CONEQ

# Overview of the CONEQ™ Technology

The Acoustic Power Frequency Response
Measurement and Equalization Technology

January 20, 2012

real sound lab

# TABLE OF CONTENTS

## ABSTRACT

CONEQ™ (pronounced /'kɒnek/) is a patented technology for measurement and equalization of loudspeakers and other electro-acoustic transducers. The CONEQ™ technology is unique in that the acoustic power frequency response of the transducers is measured and used to derive the equalization filters. The technology is developed by Real Sound Lab SIA.

The current document gives an insight into the history and future of the CONEQ™ technology as well as provides basic theoretical background to allow experts evaluate the technology.

## HISTORY

The inventor of the CONEQ™ technology is Latvia-born Raimonds Skuruls. He has worked as a sound engineer, notably with Latvian pop legends Jumprava, and has spent most of his life looking at better sound reproduction from loudspeakers. Having a degree in electrical engineering, Skuruls has a unique mix of knowledge and experience that led to creation of what is now known as CONEQ™. In 2004, Skuruls together with investor Viesturs Sosars formed Real Sound Lab SIA. Since then Real Sound Lab SIA has been developing the technology further, manufacturing CONEQ™-enabled products for professional audio market as well as licensing the technology for use in consumer electronics devices like TVs, personal audio systems, and virtually any other device that has a loudspeaker.

## CONEQ™ TECHNOLOGY OVERVIEW

The CONEQ™ technology is applied in three steps:

- A precise measurement of the acoustic power frequency response (APFR) of the loudspeaker is done;
- A filter is produced, that equalizes the unevenness of the measured APFR;
- The filter is applied in any of the compatible hardware or software products.

> ***IMPORTANT!*** *The acoustic power frequency response is used as the basis for equalization because the goal of the equalization is to make the loudspeaker emit the acoustic energy spectrum proportional to the original sound source.*

The focus on the emitted acoustic power rather than on the frequency response at the listening position(s) is what differentiates the CONEQ™ technology from any other measurement and equalization technology.

> ***IMPORTANT!*** *CONEQ™ is a speaker equalization system, not a room correction system.*

With CONEQ™, a violin recording in a subway station will sound like a violinist playing in a subway station, rather than in a concert hall or elsewhere.

# ACOUSTIC POWER FREQUENCY RESPONSE

Acoustic power generated and radiated by a sound source characterizes and quantifies it, independently from the environment. Measurement of the acoustic power is done routinely while measuring the machinery noise [1], [2]. The measurement is performed by gathering sound pressure values at many points on a surface around the sound source and the acoustic power is calculated, using the equation 1 [1, p. 3].

$$W = \sum_{i=1}^{n} \frac{p_i^2}{\rho c} dA \tag{1}$$

Here the surface over which the acoustic power $W$ is calculated is split in $n$ equal sub-surfaces, each with area $dA$, and $p_i$ is the RMS sound pressure in the sub-surface $i$. The variables $\rho$ and $c$ characterize the physical environment (the density and speed of sound, respectively).

The CONEQ™ technology applies the same principle of gathering sound pressure readings and corresponding frequency responses from many points on a surface around the loudspeaker. A single acoustic power frequency response over the measurement surface is calculated from the measured frequency responses according to equation 2.

$$APFR(f) = \sum_{i=1}^{n} FR_i(f)^2 \tag{2}$$

Here $APFR(f)$ is the acoustic power frequency response value for frequency $f$ and $FR_i(f)$ is the magnitude frequency response value for frequency $f$ at the measurement point $i$. Figure 1 shows frequency responses of individual points of a CONEQ™ measurement and the corresponding calculated acoustic power frequency response.

