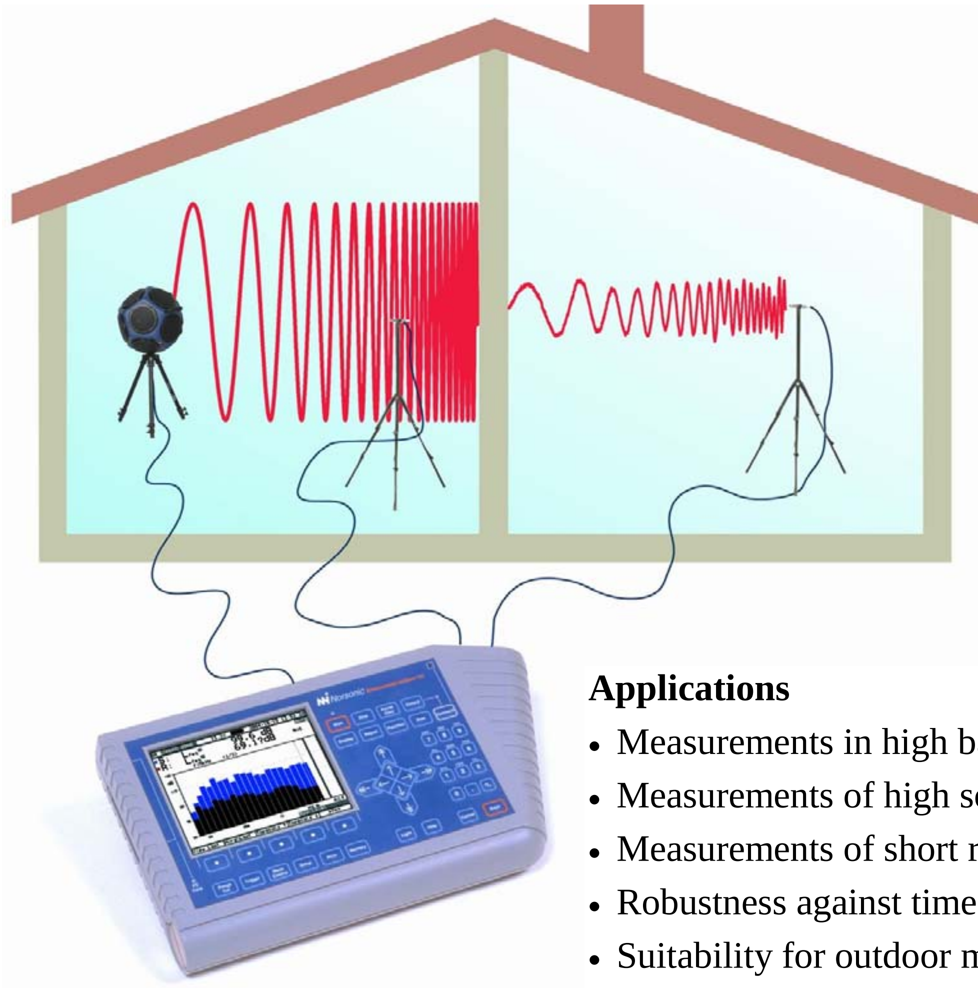
Application Note

Swept Sine Measurement Technique

Using the Nor121 Analyser



Applications

- Measurements in high background noise
- Measurements of high sound reduction indices
- Measurements of short reverberation times
- Robustness against time-variance
- Suitability for outdoor measurements

The swept-sine method uses excitation signal of a sinusoidal shape whose frequency increases exponentially with the time. The response to this excitation is recorded by the analyser and the impulse response between source and receiver position is extracted by the use of a mathematical technique known as deconvolution. As described in the international standard "ISO/DIS 18233: Acoustics – Application of new measurement methods in building acoustics", the swept-sine method provides the possibility to conduct measurements in high background noise, which is the huge advantage over the classical method. This also means that it is possible to perform correct measurements in cases of high sound insulation, where the classical measurement would be hindered by the background noise.

The following examples clearly show how the Norsonic analyser Nor121 with its optional swept-sine technique improves the measurement possibility. The example measurements are performed with Norsonic Nor121 analyser, Nor260 power amplifier and Nor250 hemi-dodecahedron loudspeaker.

Norsonic

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Sound Insulation Measurement

In this example, three measurements were conducted in order to measure level difference in sending and receiving room. First, the broadband pink noise excitation and parallel analysis are used, second, 1/3 octave filtered pink noise excitation and serial analysis are used and finally, third measurement is conducted with swept-sine technique. In order to compare results obtained by these three measurements they are presented graphically on 3 graphs. The graph in figure 1. contains levels in sending room. It can be seen that swept-sine excitation gives an increased excitation level. This is due to lower crest factor of sine signal compared to random noise. This in it self gives a direct improvement in the signal to noise ratio (SNR).

