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Development of acoustic measurement instruments by Norsonic - a historical overview

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ABSTRACT

The paper describes the start of the Norwegian manufacturer of acoustic instrumentation in 1967, Norsonic AS, and some of the company's first instruments for acoustic measurements.

Keywords: History, acoustic measurements, Norway.

1. INTRODUCTION

Norsonic has since its foundation in 1967 supplied acoustic instrumentation in Norway and worldwide. In addition to the development, manufacturing, and marketing of acoustic instrumentation the company also operates the only accredited calibration laboratory in Norway for acoustical quantities. The position of Norsonic's accredited laboratory status is put in context with the acoustics laboratory at NTH/NTNU in Trondheim which previously upheld a similar status. This historical overview is partly based on a previously published overview of Norsonic's history [1], [2]. The first author has been with the company since 1971 and has thus participated in most of the development over the years.

2. THE START

The company was founded in 1967 as Nortronic AS, but the start goes back to 1965 when the Norwegian Commission for aircraft noise requested an instrument for the measurement of "Perceived Noise Level" or PNdB, a unit developed to show the perceived annoyance from jet airliners. The audio physicist at Oslo University Hospital, Gordon Flottorp, was the chairman for this commission. An ISO recommendation described the calculation procedure based on octave-band analysis. The request was put to Central institute for industrial research (CIIR). The institute, owned by the Council of Norwegian Science and Research (NTNF) was founded after the Second World War in order to build up the post-war country. The institute is today a part of SINTEF. The institute developed an instrument based on analogue, and partly nonlinear computations to replace the time-consuming, manual calculation of the PNdB level. The value was presented directly on a meter in real time and a voltage output allowed the levels to be recorded by a y/t recorder. The leader of the department at the institute doing the instrument development was Asbjørn Nordby, who was later appointed the first CEO of Norsonic and Håkon Bjor, brother of the first author, was one significant member of the development staff.

After a successful development, the CIIR tried to find companies for the manufacture and marketing of the developed analyser, since it was assumed that there was a market for such instruments also other places than at Fornebu, at that time the main airport for Oslo. No response was obtained from the industry, and after some time parts of the development team headed by Asbjørn Nordby decided to start a new company for the purpose. In opposition to how research institutes today in general encourage the development of new companies, CIIR was sceptic but accepted to transfer the knowledge since no other had showed interest. The company, named Nortronic AS, was founded 1. March 1967 as a joint-stock company with a stock-capital of NOK 10.000, the first year without any employees.

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One main marketing activity was a full-page announcement in “Flying Review” leading to a request to demonstrate the PNdB calculator for British Aircraft Corporation (BAC) developing the supersonic transport aircraft Concord. Asbjørn Nordby and Håkon Bjor went to Bristol for the demonstration on a low fair travel budget. They received an order for NOK 70.000 the same evening and rumours tells that they immediately changed to a better hotel that had just been opened by the queen of England.

3. THE “SAMPLING FILTER”

Although BAC was very satisfied and ordered one additional unit the next year, the market did not develop as hoped. This was mainly due to two factors: a simpler frequency weighting method (D-weighting) was developed for general monitoring of aircraft noise, and for aircraft certification, the octave-band analysis was replaced by one-third-octave analysis. The company therefore looked for alternative products. A patent devolved by Håkon Bjor (still at CIIR) to control the frequency of active filters over a broad frequency range, was developed for use in different products. It was a central part of several instruments in the following years, such as tracking oscillators and filters. The method was named “sampling filters” although the important issue was that the effective value of resistors in an “RC-circuit” was controlled by the on/off ratio (duty-cycle) of a high-frequency switch in series with each resistor in the RC-network. In this way, the frequency of a filter or an oscillator could be varied up to four decades with high accuracy.

