Application Note

Measurement of Extremely Low Sound Pressure Levels

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Measurement of extremely low sound pressure levels is important for many applications. It may be used to describe the acoustic environment in recording studios, auditory rooms, concert halls and sound-insulated rooms. It may also be used for the measurement of noise emissions from quiet machinery and equipment such as lighting-armatures.

Traditional Level Measurements

Sound pressure levels are normally measured by the use of a single measurement microphone connected to a sound level meter or a sound analyser. The lowest sound pressure that can be measured with this configuration is limited by the inherent noise of the microphone, preamplifier and instrument.

Summary

Sometimes we want to measure sound pressure levels lower than the inherent noise in our sound level meter. This may be done by the use of two measurement channels and correlation technique. Levels below 0 dB may be measured with ordinary measurement microphones. This application note describes how the Norsonic realtime analyser Nor-840 may be configured for the measurement.

Most high-quality sound level meters and analysers with normal ½" measurement microphones have an A-weighted noise floor in the range 14–20 dB re 20 μPa. At the cost of reduced environmental stability, a 1" microphone system with a noise floor just below 0 dB is available. For the time being this represents the limitations of the traditional measurement technique.

The inherent noise of the measurement system adds to the level to be measured. Even if the noise level is known and compensated for, a satisfying measurement can only be done for levels 2–5 dB above the noise floor.

Level Measurements Based on Correlation Technique

The inherent noise limiting the lower end of the measuring range is normally the random noise in the electronic circuitry and the resistive part of the impedance of the microphone. This means that if the same acoustic field is measured with two identical measurement systems, an identical noise process will limit the measurements. The signals from the two noise processes will, even if they are of equal size, be independent and uncorrelated. However, the signal component originating from the acoustic field will be identical and

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thus fully correlated. Hence, the acoustic signal and the noise may be separated by the application of correlation techniques.

The sound pressure level is traditionally based on the root-mean-square (RMS) value of the microphone signal. When the microphone signal is measured with two identical microphones, an alternative definition may be formed based on the product of the microphone signals.

Let the microphone signals be s_1 and s_2:

$$s_1(t) = p(t) + n_1(t)$$
$$s_2(t) = p(t) + n_2(t)$$

p(t) is the pressure signal from the acoustic field, $n_1(t)$ and $n_2(t)$ is the noise in the microphone systems for channel 1 and channel 2, respectively. It is assumed that $n_1(t)$ and $n_2(t)$ are statistically independent and thus uncorrelated. Let p_0 be the reference pressure for the level calculation. The level from the combined signal may therefore be defined as:

$$\hat{L} = 10\log\left\{\frac{\overline{s_1(t)s_2(t)}}{p_0^2}\right\}$$

As the signal and the noise components, as well as the two noise components are mutually independent, the expected value of this level will be the normal level:

$$\hat{L} = 10\log\left\{\frac{\overline{p^2(t)}}{p_0^2}\right\}$$

Since the noise components $n_1(t)$ and $n_2(t)$ are removed by averaging, we can therefore measure levels far below the inherent noise level of each microphone. The expected value is obtained by averaging over the measurement time. Longer measurement time will enhance the noise reduction until limited by hum or other correlated components in the measurement chains.

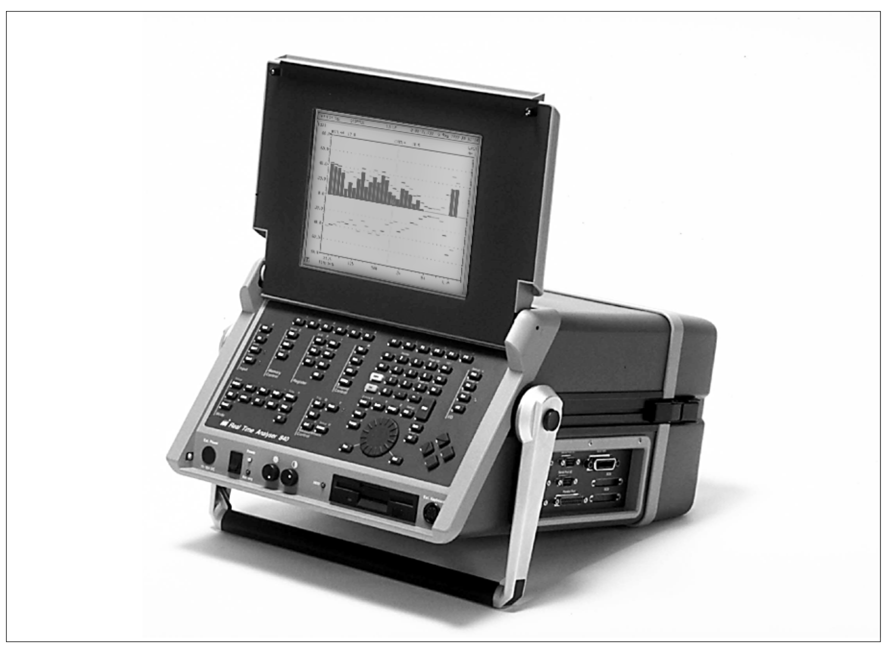
Microphones

The microphones shall be placed so they observe the same acoustical field signal. This may be done by placing the microphones face-to-face like the configuration used for sound intensity measurement. The diaphragm of the microphones shall be close together relative to the wavelength of highest frequency of interest: Less than a quarter of the wavelength is a useful guidance. A distance less than 5 mm will therefore suite normal sound level meter applications. For lower frequencies, the microphones may also be placed in a side-by-side configuration.