The graph in figure 2. contains the levels measured in receiving room and level of background noise in receiving room. The curves in figure 3. correspond to measured level difference.

The background noise level in the receiving room was 45 dB at low frequencies and 25 dB at high frequencies. It is depicted with the black curve in figure 2.

The level in the receiving room obtained by broadband excitation (blue curve) is barely above noise at lower frequencies while it is completely masked by noise at high frequencies. As a consequence the level difference is smaller then correct value, as can be seen from lower graph.

By using the serial measurement capability of Nor121 in combination with 1/3 octave filtered noise excitation, the excitation energy in measured frequency bands can be improved by 12-15 dB. By comparing the green and blue, corresponding to serial and parallel

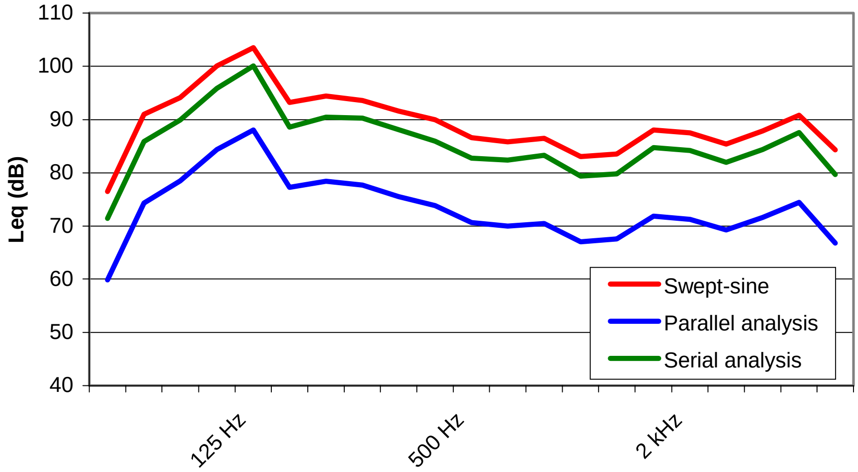

Figure 1. Levels of excitation in sending room

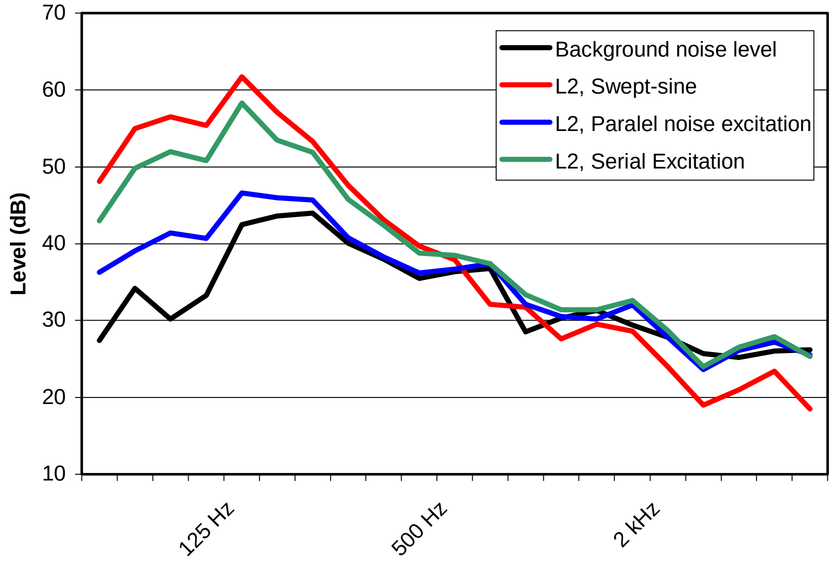

Figure 2. Levels in receiving room

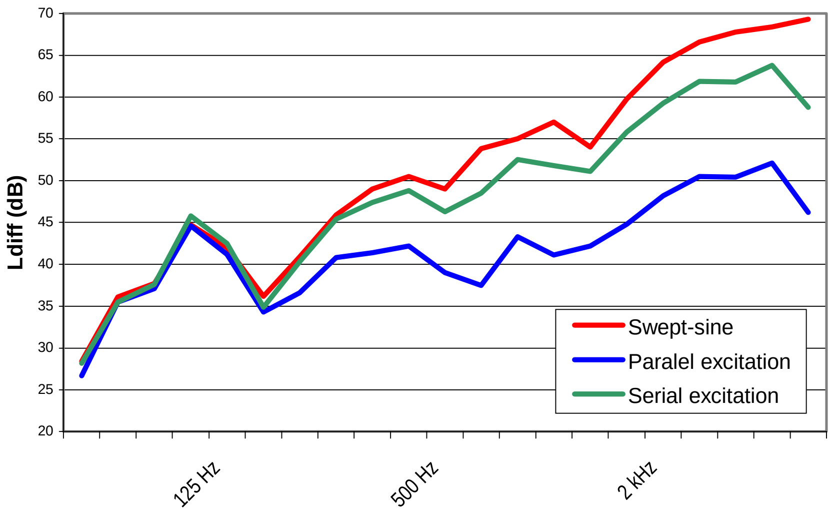

Figure 3. Level difference between sending and receiving room

analyses, we can conclude that this is the case on the lower frequencies. However this improvement was not enough to obtain correct results at higher frequencies due to prevailing background noise.

The swept-sine technique not only provided higher level of excitation but also suppressed the background noise. It can clearly be noted that measured results are under background noise at higher frequencies. Therefore swept-sine is capable of performing the correct measurements even in environments with negative signal to noise ratios, being the only method that could give the correct result in this example.

Reverberation Time Measurements

Swept-sine technique is very useful when measuring reverberation time as it reduces the difficulties related to high background noise. Example no.2 demonstrates this, through 3 measurements in a very noisy room. The background noise has a pink spectrum and is 96 dB at all frequency bands. Apart from high noise we will try to measure reverberation time by 3 different measurements: first with broadband pink noise excitation and parallel analysis, second with 1/3 octave filtered pink noise excitation and serial analysis and finally, third with swept-sine technique. In order to compare the results we would observe a 1/3 octave band with centre frequency of 2 kHz.

