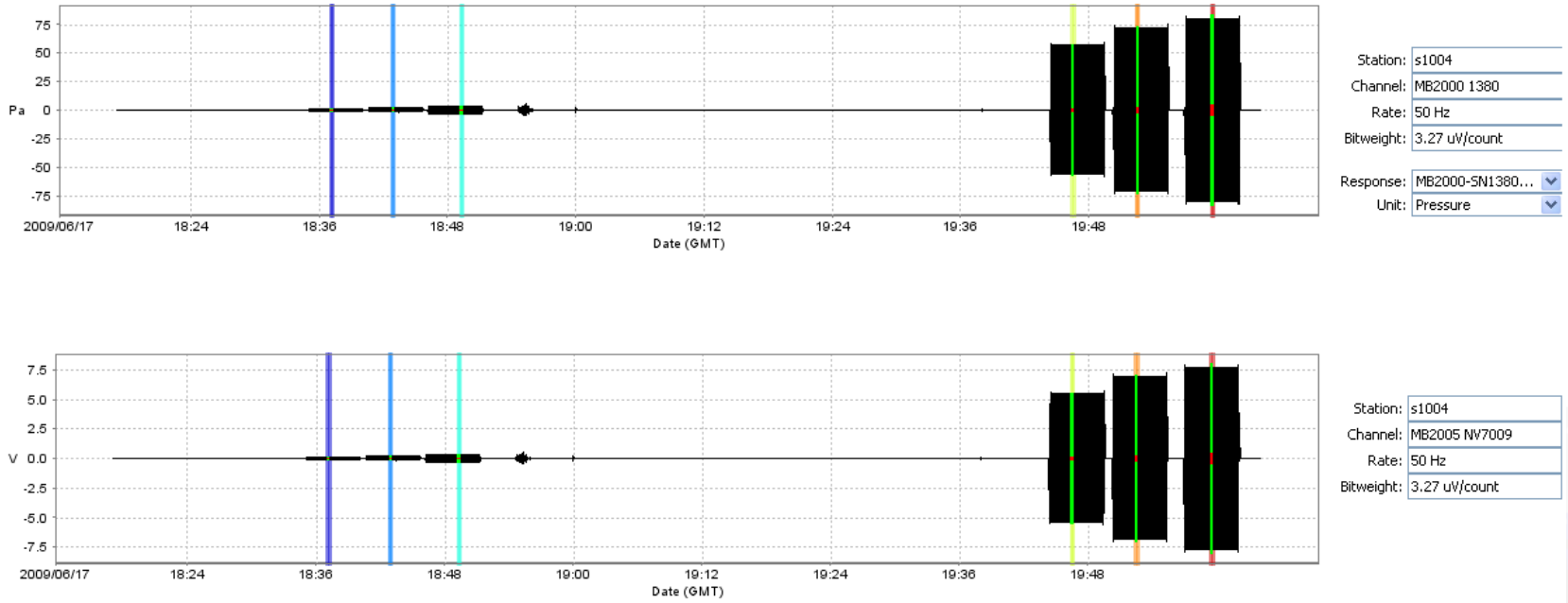
Piston-Phone Linearity / Amplitude Response Verification



