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

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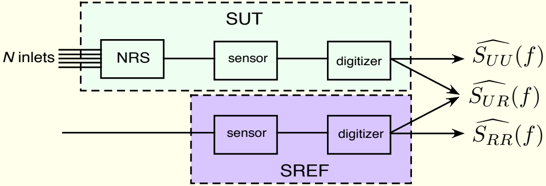
IMS study

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 estimators;
- 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.

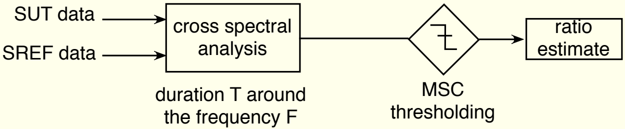
Measurement chain [Kramer and al., ITW2015]



$$\widehat{G_{\mathrm{UT}}}(f) \approx \underbrace{\frac{\widehat{S_{\mathrm{UU}}}(f)}{\widehat{S_{\mathrm{RU}}}(f)}}_{\text{spectrum ratio}} \times G_{\mathrm{ref}}$$

- objective: calibrate the system under test (SUT), i.e. NRS+sensor+digitizer, based on the knowledge of the reference system (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.

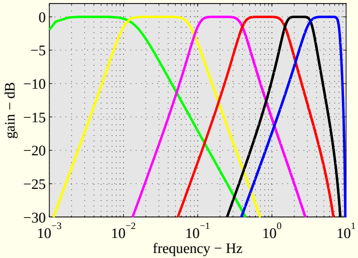
Performing process

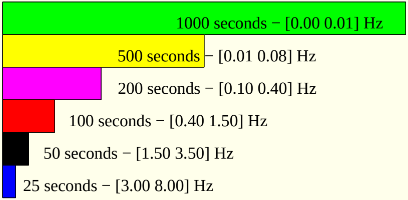


- ill-posed problem because under-determinated;
- to circumvent this issue, stationary and "almost zero-noise" time segments are selected. Fortunately it exists a test for that based on the coherence.
- theoretical results show that to get a $\pm 5\%$ on the gain, the MSC value must be at least 0.96.
- but because we only have an estimate $\widehat{\text{MSC}}$, we have to thresholding at about 0.98.

Manage the stationarity

- In relationship with the resolution but also the lack of stationarity, we have considered a sequence of durations in decreasing order with the frequencies and do pre-filtering around these frequencies. However we have noticed that the design is not critical.
- In the presented results the following filter bank, derived from empirical approach has been used.

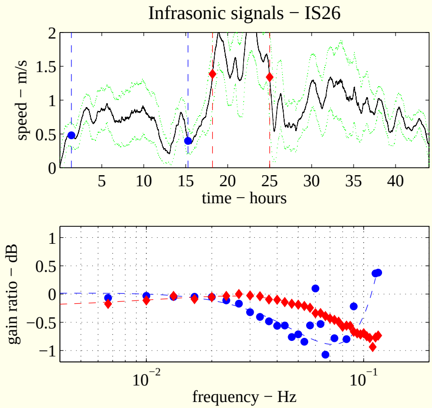




NRS effect

The ratio $\frac{v_{\text{wind}}}{f}$ 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 elements. 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 dip artefact is observed.



Deployment [A.Kramer, al., ITW2015]

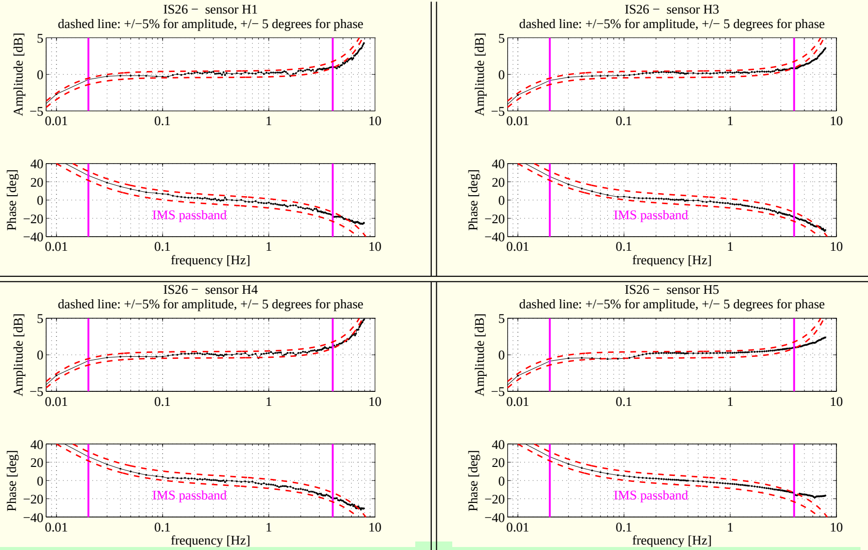
- 8 SUTs with 18 meter wind noise reduction system, each of them with 96 inlets;
- 8 SREFs have been deployed on May 2015;
- each reference sensor has been calibrated in the lab;
- capability of wind measurement on H1;

