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Characterization of NCPA Infrasound Sensors

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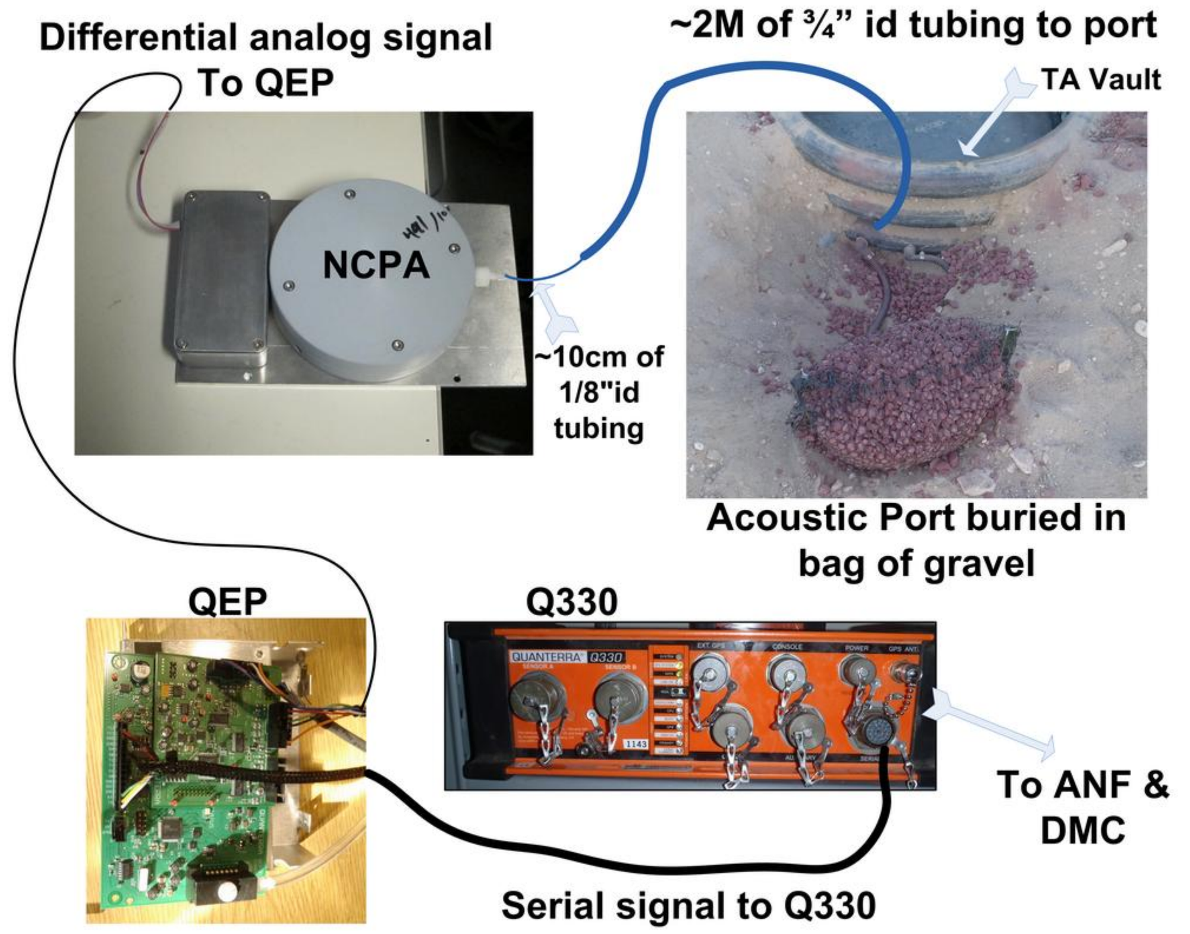
ABSTRACT

By adding NCPA (National Center for Physical Acoustics) Infrasound sensors to the eastern-half of the Transportable Array, the scientific community is gaining another powerful tool for studying natural processes. In an effort to characterize the sensors, including the effect of the wind filter and acoustical porting, researchers at Sandia National Labs (SNL) FACT Site and IRIS PASSCAL have performed a series of tests that resulted in good agreement with the NCPA-provided response (20mV/Pa +-10%, .007Hz high-pass corner frequency). Through independent testing and verification we have gained confidence in the sensor's linearity over the pressure range tested, a measure of power usage, and a measure of the dynamic range the sensors are capable of delivering, indicating the instruments can measure signals well below the Bowman (2005) Acoustic Low Noise Model up to 8Hz. Researchers at the SNL Fact site have the capabilities to not only test the NCPA sensor in an acoustic pressure chamber, but also the sensor with the wind reduction device, to fully determine the response of the system. We found that the tubing used to port the sensor to the external wind reduction device adds a measurable 18 to 30Hz resonance to the response and influences the high-frequency roll-off point. At PASSCAL, we have performed an acceptance test on more than 350 NCPA sensors, and in the process, have characterized their relative gains. The standard deviation of the relative gains is 5.32%. For 59 repeated tests of the two NCPA sensors used as references, the standard deviation is .15%, which suggests that acceptance testing can be used to constrain the gain of individual NCPA sensors to much better than the population deviation.

