HEAD acoustics

APPLICATION NOTE

About this document

Content

This document is the first part of a series of four application notes on the sound energy quantities *sound power* and *sound intensity*. The document contains definitions of terms, the understanding of which forms the basis for the other parts of this series.

Target group

This document serves as an introduction to sound power and sound intensity and is intended for acousticians who wish to refresh their basic knowledge of this subject.

Questions?

Do you have any questions? Your feedback is appreciated!
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For technical questions on our products: SVP-Support@head-acoustics.com

Sound Power and Sound Intensity – Part 1

Definition of terms

Sound pressure

Sound pressure is the term used to describe the pressure fluctuations of the sound transmission medium. It is an alternating variable that is superimposed on the static pressure (e.g., air pressure) of the surrounding medium. The sound pressure is a scalar, i.e., an undirected variable. In the case of a spherical sound wave in a free field, the sound pressure decreases by *1/r* with increasing distance r from the sound source. If the distance doubles, the sound pressure of the spherical sound wave is thus halved.

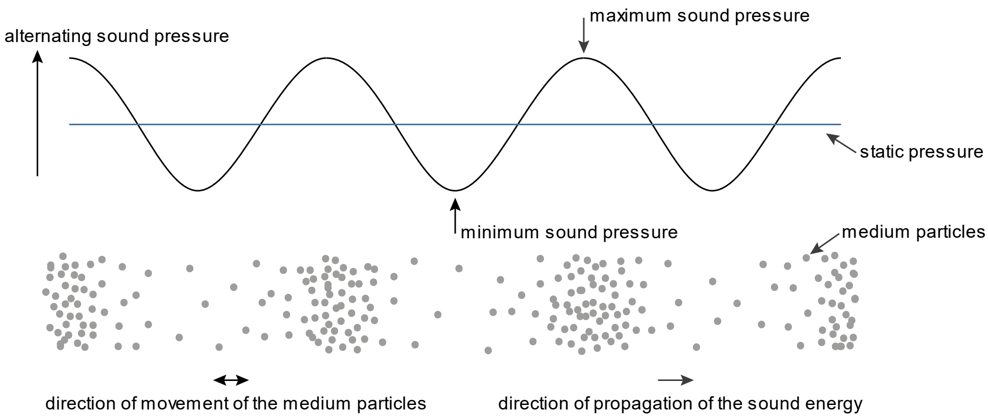


Figure 1: Motion of medium particles

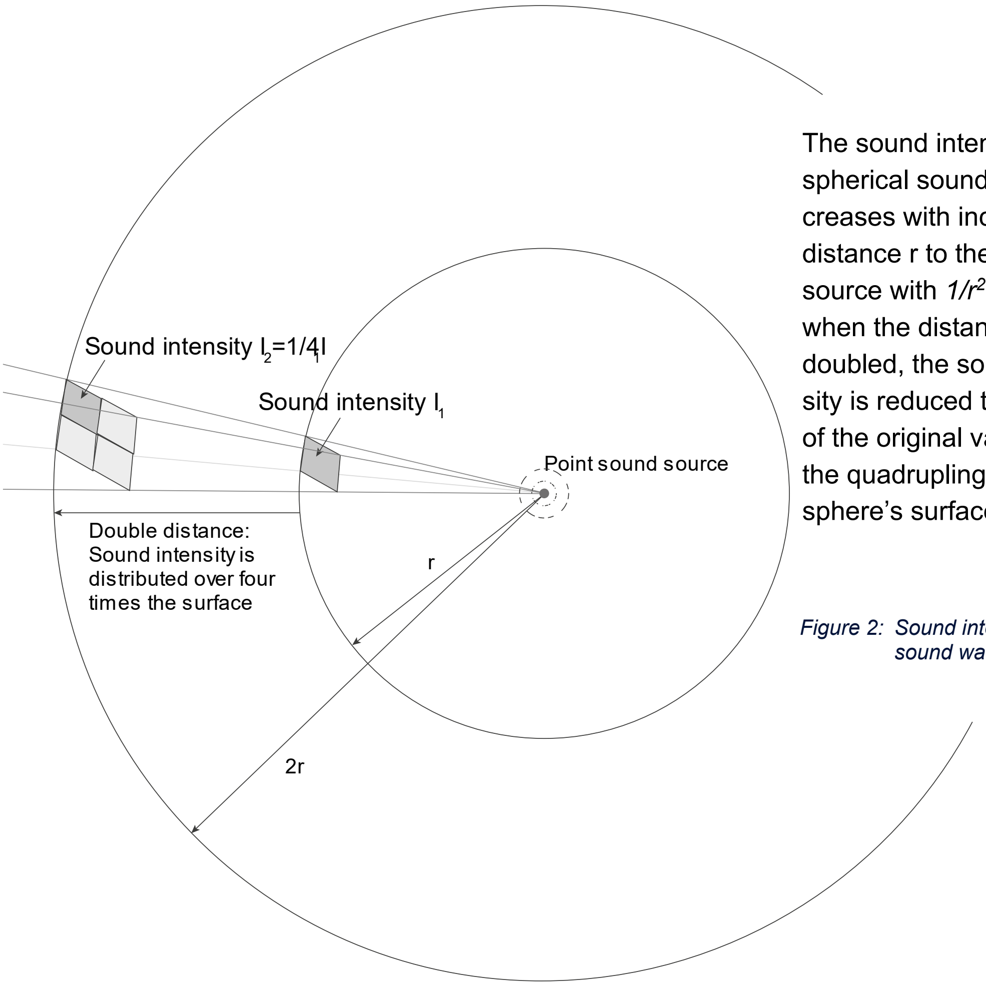
Particle velocity

The **particle velocity** is the speed at which the medium particles oscillate around their rest position (the medium particles oscillate only around their rest positions, and do not move with the sound wave). The particle velocity is a vector, directional quantity and thus has both magnitude and direction. The particle velocity is not the speed of sound which describes the propagation speed of the sound wave's energy. Usually, the speed of sound is much higher than the particle velocity.

Sound intensity

The **sound intensity** is the sound energy passing through a unit area per unit time. The sound intensity results from the product of sound pressure and sound particle velocity. Consequently, the sound intensity is a vector quantity. The energy flow in a sound field can be described with the sound intensity. The sound intensity only records the net energy flow averaged over time. Sound energy moving back and forth, e.g., in the case of standing waves, is not recorded.