PTS requirements

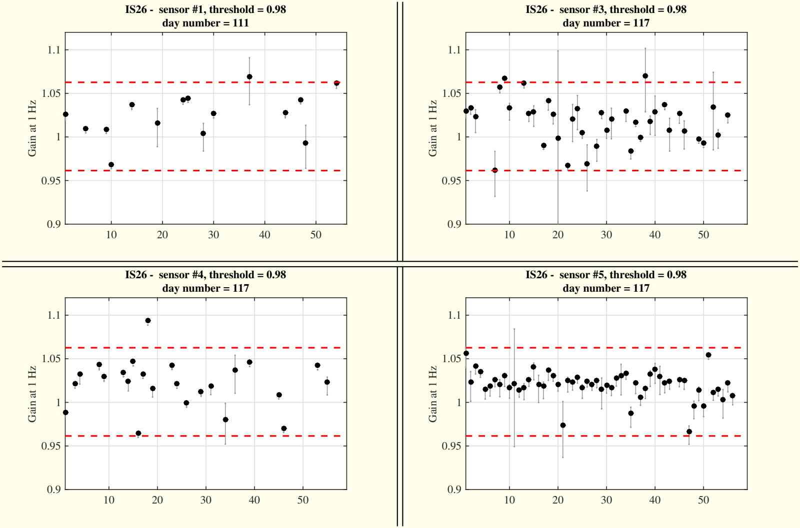
PTS specifications are:

- bandwidth $[0.02 - 4]$ Hz;
- $\pm 5\%$ on the response magnitude
- the calibration is required at least once a year;
- no requirement on the phase but ... $\pm 5^{\circ}$ as for seismic requirements.

Results


IS26 – sensor H1
dashed line: +/−5% for amplitude, +/− 5 degrees for phase
Amplitude [dB]
Phase [deg]
IMS passband
frequency [Hz]
IS26 – sensor H3
dashed line: +/−5% for amplitude, +/− 5 degrees for phase
Amplitude [dB]
Phase [deg]
IMS passband
frequency [Hz]
IS26 – sensor H4
dashed line: +/−5% for amplitude, +/− 5 degrees for phase
Amplitude [dB]
Phase [deg]
IMS passband
frequency [Hz]
IS26 – sensor H5
dashed line: +/−5% for amplitude, +/− 5 degrees for phase
Amplitude [dB]
Phase [deg]
IMS passband
frequency [Hz]

Temporal stability of successive gains averaged on 2 days



Conclusions

PTS specifications are:

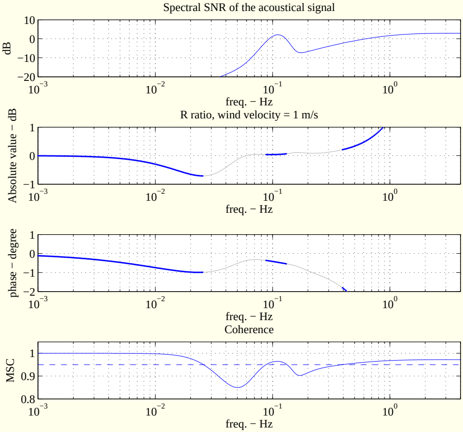
- bandwidth $[0.02 - 4]$ Hz;
- $\pm 5\%$ on the response magnitude; more specifically the calibration is required once a year;
- no requirement on the phase but ... $\pm 5^\circ$ has been considered.

Conclusions:

- The experimental results obtained 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.