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Improving self-noise estimates of seismic sensors by coherency and alignment analysis

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Self-noise estimates for broadband seismic sensors are important to compare instruments, assess their usefulness for a specific purpose and provide information on long-term stability.

The 3-channel spectral coherence technique commonly applied to compute self-noise estimates uses synchronous recordings from three co-aligned and collocated sensors. In such a setup, ideally, the three sensors' self-noise is the only source of incoherently recorded signal, and it can be extracted by the spectral correlation technique.

While results of this approach for vertical components in a real setting are relatively robust and reliable, the self-noise estimates are clearly disturbed, most dominantly in the frequency range between ≈0.1 – 1 Hz, corresponding to Earth's secondary microseisms peak, which typically constitutes the signal of largest amplitude in the recorded noise spectra.

It has been shown in previous studies that inaccuracies in the sensors' alignment during the experiment and errors in internal orientation of the sensing axes due to manufacturing limitations are likely to be the most significant contributions to the relatively higher (i.e. disturbed) power levels in the self-noise estimates in this frequency band. Estimates of the technique's sensitivity to alignment errors vary around 10 dB/0.2°, which is in the range of the manufacturers' max. errors in orientation between components (0.2° for STS-2, 0.5° for RefTek 151-60).

In this work we demonstrate a method to numerically rotate the recorded traces of two of the sensors relative to the third, in order to improve alignment, and reduce the effect of alignment errors on the self-noise estimates. Repeated self-noise computations during incremental rotations around one sensor's axes enable us to find the angles of rotation for the sensor's component to be optimally aligned with that of another, and thus estimate initial alignment errors between sensors during the experiment for each of the sensing axes, and for pairs of sensors, separately.

For vertical components our approach performs successfully, even in the presence of weak teleseismic earthquake signals, high frequency noise and increased microseisms, with angular resolutions as high as one millidegree. Unexpectedly, sensitivity to misalignment appeared to significantly vary with microseisms activity, showing expected values of ≈10 dB/0.2° during rather calm conditions (e.g. July/August), and reaching more than 15 dB/0.1° during episodes of strong microseisms (e.g. October/November).

Results for horizontal components, and specifically for periods T larger than one second, show that the reduction of spectral disturbances is less complete, and exhibits a larger dependence on noise conditions than the verticals. During periods of strong microseisms, rotation of sensors effectively yielded no reduction of the large disturbances present, and even during relatively quiet periods residual disturbances with clearly no sensitivity to rotation in large parts of the lower frequency range ($T > 1s$) were observable.

With the exact reasons for both, the variance in sensitivity to rotation and the differences in observations between horizontal vs. vertical components currently being investigated in more detail, we propose our technique as a computationally inexpensive improvement to the 3-channel spectral coherence method for estimating self-noise.