In-Situ Calibration of Infrasound Monitoring Arrays using Natural Infrasound and a Co-Located Reference Microphone

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Objectives

• In-situ calibration of infrasound monitoring array
• Comparison calibration with reference microphone
• Exploit coherence between calibrated reference microphone and reduced-wind-noise signal from IMS array
• Source – natural infrasound (or artificial source)
Sensor to be calibrated

\[ X = P_S H_X \]

Reference sensor

\[ Y = (P_S + P_{WN}) H_Y \]
Mean-Square-Averaged Comparison Calibration Technique

\[ X = P_S H_X \]
\[ Y = P_S H_Y + P_{WN} H_Y \]

\[ \overline{G_{XX}} = \frac{2}{T} \left| P_S H_X \right|^2 \]
\[ \overline{G_{YY}} = \frac{2}{T} \left[ \left| P_S H_Y \right|^2 + \left| P_{WN} H_Y \right|^2 \right] \]
\[ \overline{G_{XY}} = \frac{2}{T} \left| P_S \right|^2 H_X^* H_Y \]

\[ \frac{\overline{G_{XY}}}{\overline{G_{XX}}} = \frac{H_Y}{H_X} \Rightarrow H_X = H_Y \frac{\overline{G_{XX}}}{\overline{G_{XY}}} \]
Conditions for success

• Good suppression of wind noise by IMS pipe/hose array

• Relative phase of $P_S$ stable between the two sensors
  – co-location of phase centers

• Sources of noise other than $P_{WN}$ small compared to $P_S$
  – careful selection of reference microphone

• Good lab calibration of reference; stable reference

• Sufficient averaging for incoherent cross-products to become negligible
  – Modest reduction of $P_{WN}$ on reference sensor reduces required averaging significantly
Possible Configuration – 4 channels

\[ Y = \frac{Y_1 + Y_2 + Y_3}{3} \]

Coincidence of virtual phase centers
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Penn State; Site 1 measurements and hose array construction by Timothy Marston
Site 1: Average winter microbarom strength; low site wind

[Graph showing frequency response with various lines and markers labeling Noise Floor, Reference Mic, Hose Array, 5 %–ile, and 95 %–ile [Bowman, et al.]]
Site 1: Coherence with single reference microphone [35 avgs]

\[
\left[ P_{WN} \right]_{reduced} = \sqrt{\frac{1}{\gamma^2} - 1} \left[ P_s \right] \frac{1}{N_{avg}}
\]
Site 1: Reconstructed Magnitude Response
Site 1: Reconstructed Phase Response

Frequency [Hz]

Response Phase [deg]
Shaver Creek Demonstration Site (2)

8.3 m

21 m

8.3 m
Site 2: Low microbarom strength; typical winter wind
Site 2: Reconstructed Magnitude Response
Individual-Element Coherence

Coherence

Frequency [Hz]
Alternative Sources: Two Examples

Typical sonic boom [EAFB]

Large helicopter over-flight

Ambient PSD

Site 1