6 amplitudes at single frequency (1Hz); Sine fit in green; misfit in red

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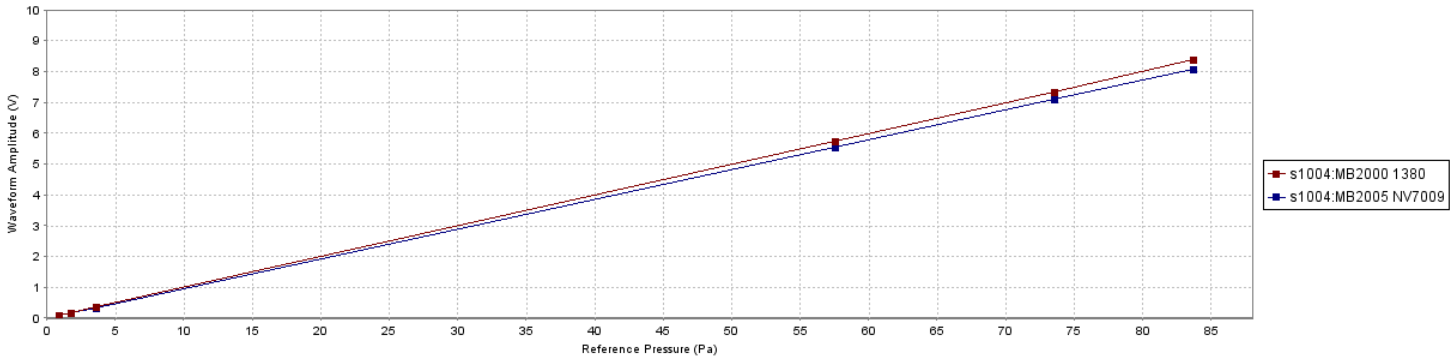
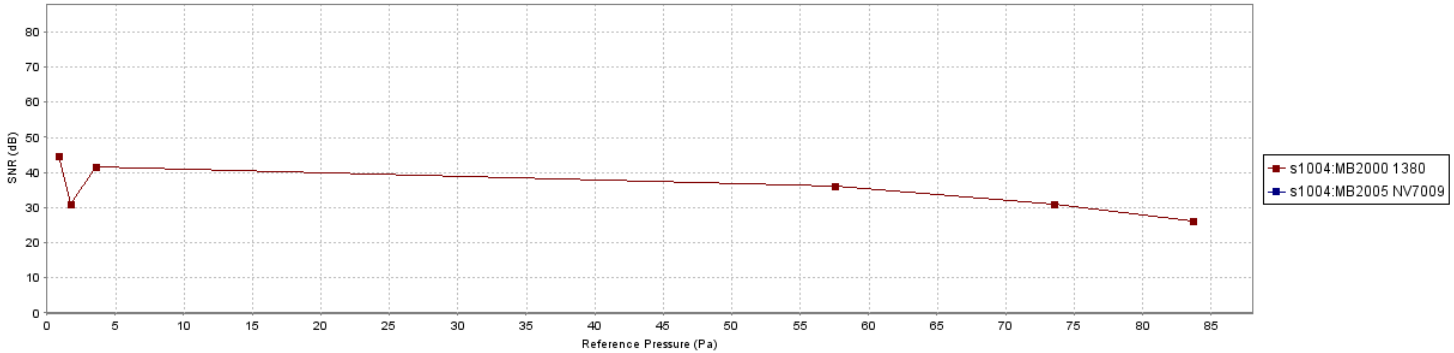
Linear voltage output with increasing amplitude



Reduced SRN with increasing amplitude



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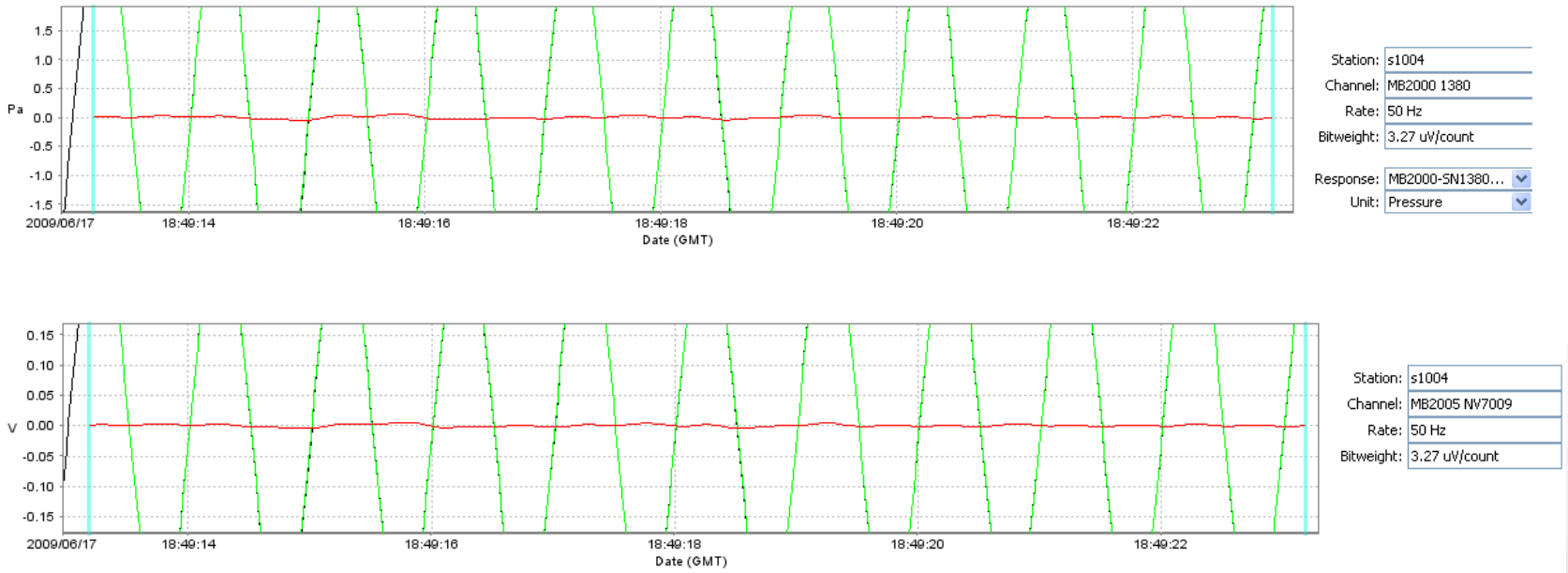
Closer look at 3.56 Pa tone…



The residual has no apparent coherent structure.