The figure 4. is the screenshot of a Nor121 with the result of parallel measurement. The excitation level of 98 dB has been achieved which is barely above the background noise and therefore it is impossible to measure reverberation time.

The screenshot in figure 5. contains result obtained with serial

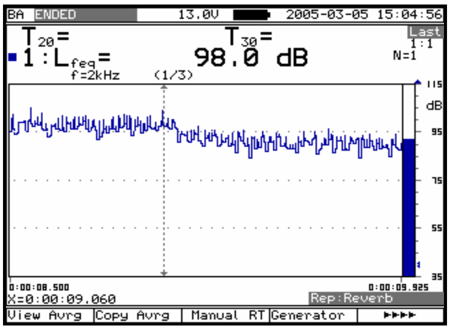

Figure 4. Reverberant decay obtained by parallel analysis

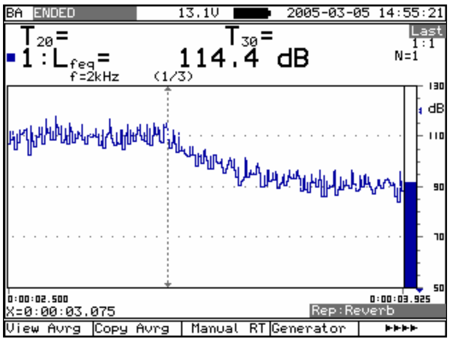

Figure 5. Reverberant decay obtained by serial analysis

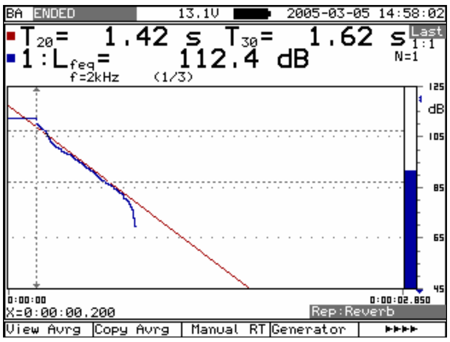

Figure 6. Reverberant decay measured by swept-sine

measurement. The excitation level is clearly improved but still SNR is far from enough to make a measurement of reverberation time possible.

Finally, use of swept-sine technique and its noise suppressing capability gives the result in figure 6.

The energy decay curve has a linearly decaying shape and enough dynamics to reliably measure both T20 and T30.

The conclusion for this experiment is that swept-sine method is superior compared to noise excitation based methods. It is capable to reliably measure reverberation times in environments with extremely low signal to noise ratios.

Measurement of Very Short Reverberation Times

Measurement of short reverberation times, associated with small chambers, cars, etc. are normally impossible at low frequency bands by traditional techniques. This is due to internal decay times of the filters used that limit the shortest possible measurable decay.

Norsonic have overcome this problem by the use of reverse filtering with specially crafted filters that both provide short decay times and conform to class 1 requirement of IEC 61260. The graph in figure 7. present limits for minimum reverberation times that can be reliably measured by classical analysis methods (parallel and serial) and swept-sine method.

Advantages of Swept-sine Compared to MLS:

MLS measurement technique uses a Maximum Length Sequence (MLS) as the excitation signal. MLS is a deterministic binary sequence with frequency characteristic of white noise. Similar to swept-sine, MLS technique uses deconvolution in the analysis part.