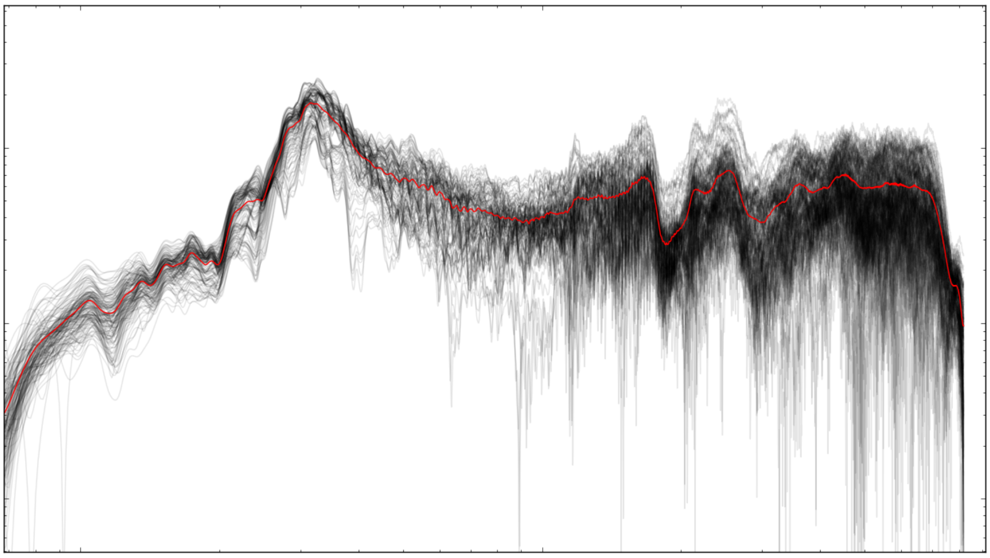

*Figure 1: Sound pressure level measurements (gray) and the corresponding calculated acoustic power frequency response (red).*

# THE CONEQ™ MEASUREMENT PROCESS

Proper measurement is instrumental in ensuring that CONEQ™ technology delivers accurate, repeatable, and trustworthy results.

## MOVEMENT OF THE MICROPHONE

In CONEQ™ technology, to gather information in many (100 to 300) points in reasonable time (e.g. 180 points in one minute), a test signal is played repeatedly and the microphone is moved during the measurement across the surface over which the acoustic power frequency of the loudspeaker is to be determined. The used test signal, a custom logarithmic sweep, allows calculating frequency response at each measurement point even in environments with high level of ambient noise.

***IMPORTANT!*** *In CONEQ™ measurements the microphone must be moved across the measured surface during the measurement.*

Figure 2 shows an example of the measurement surface and the path of the measurement microphone when measuring a loudspeaker on a stand.

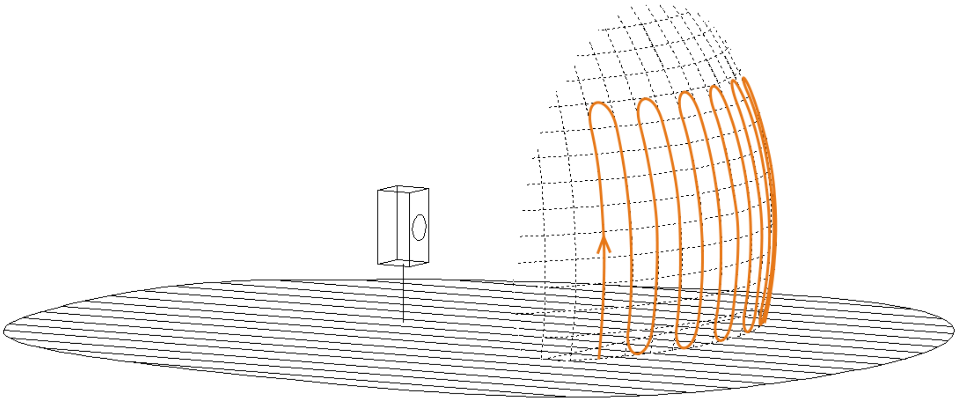

*Figure 2: The CONEQ™ measurement surface and microphone path when measuring a loudspeaker on a stand.*

## MEASUREMENT DISTANCE

The equation 1 is valid for measurements over surfaces where it can be assumed that the direction of wave propagation in every point of the surface is perpendicular to the surface and the sound intensity can be calculated as $p^2/\rho c$. This is exactly true only for ideal plane or spherical waves but in general case the sound intensity is calculated according to equation 3 (see [1, p. 62-63]).

$$I_n = pv_n\,cos(\phi) \tag{3}$$

Here $I_n$ is the sound intensity in the direction $n$ that is perpendicular to the measurement surface, $p$ is the RMS sound pressure, $v_n$ is the RMS sound particle velocity in direction $n$, and $\phi$ is the phase angle between pressure and velocity.

The lower is the measured frequency the larger the distance at which the phase angle can be disregarded and the equation 1 can be used. From the theoretical studies of spherical noise sources mentioned on [1, p.63], it can be concluded that the obtained sound power has an error of less than 0.5 dB when the phase angle $\phi$ between sound pressure and particle velocity is less than about $27°$. The frequency-dependent measurement distance that corresponds to such angle can be calculated using equation 5.

$$r * \frac{2\pi f}{< speed\, of\ sound >} = 2.5 \tag{4}$$

$$r = \frac{136.555}{f} \tag{5}$$

Here $r$ is the measurement distance in meters and $f$ is the lowest frequency in Hz where the calculated acoustic power frequency response will be accurate to 0.5 dB.