4. INSTRUMENT TYPE 811 – THE DOOR-OPENER

The first international accepted instrument, next to the PNdB-instrument, was the instrument type 811 for building acoustic measurements, such as airborne and impact sound insulation in buildings including the measurement of reverberation time. This single instrument replaced several heavy instruments normally used for such measurements. It was especially important to replace the level recorder which alone had a weight of more than 20 kg. A postulate from the acoustic consultant Gunnar Nesheim was in general accepted: All acousticians have a painful back!

Instrument type 811 included a band limited noise generator, a 1/3- or 1/1 octave band filter, a digital true RMS level detector developed during the M.Sc. thesis of the author, and an analogue reverberation time calculator. The frequency range was from 50 Hz to 10 kHz. This instrument was very well accepted in the European market and was really a door-opener to the German market when it was demonstrated at the Electronica exhibition in München in 1972. This instrument later received a gold medal at an exhibition in Leipzig in 1974. The instrument was developed after discussing the performance requested by early acousticians, such as Gordon Flottorp, Asbjørn Krokstad, Tor Erik Vigran and Wilhelm Løchstøer. One of the challenges with analogue instrumentation was to square a signal with the large dynamic range normally found in acoustics. If the amplitude varies in a range 1:1000, the square has a range 1:1000 000. In the instrument, this was solved with a digitally controlled amplifier to normalize the signal before squaring. The needed amplificant then indicated the RMS-value of the signal. The value of the level and the reverberation time were presented on a digital display – quite modern at that time. Still the instrument needed to have an analogue display with a pointer since the standard for sound level meters only specified analogue meters with a specified minimum size!

However, after the well-received introduction, it was requested by a new German standard to step the octave filter in half-octave steps. This was not foreseen by the construction and looked like a real obstacle for further sales. Due to the application of the “sampling filter”, the problem was solved one late evening by a switch and a resistor which shifted all frequencies by one half octave. The instrument was in production from 1972 to 1982.

Figure 1. Asbjørn Nordby demonstrating instrument 811 after receiving gold medal for the instrument in Leipzig (1974)

5. REVERBERATION DECAY SHOWN GRAPHICALLY

The next important instrument was type 823 introduced in 1980, a replacement for type 811. This was also a serial analyser mainly for building acoustic applications. The instrument was controlled by a microprocessor and the "sampling filters" were replaced by digitally controlled analogue filters, and most important: the results were presented on an integrated video monitor which allowed the reverberation decay to be displayed graphically. The instrument had two measurement channels so the level in the source and the receiving room could be measured simultaneously. Most parts of the instrument, except the graphical screen, were developed through a special delivery of a four-channel instrument to NTNU/Acoustic Laboratory in Trondheim in 1976. The application of the programmable 4-bit and 8-bit microprocessors had started some year earlier in a control unit for type 811 and additional instruments like a microphone multiplexer. The development of programs for the microprocessor was demanding at that time, the code was stored as rows of up to eight holes punched on a paper tape. It was very time-consuming to make even small changes in the low-level code. The instrument was manufactured in the years 1981 to 1990.

Figure 2. The first portable computer of the Acoustic laboratory NTNU, for control of the 4-channel custom-built analyser made by Norsonic. Vigran and Sørsdal (NTNU/Sintef) are seen in the background, Krystad from Norsonic operates the computer.

6. REAL TIME ANALYSER AND SOUND INTENSITY

The analysers 811 and 823 could only measure one frequency band at the time. The first instrument measuring all frequency bands simultaneously was RTA830. Such analysers are normally called "real-time analysers." The instrument had two measurement channels. In addition, the instrument was intended for the measurement of sound intensity where one channel was used for the sound pressure and one for the particle velocity. The company received official research funding from the Council of Norwegian Science and Research (NTNF) for the development of the analyser and the accompanying microphone system for sound intensity named 216.

