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



March 15, 2012

Albuquerque, NM



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



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.



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
 - $20 \cdot \log_{10} (\text{FS}/\text{Noise})$



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 Pa²/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 RM2000/MB2000/MB2005

- Sensitivity: MB2005 96.3 mV/Pa
- Noise: -64 dB rel 1 Pa²/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



Sandia Evaluation Result

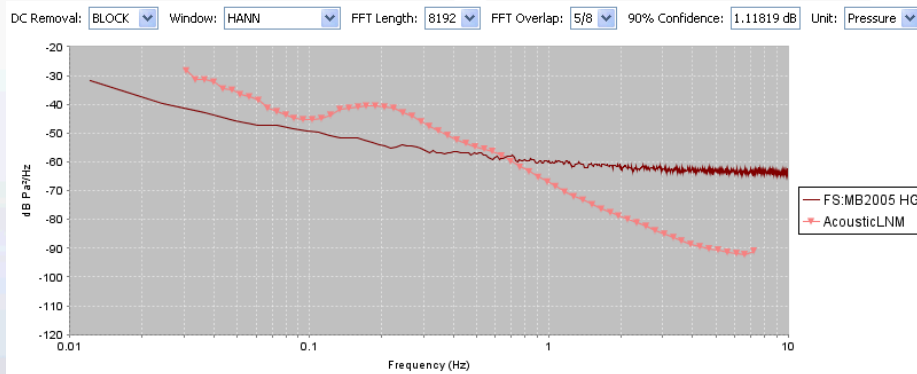


Figure taken from: Infrasond Monitoring for Atmospheric Studies, p.130

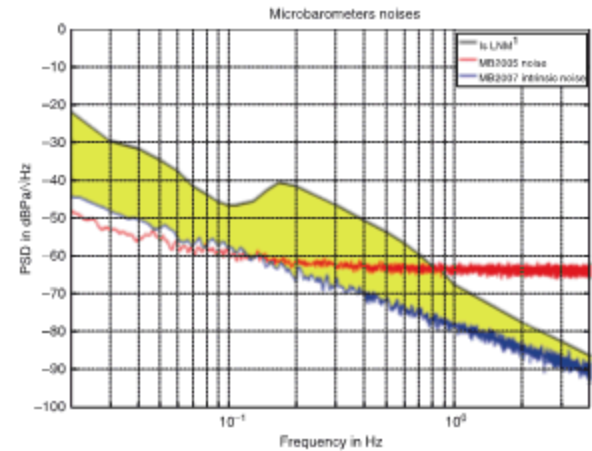


Fig. 4.10 Comparison between MB2007 MB2005 self-noise (Ponceau et al. 2008) and Infrasound Low Noise Model from Bowman (Bowman et al. 2007)



Chaparral 50A (102220 and 102221)

Power: CP50A = 0.35 watts @ 12V

Sensitivity: 0.420 mV/Pa

Noise: -81 dB rel 1 Pa²/Hz ~ 80 uPa rms (0.5-2 Hz)

Full-scale Pressure: 44.7 Pa (zero to peak)

Dynamic Range: 112 dB

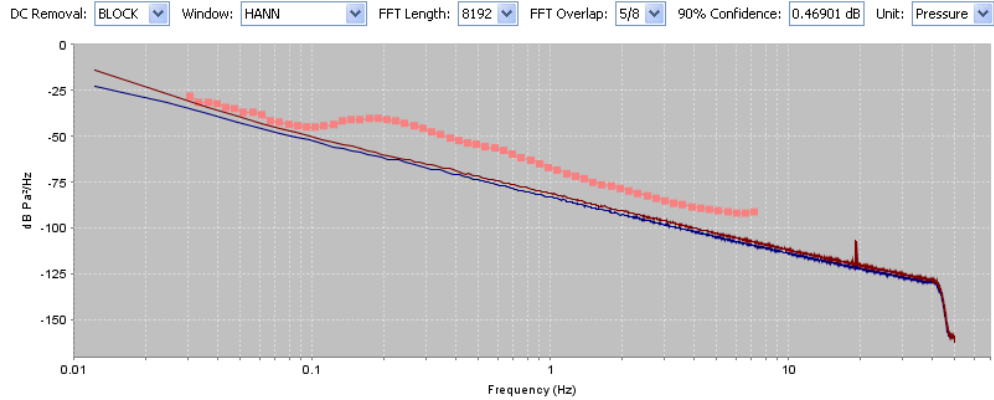
Passband: 0.01 – 50 Hz

Observations:

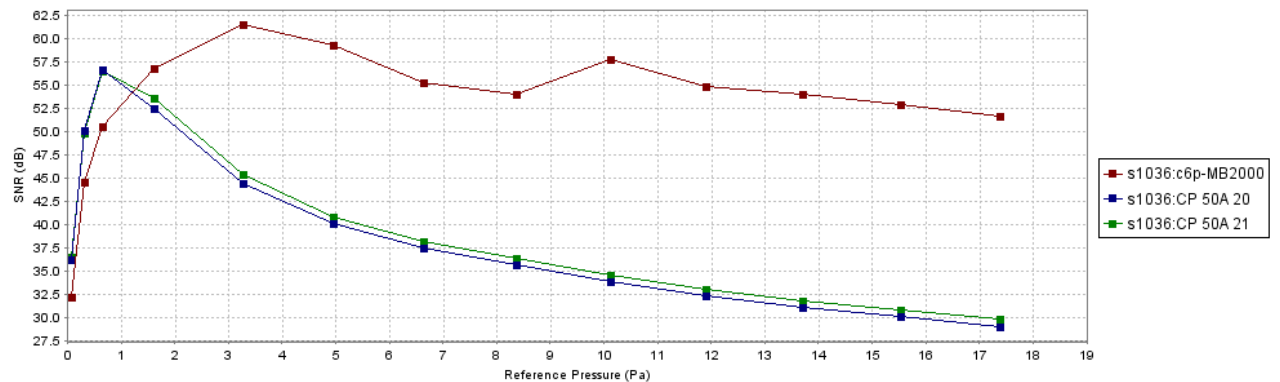
- DC offset increased with signal amplitude, a check of the balance of differential outputs is warranted
- Testing was not conducted on temperature sensitivity
- Datasheets imply traceability to LANL infrasound calibration capability
- Decreased tonal SNR for amplitude linearity Test



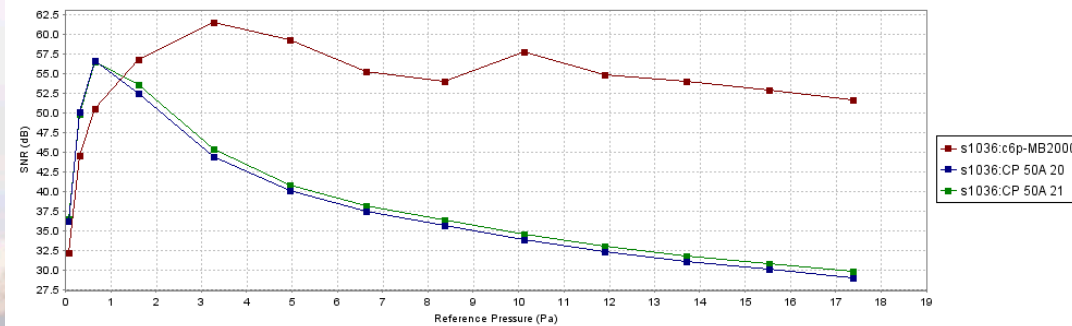
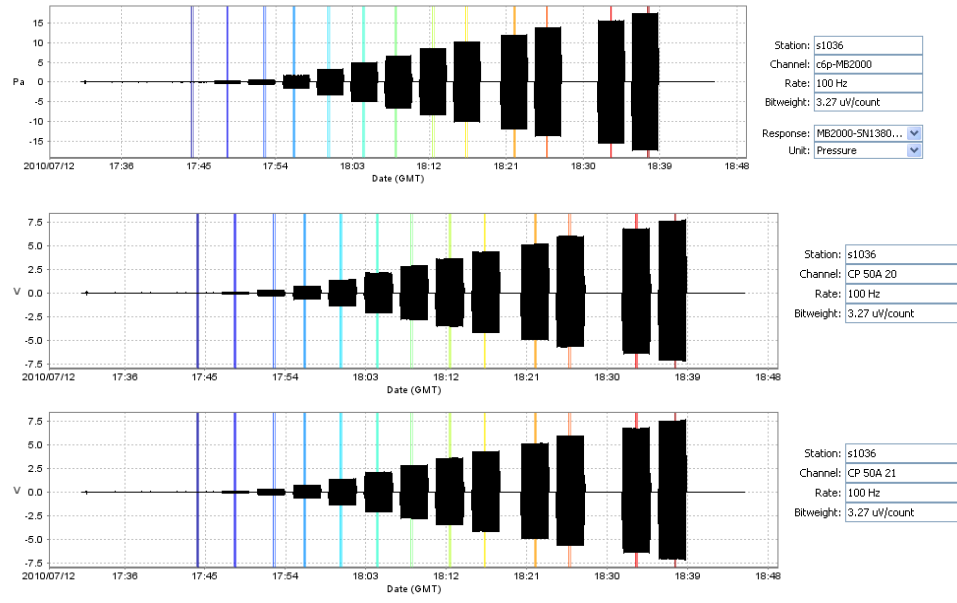
Chaparral 50A (102220 and 102221) Noise