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Chaparral 50A (102220 and 102221)

Power: CP50A = 0.35 watts @ 12V
Sensitivity: 0.420 mV/Pa
Noise: -81 dB rel 1 Pa^2/Hz ~ 80 uPa rms (0.5-2 Hz)
Full-scale Pressure: 44.7 Pa (zero to peak)
Dynamic Range: 112 dB
Passband: 0.01 – 50 Hz

Observations:
- DC offset increased with signal amplitude, a check of the balance of differential outputs is warranted
- Testing was not conducted on temperature sensitivity
- Datasheets imply traceability to LANL infrasound calibration capability
- Decreased tonal SNR for amplitude linearity Test
- Self-Noise varies by analysis technique used

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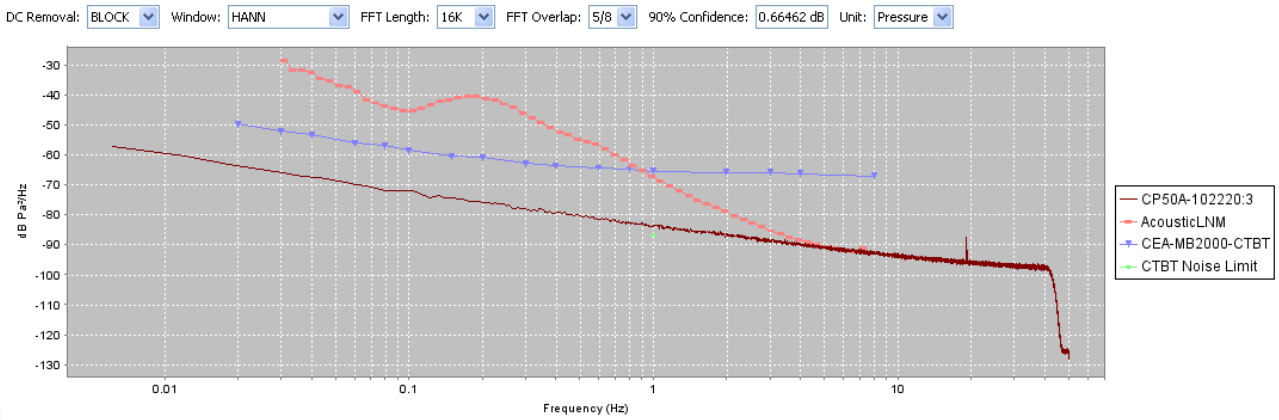
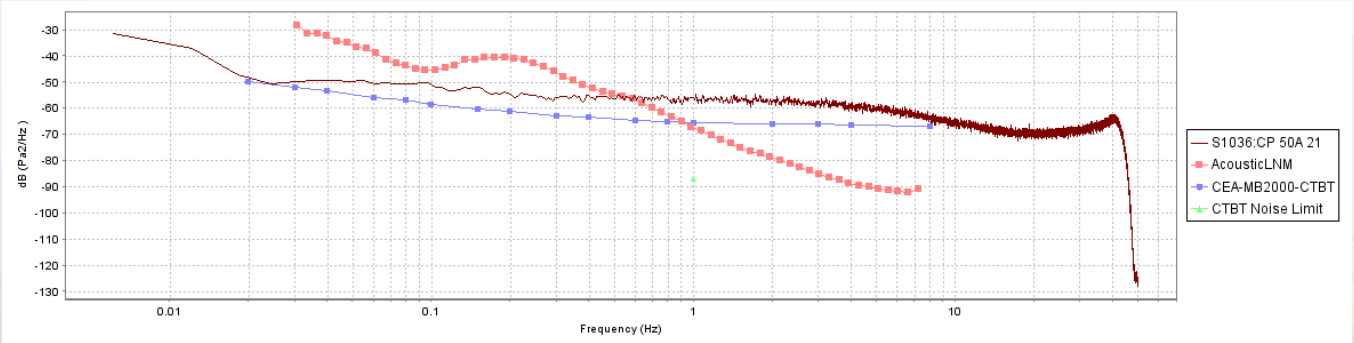
Chaparral 50A (102220 and 102221)
Isolation Self-Noise (static)



2-Channel Coherence – Distributed model Self-Noise (dynamic)