TA Station Standard Infrasound Setup

Prior to Sandia Labs testing, the NCPA sensors were characterized with a sensitivity of 20.3mV/Pa, standard deviation = .7mV/Pa, and a low-frequency corner at 6.57mHz, standard deviation = .82mHz. Below is a schematic diagram showing how the sensor is ported and the signal path from analog sensor to the Quanterra Environmental Processor (QEP) digitizer, which sends the data to the Q330 via a serial connection.



Testing – QEP Digitizer characterization

The first test performed by Sandia Labs at PASSCAL independently determined the bit-weight of the QEP digitizer. There are 3 digitizer channels on each QEP, with CH2 reserved for the NCPA sensor. All 3 QEP digitizer channels were fed a precision step voltage and Channel 2 & 3 agreed well within 1% of the published bit-weight of 3.188 counts/uV. Channel 1's published and tested response disagreed by 87%, indicating a hardware configuration error – the QEP's tested were not configured correctly for the assigned Setra 278 inputs. Discovering this early through lab testing saved much field effort.

NCPA Power measurements

NCPA power requirements vary linearly with differential input voltage. For standard TA operation at 9V differential input, the measured average power for 4 units was 12 mW with a maximum standard deviation of 31.1 uW.

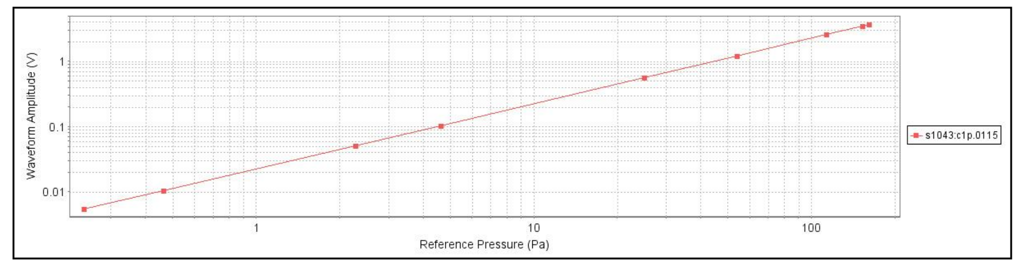
NCPA Power versus sensitivity

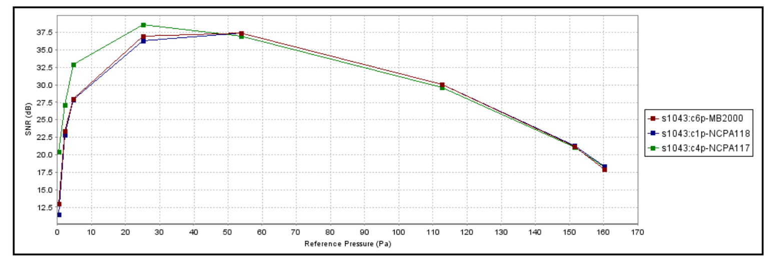
For the one tested unit (NCPA118), sensitivity @1.4Hz & 4.6Pa remained constant with a change in differential input voltage from 9 to 16V – 22.60 mV/Pa