Typical driver displacement distances of loudspeaker drivers and loudspeaker frequency response correlation to loudspeaker size allow statement of the following empirical rule of thumb for the measurement distance:

***IMPORTANT!*** *Good CONEQ™ measurement results are obtained if measurement is done at a distance that is between one and two times the largest dimension of the measured loudspeaker.*

## SURFACE OF THE MEASUREMENT

Choice of the measurement surface determines the area over which the acoustic power will be calculated and subsequently equalized. The choice of the surface together with the measurement distance also determines how much of the room reflection characteristics will be compensated for in the generated filter. CONEQ™ is intended to be a loudspeaker equalization system and the room treatment is typically left for other tools (and materials). Sometimes, though, it may be possible and beneficial to correct for the room influence on the perceived sound.

Depending on the environment there are several distinct cases which require different measurement surfaces.

### Free-field extreme

As the first case let's examine a situation where a loudspeaker is put in a free-field environment (anechoic room or suspended in the air outdoors). Then the only sound that would reach the listener would be that which is radiated exactly towards them. This case shows one important principle – there is no need to measure and equalize the sound that never reaches the listener. Thus, in this case, the measurement surface would be a small patch between the loudspeaker and the listener.

### Diffuse-field extreme

Another extreme case is a small very reverberant room (e.g. reverberation chamber). The sound radiated by the loudspeaker in any direction will quickly reach the listener through reflections from the walls, floor, and ceiling. In this case the measurement surface should be a complete sphere around the loudspeaker.

### A free-standing loudspeaker

For a loudspeaker that is free-standing inside a room and has no sound reflecting surfaces nearby (e.g. on a pole and away from walls), the sound radiated in any direction from it will eventually reach the listener through reflections from the walls, floor, and ceiling. In this case the measurement surface could be a complete sphere around the loudspeaker just like in the case of the diffuse-field extreme. However, due to the directivity of the loudspeakers, location of the listeners, and absorptive characteristics of the materials in the room, the sound that will have travelled much farther than the direct sound to reach the listeners will not only be attenuated by 6dB on every doubling of distance but will also be partially absorbed at each reflection.

> ***IMPORTANT!*** *The task is to equalize that portion of the total acoustic energy coming from the loudspeaker, which constitutes dominant portion of the acoustic energy that arrives at the listeners position(s). This task cannot be resolved by measuring at the listeners' position because that would compensate for the room influence which is contrary to the principle of CONEQ™ to equalize the sound source.*

For typical loudspeakers, a good rule is to measure over its manufacturer-specified coverage angle. If we were to measure on a full sphere around the loudspeakers then the results would show lack of high frequencies due to directivity of the loudspeakers. If the manufacturer-specified coverage angle is unknown, move your head sideways until you hear a significant loss in high frequency content and mark where the boundary is and do the same for the up-down direction.

> ***IMPORTANT!*** *For a typical loudspeaker, measure over its manufacturer-specified coverage angle.*

### Presence of a reflective surface

If there is a sound-reflecting surface near the loudspeaker (e.g. the floor) then sound is reflected off the surface, creating a secondary virtual loudspeaker on the "other side" of the surface.

In this case the two loudspeakers (the real and the virtual one) must be measured as a single system. It is not possible to measure below the floor or inside the wall but the measurement surface must be extended to touch the reflective surface.

### MEASUREMENT MICROPHONE

The CONEQ™ measurements should be performed with an omni-directional measurement microphone. During the CONEQ™ measurement, microphone should be held pointing towards the loudspeaker. If available, a correction for the free-field $0°$ incidence frequency response should be applied for maximum precision.

## CONEQ™ EQUALIZATION FILTERS

After a measurement is done, the CONEQ™ Workshop software generates a CONEQ™ equalization filter that can be applied to signal path by any of the hardware and software tools supporting CONEQ™ filters. Filters can also be exported and used in compatible third party products supporting FIR filters.

The CONEQ™ filters are minimum phase FIR (Finite Impulse Response) filters. The length and sample rate can be specified according to filter precision requirements and capabilities of the filter application tool.

## REFERENCES

[1] S.J.Yang and A.J.Ellison, Machinery noise measurement. Clarendon Press, Oxford, 1985.

[2] Erik Cietus Petersen, Brüel & Kjær, Denmark, An Overview of Standards for Sound Power Determination. http://www.bksv.com/doc/bo0416.pdf, retrieved 30.08.2011.