Evaluation of infrasound in-situ calibration method on a 3-month measurement campaign

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IMS study

In the framework of the calibration program, a study was conducted with the following theoretical and practical results:
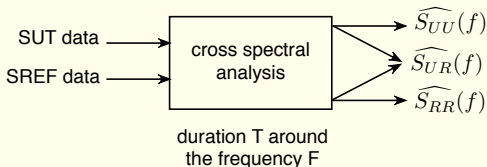
- closed form expression for the asymptotic probability distributions of the spectrum ratio which is the base of the estimation;
- sizing the statistic of test for the **magnitude square coherence (MSC)** level;
- introducing a weighted estimator of the **system under test (SUT)** response based on the estimated value of the MSC;
- proposal of a filter bank analysis for the SUT estimation;
- providing a simple wind coherence model which explains an observed artefact of the **noise reduction system** (NRS), in relation with the wind velocity;
- **Evaluation on a measurement campaign at station IS26 during several months.**

Measurement chain [Kramer and al., ITW2015]
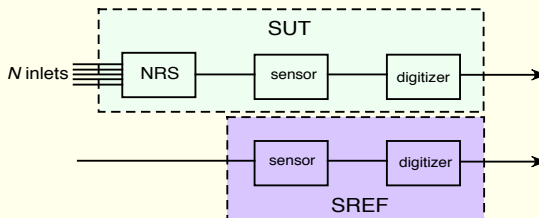
- the objective is the calibration of the SUT, which consists of the NRS, the sensor and a digitizer, based on the knowledge of the **system of reference (SREF)**;
- 2 kinds of signals: acoustic and non acoustic (typically wind) with different ranges of velocity;
- non spatially coherent signals are called "noise";
- acoustic signals is spatially coherent, in all frequency band of interest, regarding the size of the SUT.
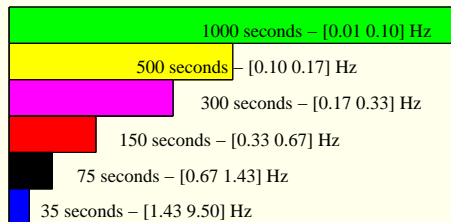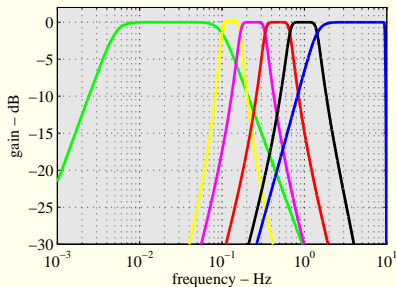
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Performing process

SUT data ⟶ cross spectral analysis ⟶ $\widehat{S_{UU}}(f)$, $\widehat{S_{UR}}(f)$, $\widehat{S_{RR}}(f)$

SREF data ⟶

duration T around
the frequency F

- ill-posed problem because under-determinated;
- but for stationary and "almost 0-noise" time segments we have:

$$\widehat{G_{\mathrm{UT}}}(f) \approx G_{\mathrm{ref}} \times \frac{\widehat{S_{\mathrm{UU}}}(f)}{\widehat{S_{\mathrm{RU}}}(f)}$$

- the MSC provides a way to test "almost 0-noise" time segments;
- theoretical results show that, to get an accuracy of $\pm 5\%$ on the gain, we need an MSC value greater than 0.96;
- but because only an estimate of the MSC is available, we have to threshold at about 0.98.

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Manage the stationarity

- In relationship with the resolution but also to take into account the lack of stationarity, we have considered a sequence of 6 durations in decreasing order with the frequency. A pre-filtering is also performed.

1000 seconds – [0.01 0.10] Hz

500 seconds – [0.10 0.17] Hz

300 seconds – [0.17 0.33] Hz

150 seconds – [0.33 0.67] Hz

75 seconds – [0.67 1.43] Hz

35 seconds – [1.43 9.50] Hz

NRS effect

If v denotes the wind velocity, the ratio $\dfrac{v}{f}$ can be viewed as a "wavelength" [Alcoverro, al., JASA, 2002]. Therefore

- at very low frequency, the wind appears as spatially coherent for all SUT/SREF inlets. Therefore everything occurs as there is NO noise, and the MSC is almost 1,

- at high frequency, the wind appears as spatially NON coherent. Therefore the NRS plays its role to reduce the noise,

- around 0.8 Hz, a small part of the wind appears as spatially coherent for a few NRS inlets. Therefore a small dip artefact is observed.