Reduced SRN



Chaparral 50A (102220 and 102221) Reduced SRN with increasing amplitude

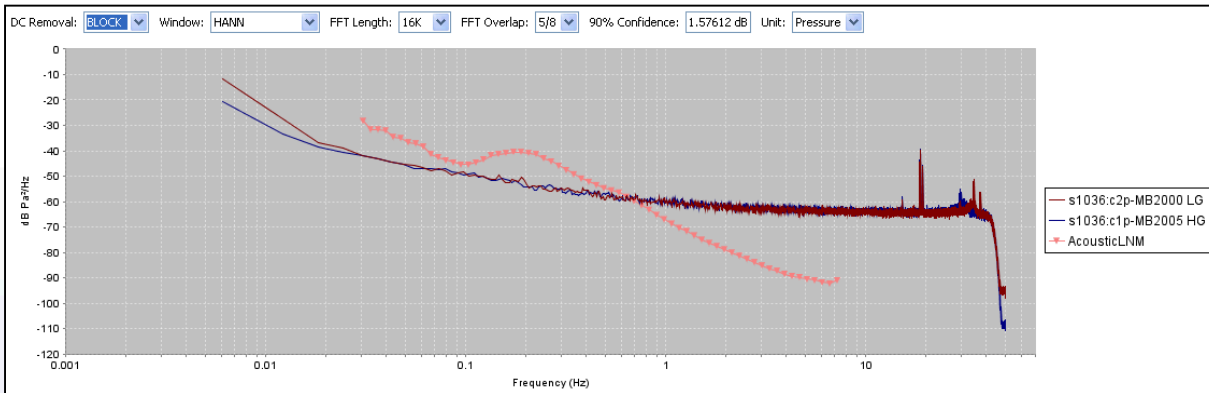
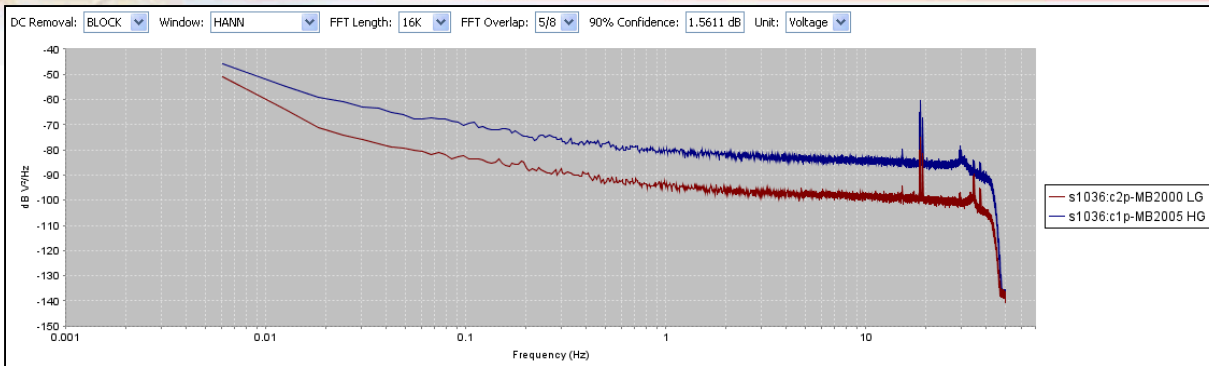