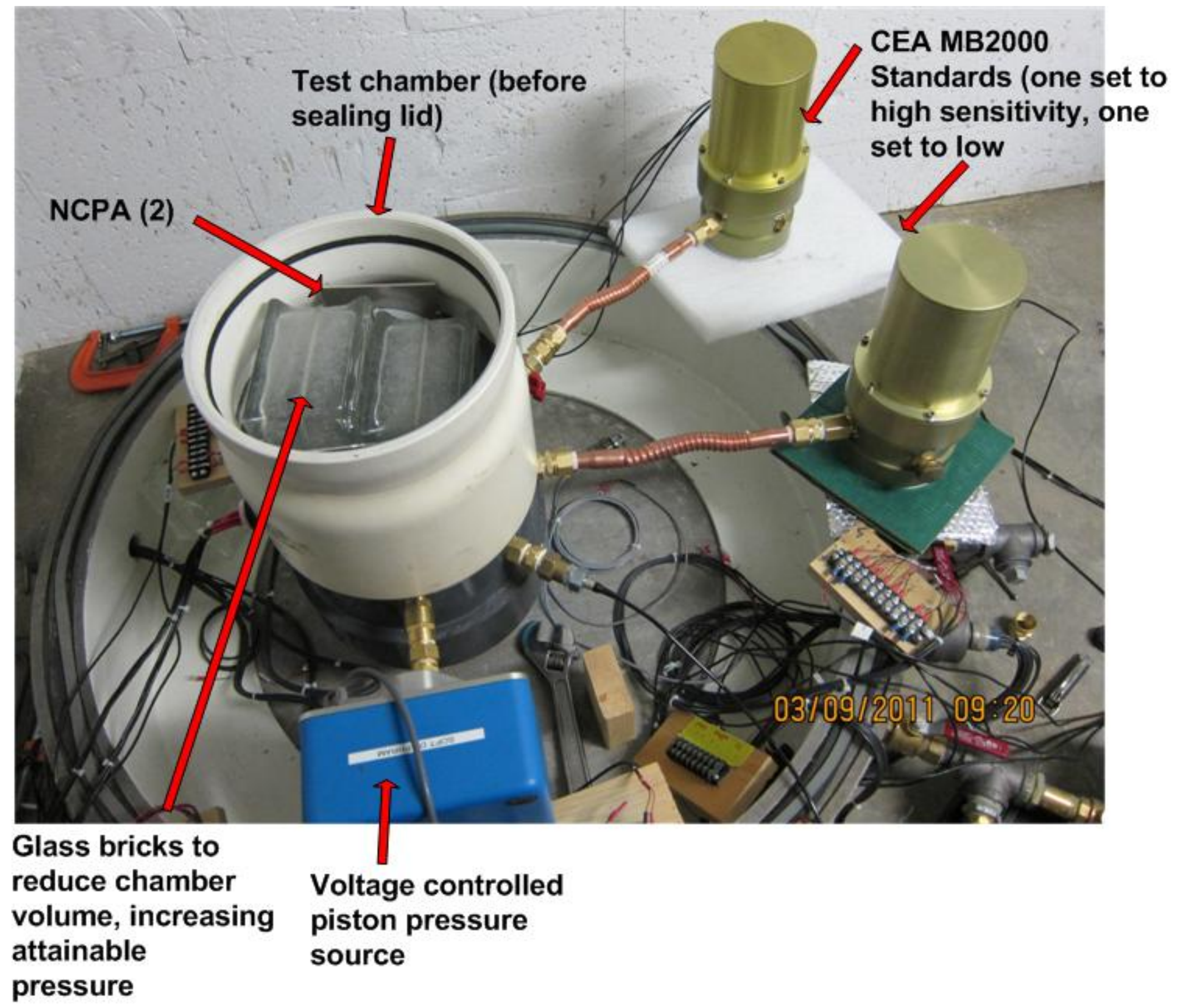
NCPA Sensor Piston-phone Linearity Verification

Purpose: To determine or verify the sensor linearity at one frequency using a variable amplitude piston-phone acoustic signal generator.

As the representative plot for NCPA 115 indicates (below left), the output is linear over the pressure range tested. Sensitivities measured (mV/Pa): NCPA115 – 22.6, NCPA117 – 20.9, NCPA118 – 22.6, NCPA55 – 20.6. (Below) As pressure increases the SNR in dB decreases in relation to the MB2000.