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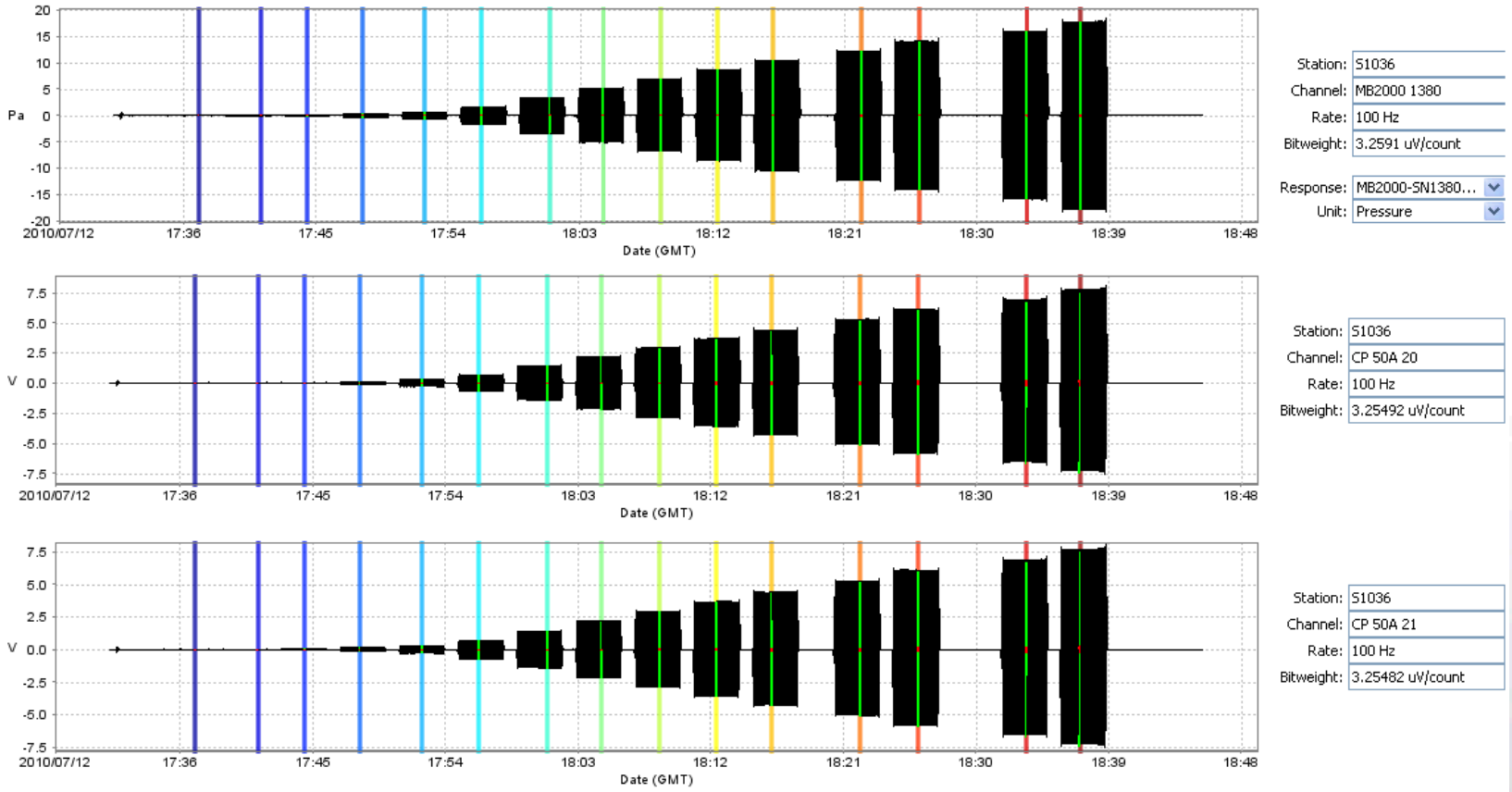
Piston-Phone Linearity / Amplitude Response Verification



