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

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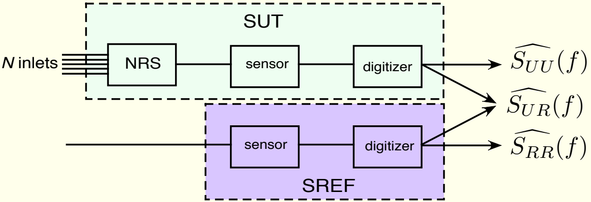
IMS study

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



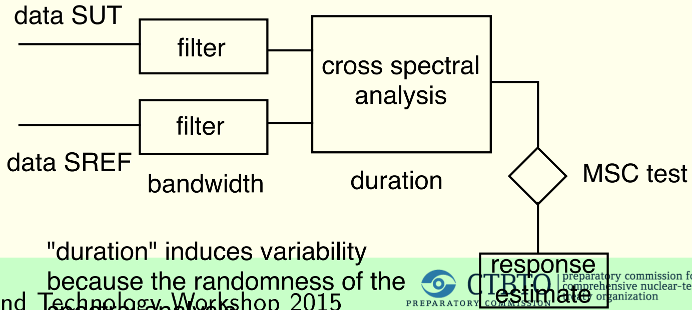
$$\widehat{G_{\mathrm{UT}}}(f) \approx \frac{\widehat{S_{UU}}(f)}{\widehat{S_{UR}}(f)} \times G_{\mathrm{ref}}(f)$$

- 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

- Stationarity + (MSC close to 1) solves the problem of underdetermination
- Typically, if we want $\pm 5\%$ on the gain, theoretical results show that we need an MSC value 0f 0.96, but unfortunately we only have an estimate of the true MSC. Therefore to get a confidence level of 90% we have to thresholding at 0.98.

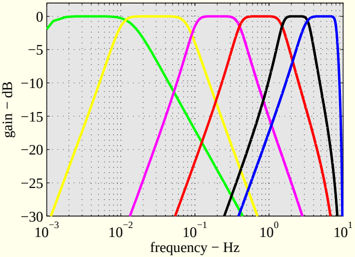
the problem is underdeterminated

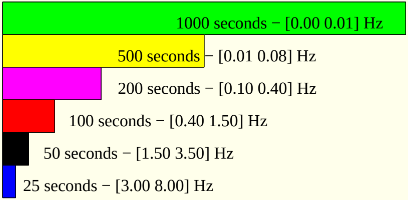


"duration" induces variability because the randomness of the spectral analysis

Manage the stationarity

For stationary signals the accuracy on the estimation does depend on the number of time windows we have for averaging the Fourier components. This number appears as the product of the duration by the spectral resolution. Hence the idea to use a filter bank with a logarithmic pavement.

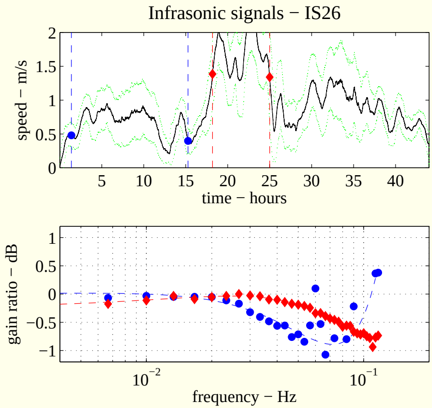




NRS effect

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]

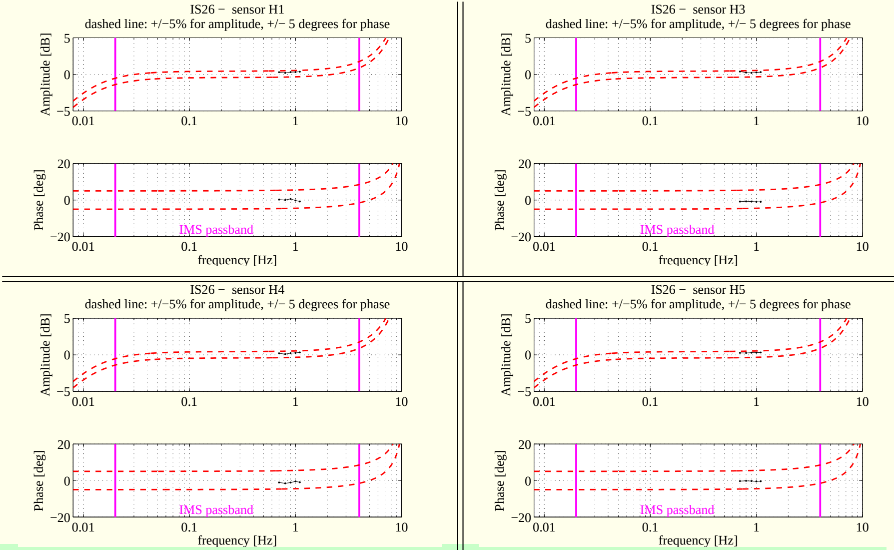
- 8 SUTs with 18 meter wind noise reduction system, each of them with 96 inlets;
- 8 SREFs have been deployed on May 2015;
- each reference sensor has been calibrated in the lab;
- capability of wind measurement on H1;