The development started around 1980 and the first instrument was delivered in 1984. At that time, no digital signal processor was available, and the instrument was therefore based on the use of ordinary logical components. Digital signal processing normally makes use of additions and multiplications. Without a signal processor, multiplications were very demanding and a table look-up involved a large, two-dimensional table. The solution was to use a logarithmic number system with an additional sign-bit. Due to the number system, multiplications were replaced by simple additions. However, the linear addition of the logarithmic values was difficult. The problem was solved like how an acoustician adds levels in dB: Take the largest value and correct for the difference between the numbers. The correction could be made with a small, one-dimensional table. The application of the logarithmic number system was very efficient and led to a very compact instrument and low power consumption compared to other real-time analysers at that time.

Sound intensity may be calculated from the observation of sound pressure and sound particle velocity. The pressure was measured with an ordinary pressure microphone but the particle velocity was measured by two pairs of ultrasonic transducers. The transducer system, named 216, was one of few transducers measuring the particle velocity directly. The first unit was introduced in 1985.

The speed of blowing air adds to the speed of sound traveling in the same direction. The particle velocity may be considered as an alternating airflow. By having two pairs of ultrasonic transducers sending the ultrasound in two opposite directions, an airflow will reduce the transmission time for one set and increase the transmission time in the other. This was the principle for measurement of sound particle velocity in the intensity probe 216, where the difference in transmission time was measured as a phase difference between the sets of ultrasound transducers. The challenge by the measurement principle was that the particle velocity in a sound wave is very, very low compared to the normal speed of sound. The distance between the source and receiver for the ultrasound was 30 mm limiting the upper frequency range to 6,3 kHz.

Although the probe hardly was an economic success, it was technically interesting, and made a good job for promoting the dual channel analyser. The probe 216 was manufactured in the period 1985 to 1992.

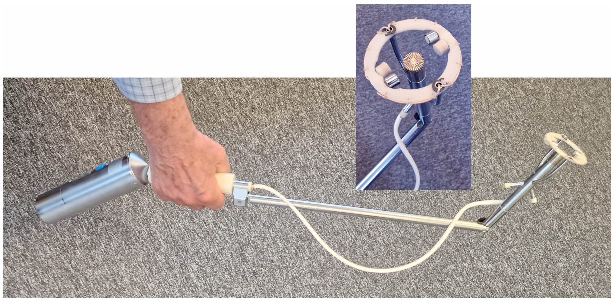

Figure 3. The sound intensity probe 216.

FFT-analysis was also introduced as an option in the RTA 830 instrument. In cooperation with Volkswagen AG, the real time analyser was adapted to the measurement of noise from vehicles in a system called VNA 836. Photo-detectors and a radar logged the position and speed of the car.

7. MLS AND HADAMARD

The successor of 830 was named 840 and introduced in 1992, again a dual channel real time analyser with a frequency resolution down to 1/12-octave and this time with a colour screen to display the results. At this time digital signal processors were available, and the logarithmic number system, successfully applied in 830 analyser, has never since been used by the company. The introduction of the processors solved a lot of problems from the time of analogue instrumentation like squaring of a signal with a wide dynamic range.

With TRA 840, the MLS-technique was introduced. A maximum-length-sequence (MLS) is a signal appearing in the number theory. The technique allowed the impulse response of a transmission system to be obtained by processing the response of the noise-like MLS-signal by a very efficient algorithm: Fast Hadamard transformation. The technique, although then not yet allowed by international standards, improved the measurement accuracy of reverberation time and airborne sound insulation. Even situations where the measurement signal was buried in noise could be measured.

8. REQUEST FOR SMALLER INSTRUMENTS

In addition to the more sophisticated instruments, there were demands for smaller, hand-held sound level meters. The first, Nor110, launched in 1988, was not really small, but battery operated and powerful and could do frequency analysis.

A further development was the dual channel instrument Nor121 launched in 1998. The instrument was the first of our instruments with the ability to not only measure, but also to record the microphone signal digitally. The user could then after the measurement listen to the noise event. The instrument was used for general noise measurement, for reporting the annoyance from noise, and for building acoustic measurements. The instrument was the first instrument from Norsonic to apply the swept-sine method. This technique has mainly the same applications and features as the MLS-technique, but is more robust to distortion in the transmission channel and to fluctuation due to temperature and wind. Experience from the development was used to create a new ISO standard 18233: “Acoustics - Application of new measurement methods in building acoustics” (2006) which describes both MLS and swept-sine methods. This instrument was later developed to be an instrument for measuring noise during periodic test of cars (EU-control), Nor117. It had the ability to measure the rotational speed of the engine by analysing the sound from the car.