15 amplitudes at single frequency (1Hz); Sine fit in green; misfit in red

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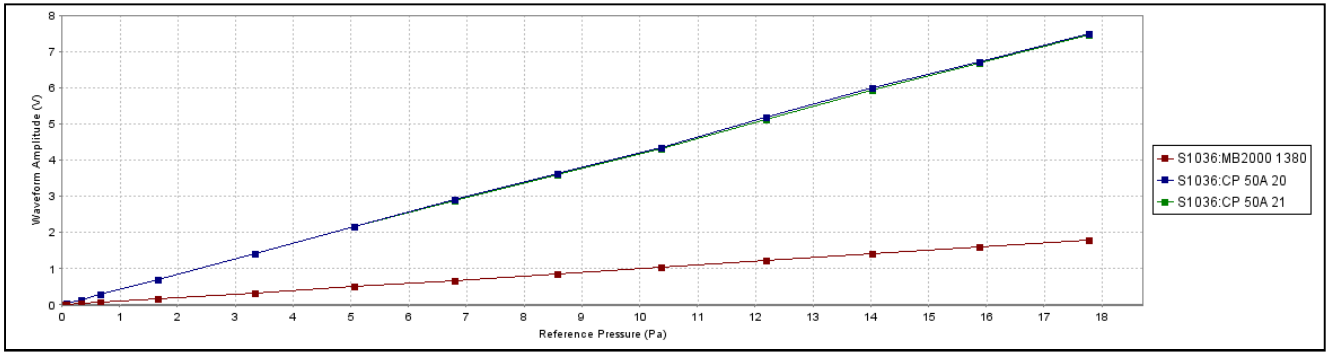
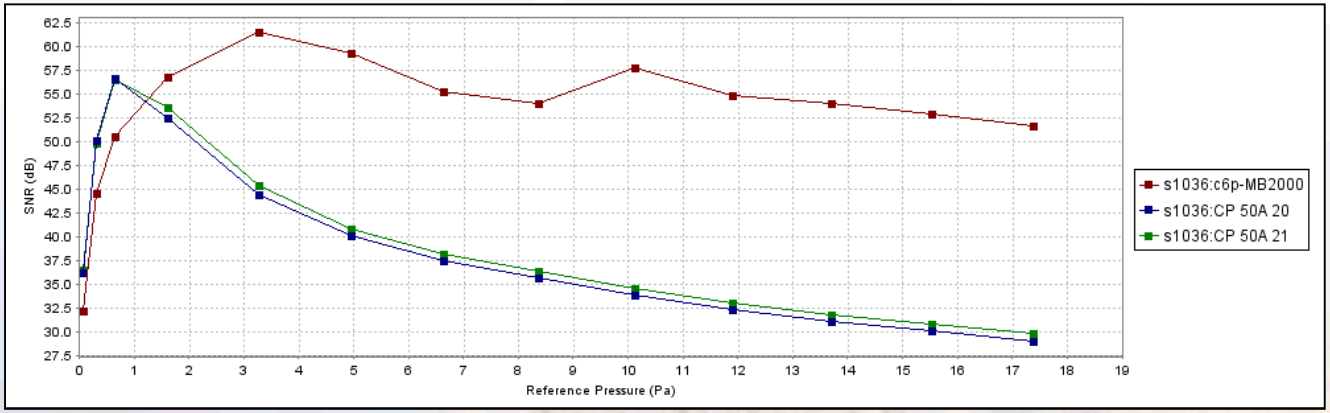
Linear voltage output with increasing amplitude



Reduced SRN with increasing amplitude



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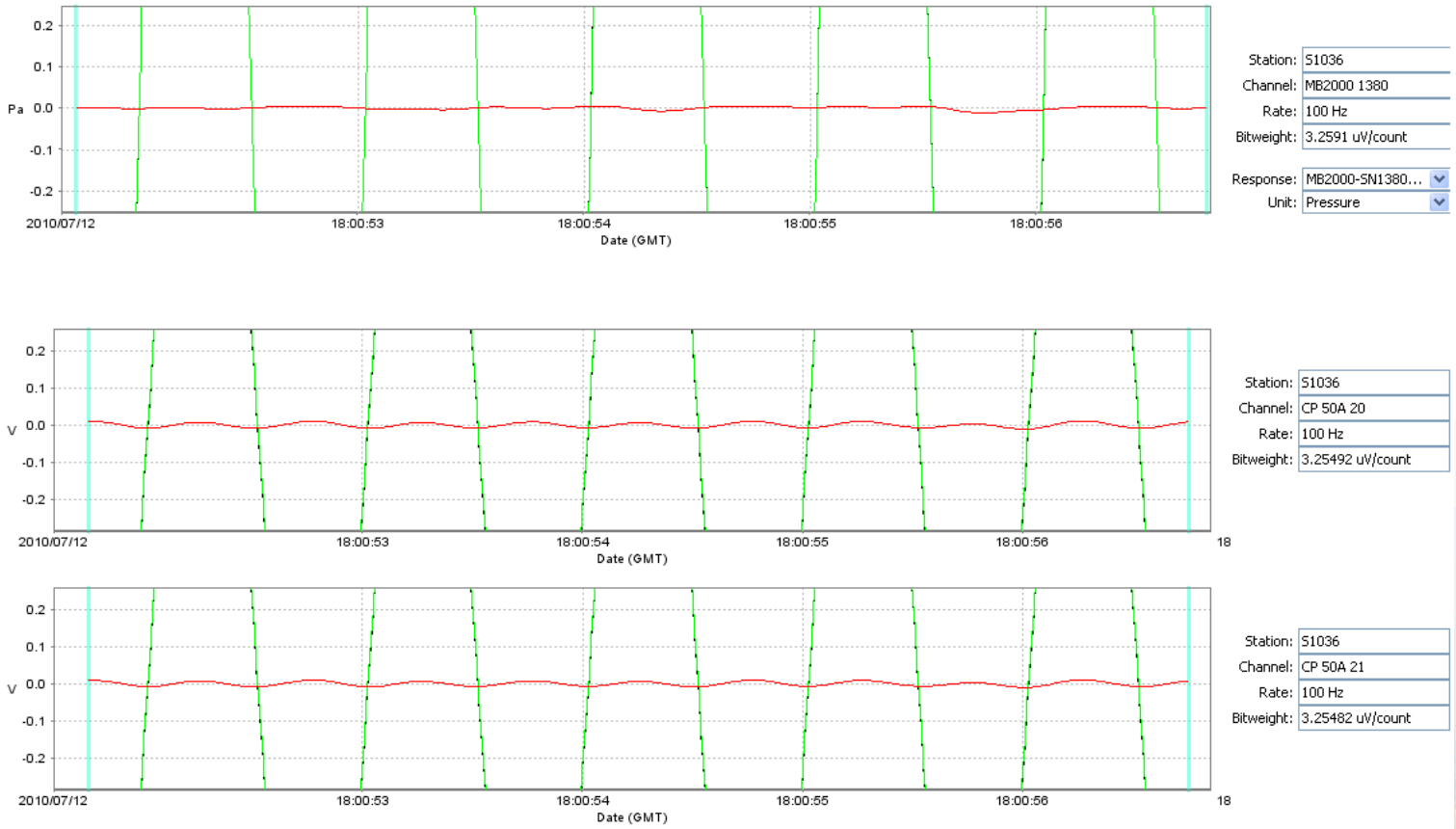
Closer look at 3.34 Pa tone…