Normal ½″ measurement microphones like Norsonic Nor-1220 or Nor-1225 may be used. These have a sensitivity of 50 mV/Pa. In general, the use of less sensitive microphones cannot be recommended.

Unlike the situation for sound intensity measurement, this application has very relaxed requirements to the phaseresponse of the microphones. Therefore, there is no need for a tight phase matching between the microphones. The microphones should, however, be of same brand and type.

The dual preamplifier holder Nor-1264 permits a continuous adjustment of the microphone spacing



The real time analyser Nor-840 can be equipped with the optional pu (pressure-velocity) probe extension providing support for intensity measurements with pu- probes. This extension can be used to measure extremely low sound pressure levels by means of correlation technique – see the text for details.

Using the Nor-840 Analyser

A real-time analyser equipped with pu-intensity extension (pressure / particle velocity) turns out to be a very convenient instrument for the measurement of low levels with the described two-microphone method.

This extension is found in the Nor-840 when equipped with option 6. The normal filters and weighting networks in the analyser are used to obtain weighted levels as well as results with the selected frequency resolution.

The real time analyser Nor-830 may also be used. Note, however, that the following detailed description is restricted to the Nor-840 only.

Calibration

The Nor-840 analyser equipped with option 6 and set in the *pu-mode* of operation, has been designed for the measurement of sound intensity. The pressure probe is then connected to the channel 1 input and the particle velocity probe to channel 2.

Due to the difference in reference level for a velocity and a pressure transducer, channel 2 must be calibrated with an offset of 52,04 dB ($20\log\{2\times10^{-5} / 5\times10^{-8}\}$) to obtain correct readings for applications where both channels are connected to a pressure microphone.

Although the preamplifiers may be connected to the socket for the intensity probe, the following description is based on the use of the normal microphone sockets, one for each channel.

Do as follows:

1. Connect the first microphone to the input sockets for channel 1 (The normal microphone socket) and the second microphone to the input socket for channel 2. Set the instrument in “Level mode” and select Microphone input in the Input menu. If appropriate for the measurement, set the optional highpass filter to 20 Hz in both channels as this may reduce the risk for overloading the input with low-frequency noise. Both channel must have the same filter setting
2. Let the instrument be in “Level mode” and make a normal level calibration by applying a sound calibrator to each microphone. Note the sensitivity values, for example –26.3 for channel 1 and –25.8 for channel 2
3. Set an appropriate measurement range. Normally this will be the lowest possible fullscale value not giving overload for the actual measurement signals
4. Set the instrument to “Sound Intensity Mode”
5. Select “Measurement Set-up” and select pu-probe, frequency range (e.g. 20–20000 Hz) and frequency resolution (e.g. ⅓ octave) and measurement time (e.g. 30 sec). The setting of the area for the L_W does not matter, but may be set to 1
6. Press the calibration key and set the sensitivity value for channel 1 to the value obtained by the level calibration (for example –26.3). Set the sensitivity for channel 2 to the value obtained from the level calibration plus the value 52.0 dB (for example –25.8+52.0 = +26.2).

Making the Measurement

1. Select the appropriate display. We will recommend the following setting during the measurement:

Upper display:		**Lower display:**	
Curve 1:	SIL (5)	Curve 1:	Ieq (2)
Curve 2:	Off (0)	Curve 2:	Off (0)
Curve 3:	SPL (4)	Curve 3:	Leq (1)

2. Press **START** to begin the measurement.
3. Use the value labelled Ieq as the measurement result. The value designated Leq will be a traditionally measured level for the microphone connected to channel 1.
4. Select the numeric display in the upper part of the screen after the measurement to view the results more conveniently. The noise improvement may be seen by reading the PI-index which is the difference between the Leq-value (traditional measurement) and the Ieq-value (correlation method).
5. If the distance between the microphones is too large, this will show up as a too low Ieq value or even a value with a negative intensity direction. The value shall always, for a proper measurement, have a positive intensity direction. Note that an intensity display has two signs, one for the intensity direction and one for level above or below the reference level. This correlation technique allows you to measure levels below the reference level. The result may therefore often be a negative level.

References:

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