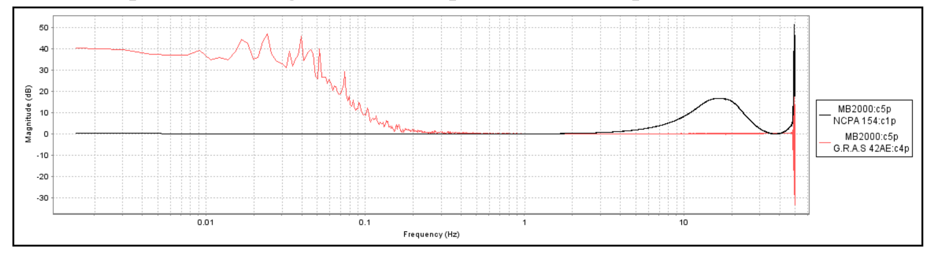




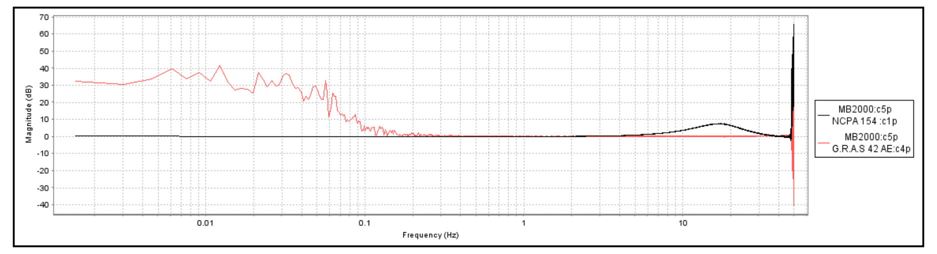
NCPA Sensor and "Mock-up" Wind screen

"Hockey Puck" drainage system shown prior to burial (top) and the full NCPA wind filter system inside the large test chamber (left).

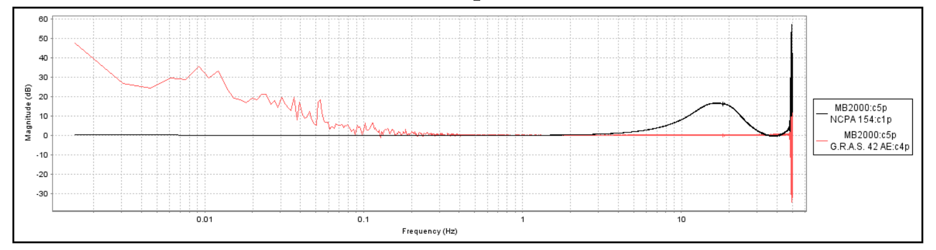
Complete System (In Rock)



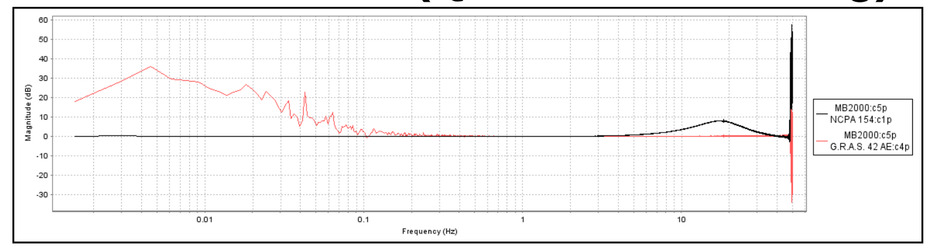
Black Hose Removed



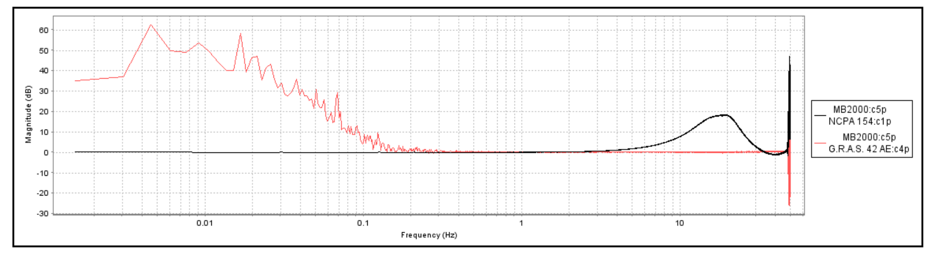
"White Inlet" on Top of Rocks



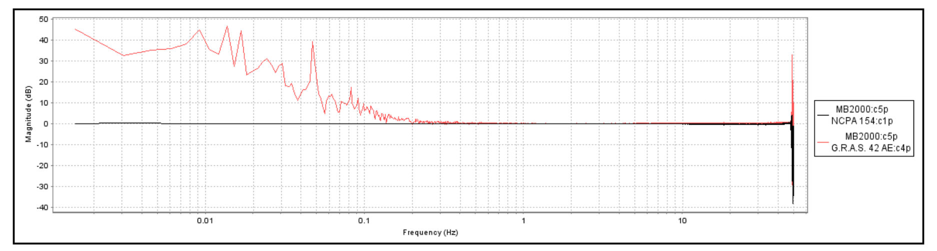
Brass Removed (QEP Plastic Tubing)