The residual has twice the frequency as the test tone. Harmonic distortion…

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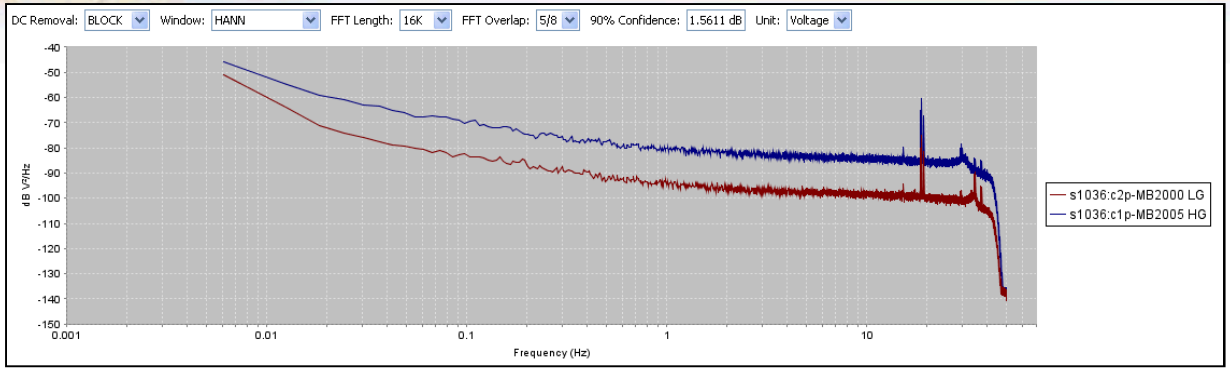

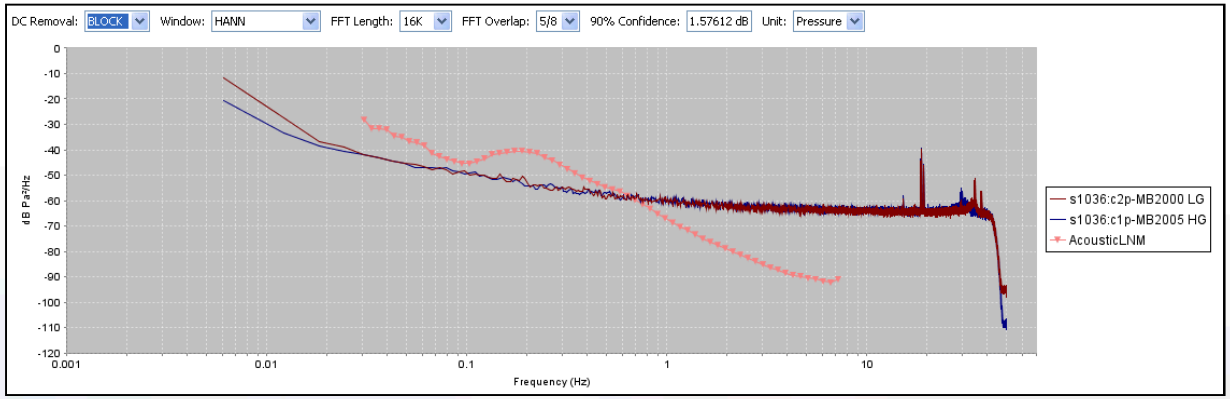

Sensor:
Low Gain: 0.02 V/Pa
High Gain: 0.1 V/Pa
Output(V): +/- 10

13 dB difference in Voltage in noise.

When converted by response to Pa, the Pa noise is the same.