The next small instrument, Nor116, was a step back to microprocessor controlled analogue circuitry. It measured simultaneously A-weighted equivalent SPL and C-weighted peak SPL and was therefore a typical sound level meter. The company had then expanded the range from low-volume sophisticated instruments to a higher volume market. The analogue signal processing in the instrument applied the logarithmic ratio between the voltage and current in a semiconductor diode for squaring the signal to obtain the RMS-value.

The successor of 116 was an instrument with the same small size, but applying digital signal processing, Nor 118. This allowed real time frequency analysis in 1/1-octave and third-octave bands to be included together with additional functions such as the measurement of reverberation time. Except from being a one-channel instrument, the functionality of the real time analysers Nor830 and Nor840, was achieved in a small hand-held, battery-operated instrument. The technology was developed and brought to the next generation, Nor140, that was still a very successful instrument.

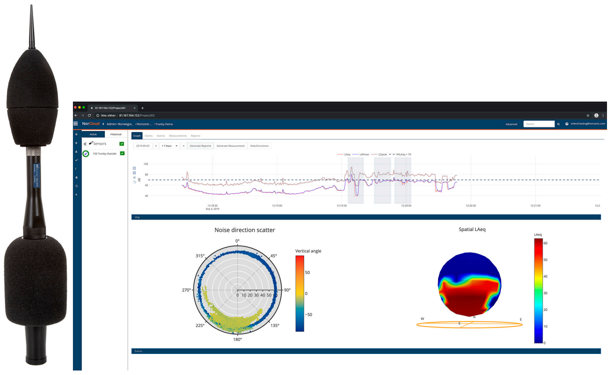

Figure 4. Example of later developments of instrumentation from Norsonic. A conventional outdoor microphone is supplied with the "Noise compass" (lower part) indicating the direction to the dominant sound source. The three-dimensional direction is obtained from 8 microphones in the lower part. AI may be used for identification of the type of noise.

9. RELYING ON THE CONDENSER MICROPHONE

During the history of Norsonic, the transducer for sound has mainly been the ½ inch condenser measuring microphone. It is impressive that this transducer has survived this long time-span without significant changes. The production method has improved and electrets have partly replaced the externally supplied polarization voltage, but the specifications have not changed significantly. However, the electronic system measuring and analysing the output voltage from the microphone has had an enormous development as indicated above. Today, for most applications, an analogue to digital converter measures the signal from the microphone directly and all signal analysis is done by digital circuitry.

10.NORSONIC CALIBRATION LABORATORY

Norsonic started to manufacture sound calibrators in 1995. This also raised the question on how to secure the quality of the calibration. The work for establishing traceability to internationally recognised references, led to the creation of Norsonic Calibration Laboratory. The laboratory was accredited by Norwegian accreditation first time in February 1999. Since Norwegian Accreditation is one of the signatories to the EA Multilateral Agreement for mutual recognition of calibration certificates (European Co-operation for Accreditation), calibrations done by the laboratory have a worldwide acceptance. The laboratory is still the only accredited calibration laboratory for acoustical quantities in Norway. The position of Norsonic's accredited laboratory status is put in context with the acoustics laboratory at NTH/NTNU in Trondheim which previously upheld a similar status. The service is open for equipment from different manufacturers.

11.INTERNATIONAL STANDARDIZATION

It has always been important for Norsonic to design instruments fulfilling current international standards. The history back to the PNdB-calculator showed how important it is to be prepared for changes in the standards for instruments and measurement methods. Since the first part of 1980 the company has participated in the development of National and International standards through ISO and IEC.

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