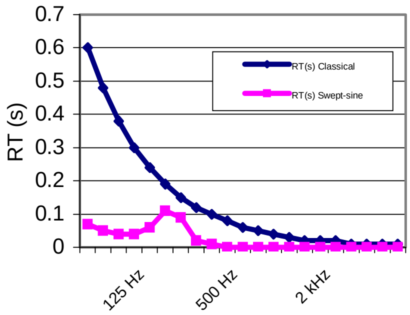

Figure 7. Minimum reverberation times

However swept-sine technique has number of advantages over MLS. Some of advantages are:

- Immunity against harmonic distortion
- Higher excitation level might be used
- Robustness against time-variance

With swept-sine techniques higher loudspeaker output levels can be used. This will result in higher level of excitation signal (highly desirable feature as it increases SNR) but may also cause harmonic distortion due to the non-linearity of the loudspeaker. This distortion will appear in impulse responses obtained by MLS and swept-sine in two different ways. In an MLS measured response, the distortion will appear as spurious peaks. This reduces the SNR and may deteriorate the measured IR in such an extent that it limits the applications.

On the other hand, when the impulse response is measured with the swept-sine technique, the effects of harmonic distortion can be completely removed. Use of linear deconvolution makes distortion components appearing at the “negative” times in measured impulse response and these components can be removed by windowing. This useful feature also makes it possible to reduce the size and weight of the excitation loudspeaker.

Robustness Against

Time-variance

In order to increase SNR, MLS measurement might consist of several consecutive synchronous measurements whose results are averaged. This approach indeed increases SNR but it also increases sensitivity to time variance. Time variance typically occurs due to variations of speed of sound as a consequence of changes in humidity, temperature or wind speed. This seriously limits the application of MLS technique for outdoor measurements.

As a contrast to this, swept-sine measurement consists of a single measurement, therefore synchronous averaging is not used, which dramatically increases robustness against time-variance as depicted in this example.

The variations in speed of sound are simulated by use of variable delay line. Two groups of measurements are made. One group is made using Norsonic real time analyser Nor840 with MLS and the other by Nor121 with Swept-sine. Each group consists of 2 measurements one with and one without simulated variations of speed of sound. Leq values of reverberant decay are compared.

The figure 8. contains reverberant decay with simulated time-variance. It can be noted that the level of background noise is increased by approx. 25 dB compared to decay in figure 9. where results were obtained without simulated time-variance.

The screenshots in figures 10. and 11. are results of swept-sine measurement. Performing the same comparison on those decays leads to no noticeable increase of background noise level, which leads to conclusion that swept-sine is the method of choice for outdoor measurements.

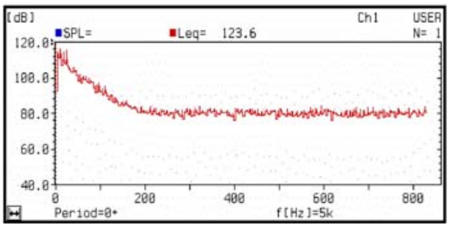

Figure 8. Squared impulse response, MLS with simulated time variance

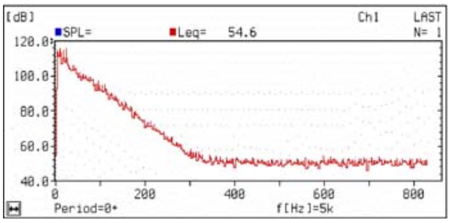

Figure 9. Squared impulse response, MLS

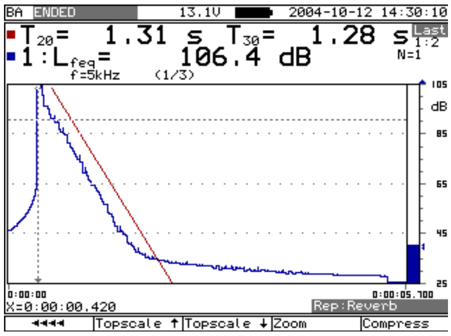

Figure 10. Squared impulse response, Swept-sine with simulated time variance

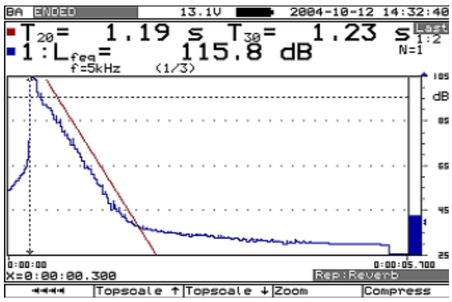

Figure 11. Squared impulse response, Swept-sine

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