Waveform	Noise (mPa rms)	Full-Scale (Pa)	DR 0.02-4 Hz	Noise (mPa rms)	Full-Scale (Pa)	DR 0.5-2 Hz
MB2005 HG	2.60	100	89.3 dB	1.16	100	96.0 dB
MB2000 LG	2.90	500	102.9 dB	1.13	500	110.0 dB

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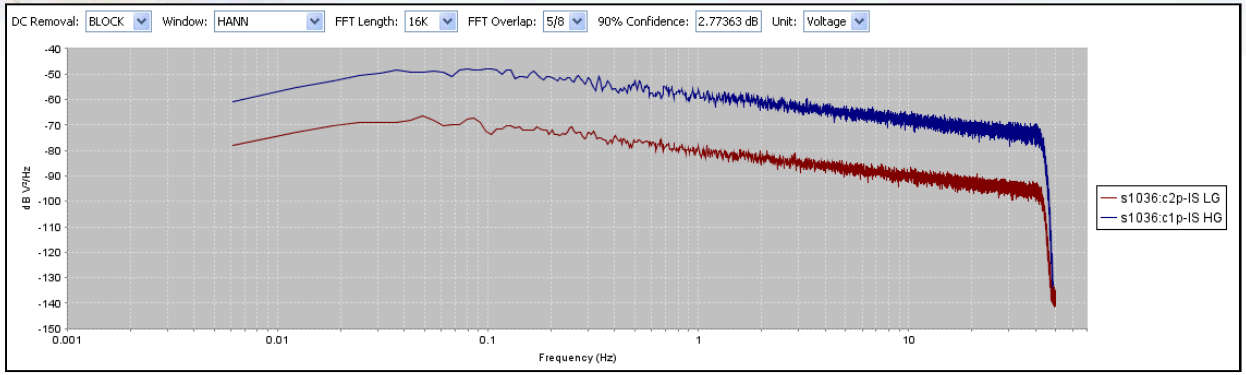

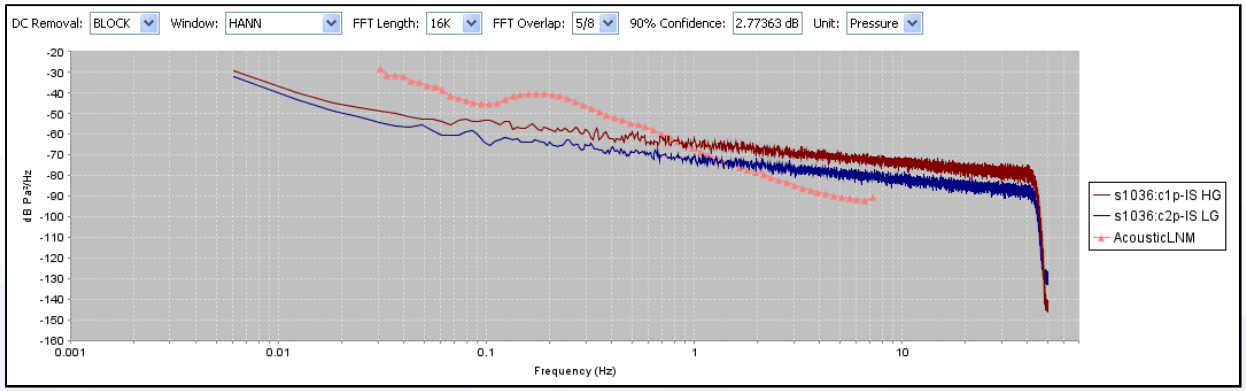

Sensor:
Low Gain: 0.4 V/Pa
High Gain: 2.0 V/Pa
Output(V): +/- 18

20 dB difference in Voltage in noise.

When converted by response to Pa, the Pa noise is 5 dB higher for HG.

Waveform	Noise (mPa rms)	Full-Scale (Pa)	DR 0.02-4 Hz	Noise (mPa rms)	Full-Scale (Pa)	DR 0.5-2 Hz
IS HG	1.37	9	73.3 dB	0.72	9	78.9 dB
IS LG	0.63	45	94.1 dB	0.29	45	100.1 dB

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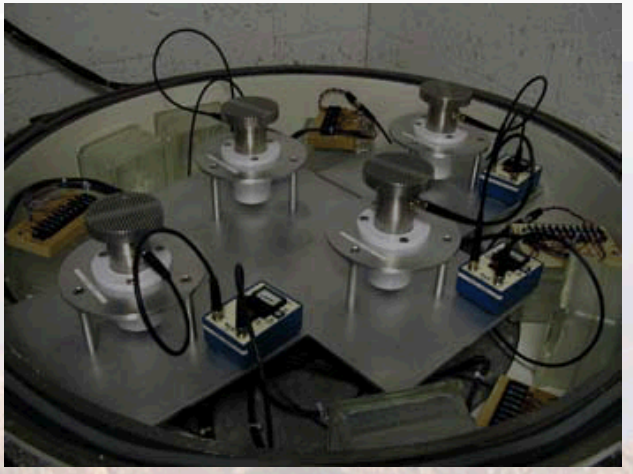
Sensors

- Chaparral 2.2, 2.5, 25
- IML SS and ST
- Miltec
- NCPA (IRIS-PASSCAL)
- infraNMT
- PCB Piezotronics