RGITC 2012

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

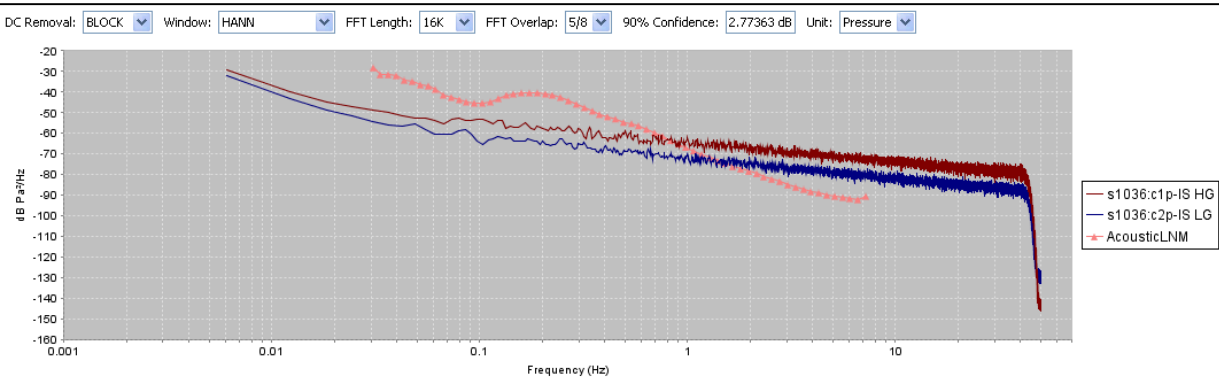
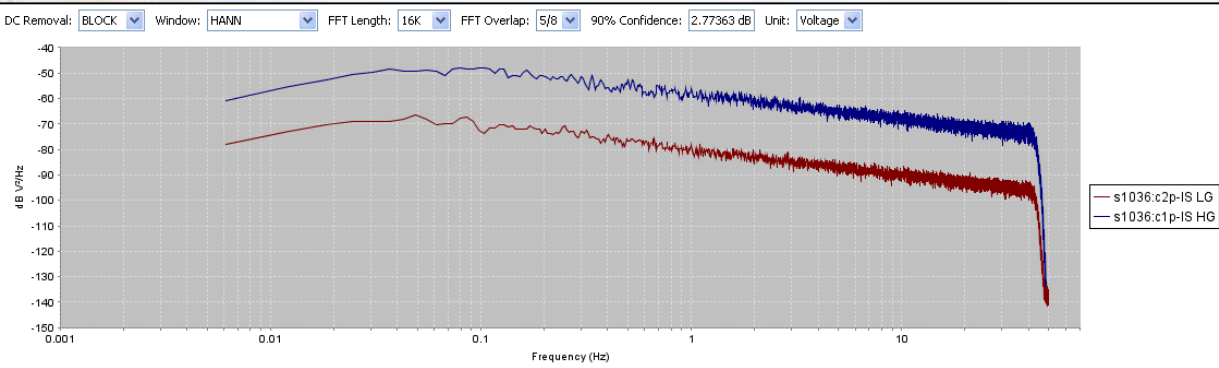


RGITC 2012

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.

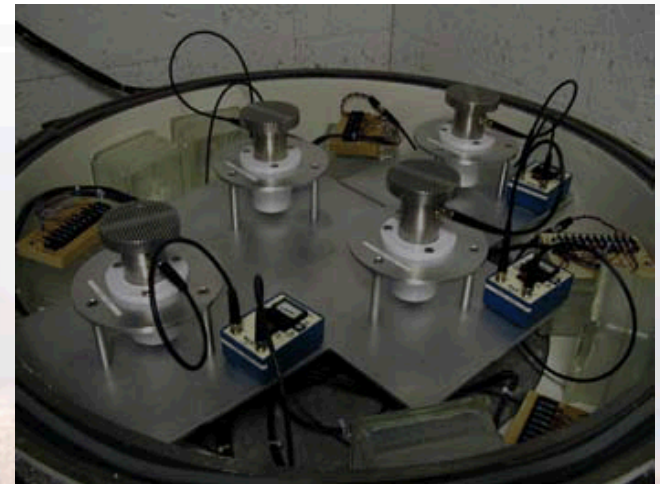


Waveform	Noise (mPa rms)	Full-Scale (Pa)	DR 0.02-4 Hz	Noise (mPa rms)	Full-Scale (Pa)	DR 0.5-2 Hz
IS HG	1.37	9	73.3 dB	0.72	9	78.9 dB
IS LG	0.63	45	94.1 dB	0.29	45	100.1 dB