Infrasonic signals – IS26
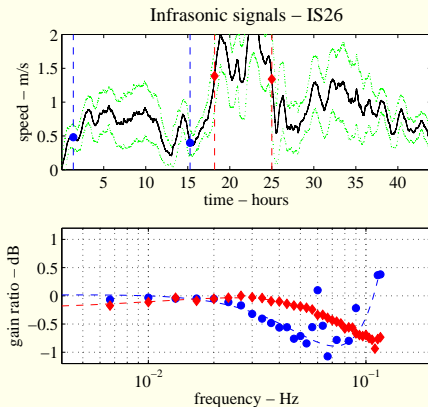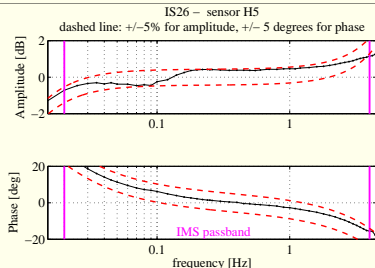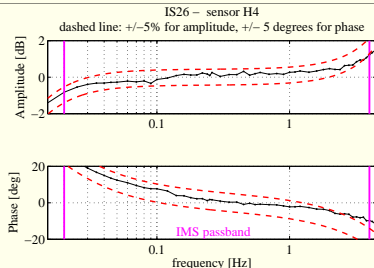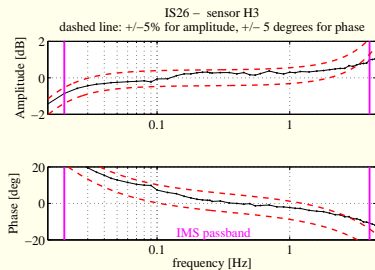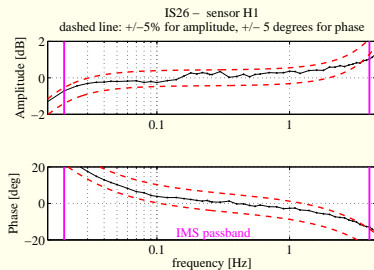
Deployment [A.Kramer, al., ITW2015]

- 8 SUTs with 18 meter wind noise reduction system, each of them with 96 inlets;
- 8 SREFs have been deployed on May 2015;
- each reference sensor has been calibrated in the lab;
- capability of wind measurement on H1;
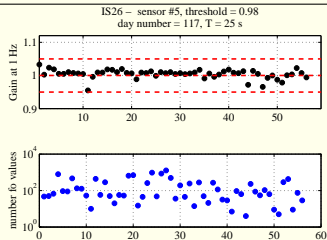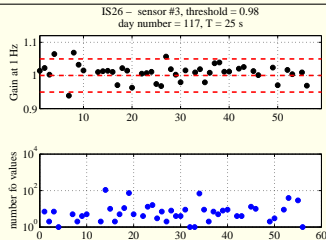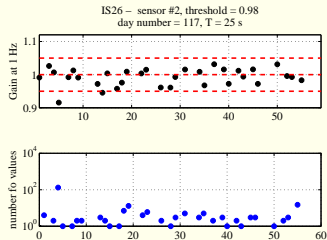
PTS requirements

PTS specifications are:
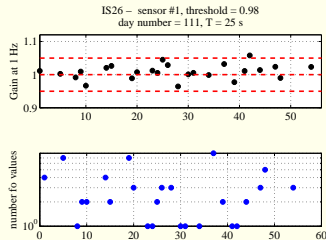
- bandwidth $[0.02 - 4]$ Hz;
- $\pm 5\%$ on the response magnitude, i.e. ± 0.43 in dB scale;
- the calibration is required at least once a year;
- no requirement on the phase but ... $\pm 5°$ as for seismic requirements.

Results

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Temporal stability of successive gains averaged on 2 days

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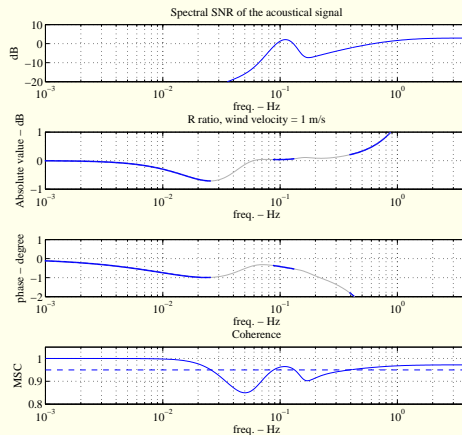10 / 14

Conclusions

PTS specifications are:

- bandwidth $[0.02 - 4]$ Hz;
- $\pm 5\%$ on the response magnitude; more specifically the calibration is required once a year;
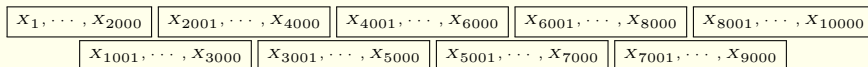- no requirement on the phase but ... $\pm 5°$ has been considered.

Conclusions:

- The numerical results obtained on a large campaign of measurements fully validate the calibration method;
- The experimental results obtained by couples of 2 days show a high stability in full agreement with the PTS requirements;

THANKS FOR YOUR ATTENTION

NRS effect simulation

Rks

$x_1, \cdots, x_{2000}$	$x_{2001}, \cdots, x_{4000}$	$x_{4001}, \cdots, x_{6000}$	$x_{6001}, \cdots, x_{8000}$	$x_{8001}, \cdots, x_{10000}$

$x_{1001}, \cdots, x_{3000}$	$x_{3001}, \cdots, x_{5000}$	$x_{5001}, \cdots, x_{7000}$	$x_{7001}, \cdots, x_{9000}$

- If we have $N = 2000$ samples the resolution is $F_s/N = 0.01$ Hz.
  Therefore there is a possibility to decimate if the bandwidth is $B < 0.01$.
  But for sake of simplicity, we keep the common value F_s to all filters of
  the bank (no decimation).

- For each frequency bin, an averaging is applied on the $L = 9$ segments. If
  a few number of bins is required the fft algorithm is not needed.