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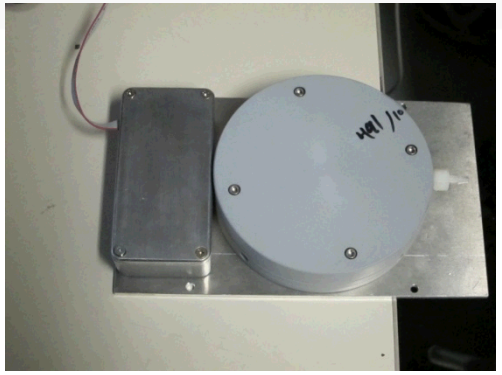
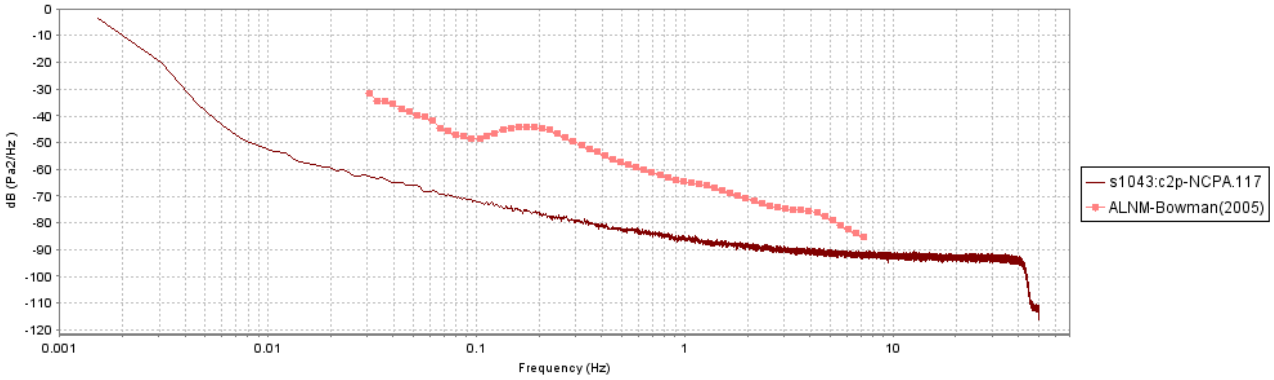
National Center for Physical Acoustics (NCPA-IRIS)

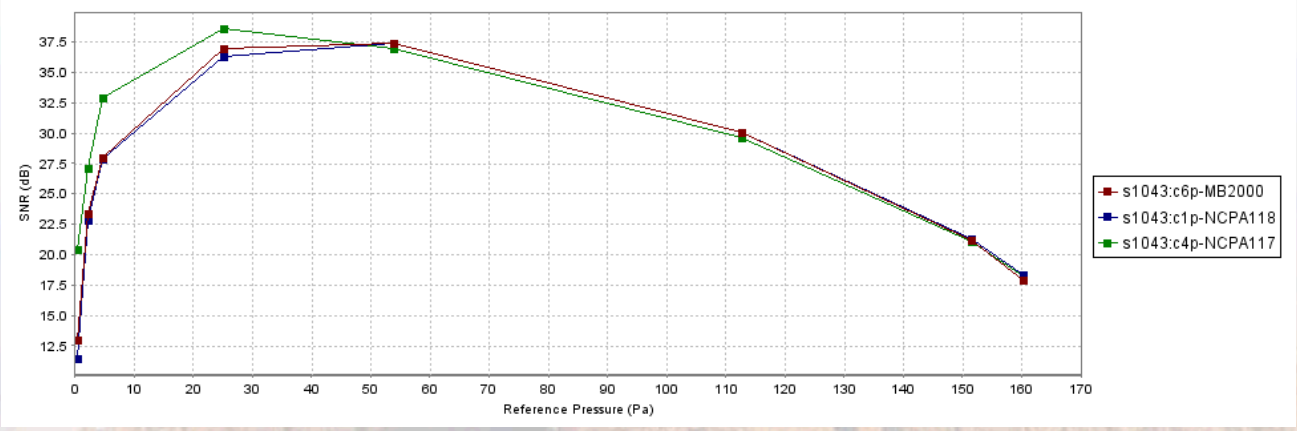


Power: 12 mwatts @ +/- 4.5V (9V)
Sensitivity: 23 mV/Pa
Noise: -86 dB rel 1 Pa^2/Hz ~ 60 uPa rms (0.5-2 Hz)
Full-scale Pressure: 160 Pa (zero to peak)
Dynamic Range: 125 dB
Passband: 0.007 – 40 Hz (acoustic inlet controlled)

Observations:
- Testing was not conducted temperature sensitivity
- Sensor design requires differential power (-4.5, gnd, +4.5)
- Very small seismic sensitivity (only observed during isolation noise test)
- Possible issue with sensitivity change with shipping method (sealed back volume)

National Center for Physical Acoustics (NCPA) Noise and Tonal SNR





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Discussion:

- Temperature Testing specifications
- Multiple Facilities for sensor evaluation tasks
- Stability of sensor specifications
- Multiple sensors at stations
- Incorporate MET data into analysis