Sensors

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



National Center for Physical Acoustics (NCPA-IRIS)

Power: 12 mwatts @ +/- 4.5V (9V)

Sensitivity: 23 mV/Pa

Noise: -86 dB rel 1 Pa²/Hz ~ 60 uPa rms (0.5-2 Hz)

Full-scale Pressure: 160 Pa (zero to peak)

Dynamic Range: 125 dB

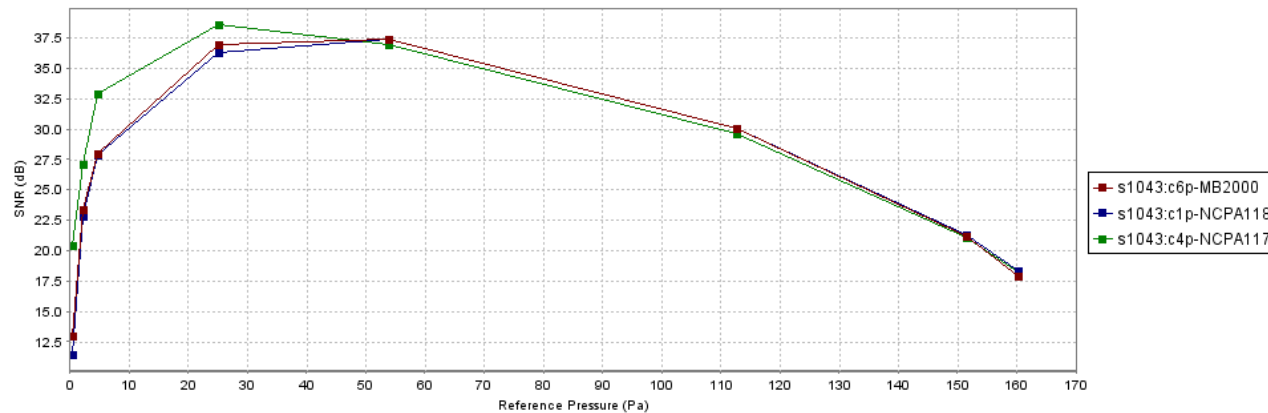
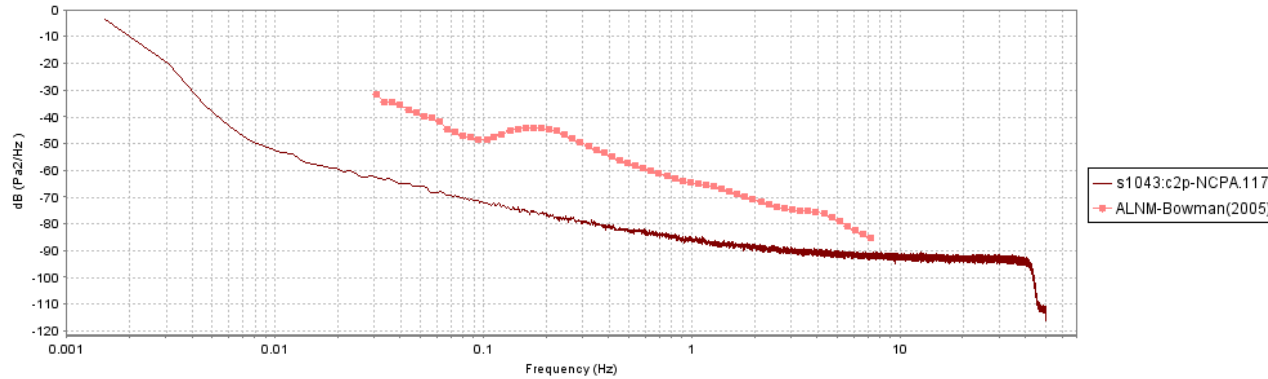
Passband: 0.007 – 40 Hz (acoustic inlet controlled)

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



Discussion:

- **Temperature Testing specifications**
- **Multiple Facilities for sensor evaluation tasks**
- **Multiple sensors at stations**
- **Incorporate MET data into analysis**
- **Issue with CALIB definition for Infrasound**