PTS requirements

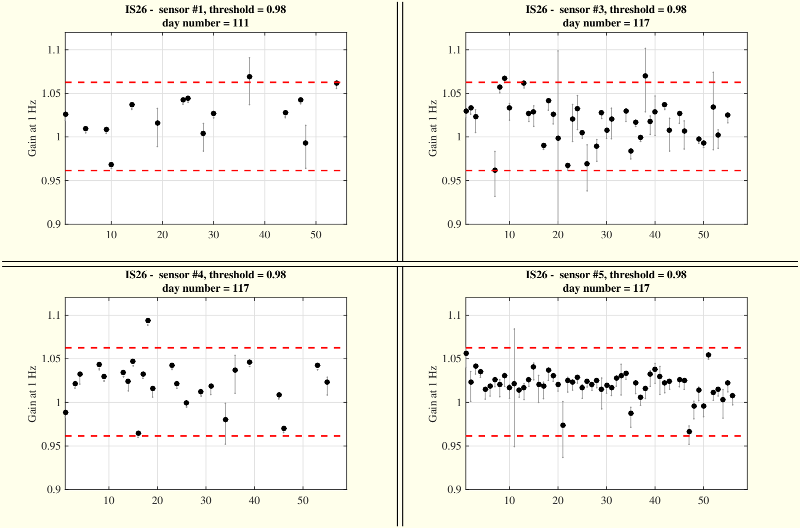
PTS specifications are:

- 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:

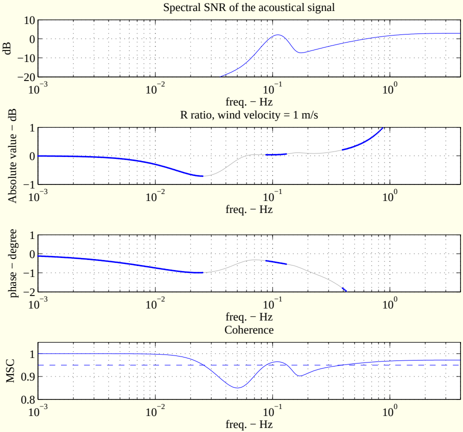
- bandwidth $[0.02 - 4]$ Hz;
- $\pm 5\%$ on the response magnitude; more specifically the calibration is required once a year;
- no requirement on the phase but $\ldots$ $\pm 5°$ has been considered.

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

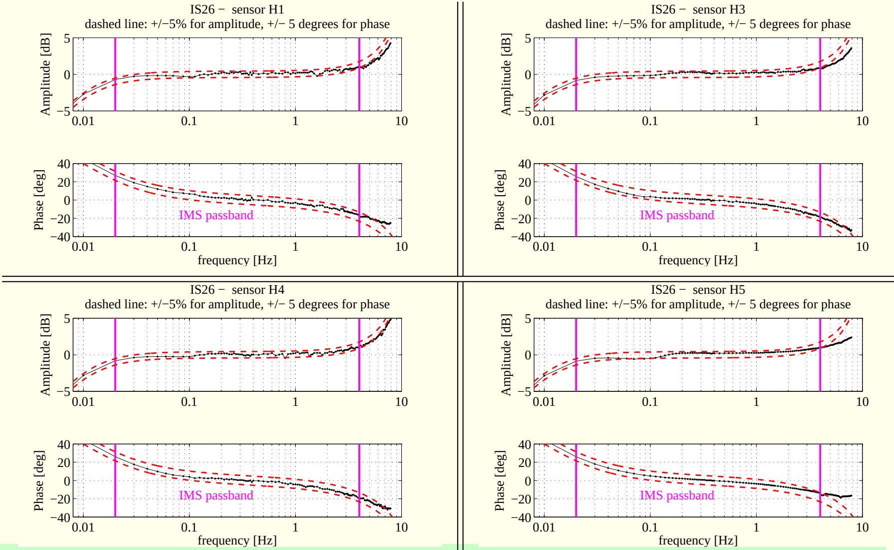


Rks

$x_1, \cdots, x_{2000}$	$x_{2001}, \cdots, x_{4000}$	$x_{4001}, \cdots, x_{6000}$	$x_{6001}, \cdots, x_{8000}$	$x_{8001}, \cdots, x_{10000}$
$x_{1001}, \cdots, x_{3000}$	$x_{3001}, \cdots, x_{5000}$	$x_{5001}, \cdots, x_{7000}$	$x_{7001}, \cdots, x_{9000}$	

- 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.

Results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Amplitude [dB]
Phase [deg]
IMS passband
frequency [Hz]
5
0
−5
40
20
0
−20
−40
0.01
0.1
1
10