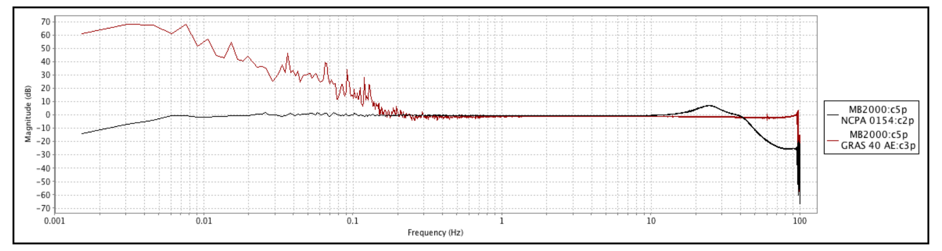
"White Inlet" Removed



Sensor Only



Complete System Re-Test

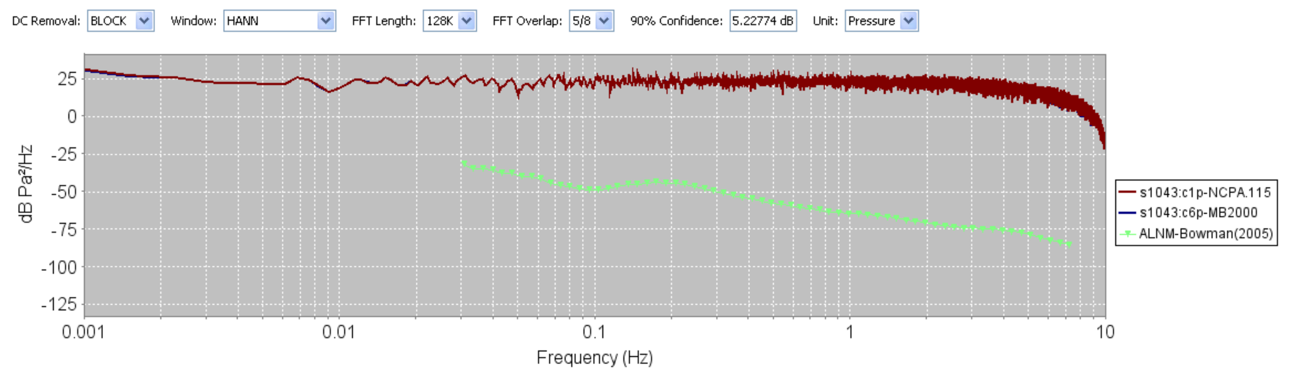


The TA windscreens were evaluated component by component (above and right). This was accomplished by testing the entire system followed by removing each component of the windscreen system until only the sensor remained. Throughout the testing a mode persisted between ~6 – 30 Hz. It was discovered that the sensor was attached to the wrong side of the QEP plastic tubing. After placing the sensor in the correct configuration a complete system re-test showed that the mode had narrowed and moved higher to between ~18.51 – 30 Hz.

NCPA Frequency/Phase Response Verification

Configuration: With the same setup as shown in the (middle/right-most) picture, a bandwidth-limited white noise function is used to drive the variable-amplitude, variable-frequency piston-phone acoustic signal generator.

Evaluation: The sensor frequency/amplitude/phase response is determined by coherence analysis with the reference, by mathematically correcting for the response of the reference. The following plot shows a representative plot of NCPA 115 and MB2000 power from .002 to 10 Hz, with the addition of the determined best-fit high-pass pole at .0069Hz for the NCPA response. The 2 sensor signals are difficult to pick apart. Green shows the Bowman(2005) low noise model.



High-pass corner frequency determined by this method for the 4 NCPA's are:
NCPA115 - .0069Hz, NCPA117 - .00695Hz, NCPA118 - .007Hz, NCPA55 - .007Hz. The Grass 42AE (inside the chamber) reference was used to determine the high frequency corner. This frequency appears to be dependent on the type of acoustic termination at the NCPA inlet. For this test, the standard TA 1/8" nylon barb fitting was exchanged with a larger diameter (1/4") brass fitting. This gave a roll-off frequency of 110Hz for NCPA 115, 118, and 55. NCPA 117's best fit was at 67.64Hz. The smaller barb gives a roll-off nearer to 40Hz and testing with close to the actual TA porting (see first picture).

3 dB Points (left and right of mode)

Configuration	3 dB (left of mode)	3 dB (right of mode)
Complete System	6.34 Hz	29.66 Hz
White Inlet on Rocks	6.35 Hz	29.32 Hz
White Inlet Removed	6.48 Hz	30.11 Hz
Black Hose Removed	9.15 Hz	26.67 Hz
QEP Plastic Tubing Only	9.30 Hz	28.31 Hz
Sensor Only	-	-
Complete System (Re-test)	18.51 Hz	30.74 Hz

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