The sound intensity describes a sound field at any point and can be used to determine the sound power of a sound source.



The sound intensity of a spherical sound wave decreases with increasing distance r to the sound source with *$1/r^2$*. Thus, when the distance is doubled, the sound intensity is reduced to a quarter of the original value due to the quadrupling of the sphere's surface.

Figure 2: Sound intensity of a spherical sound wave

Sound power

The **sound power** is the energy emitted by a sound source per unit time. The sound power thus describes the source strength of a sound source, not the sound field. In contrast to sound pressure and sound intensity, the sound power of a sound source is independent of the distance to the source.

Overview

Size	Unit	Definition	Description
Sound power *P*	Watts (W)	Sound energy emitted by a sound source per unit of time: $P = \frac{W}{t}$	Scalar sound energy quantity
Sound intensity $\vec{I}$	Watts per square meter (W/m²)	Product of sound pressure and particle velocity: $\vec{I} = p \cdot \vec{v}$	Vector sound energy quantity
Sound pressure *p*	Pascal (Pa)	Force per size: $p = \frac{F}{S}$	Scalar sound field quantity
Particle velocity $\vec{v}$	Meters per second (m/s)	Derivation of the deflection: $\vec{v} = \frac{\vec{\xi}}{dt}$	Vector sound field quantity

Table 1: Summary of term definitions

Sound energy quantities are used to describe a sound field or sound sources. Sound field quantities are used to describe the state of a sound field.

Specification as ratio value

To provide a better handling of the wide range of values of these quantities[1], the sound pressure level, sound intensity and sound power are in most cases given as ratio values in *dB*:

Sound pressure level L_P	$L_P = 10 \cdot log_{10} \frac{\tilde{p}^2}{{p_0}^2} = 20 \cdot log_{10} \frac{\tilde{p}}{p_0}$ $with\ p_0 = 2 \cdot 10^{-5} Pa$
Sound intensity level L_I	$L_I = 10 \cdot log_{10} \frac{I}{I_0}$ $with\ I_0 = 1 \,{}^{pW}/_{m^2}$
Sound power level L_W	$L_W = 10 \cdot log_{10} \frac{W}{W_0}$ $with\ W_0 = 1 pW$

The symbol L_P is reserved for the sound pressure level, therefore the sound power level – in deviation from the convention – has the symbol L_W.

The reference value chosen for the sound pressure level is the sound pressure that corresponds approximately to the hearing threshold of the human ear at 1kHz ($p_0 = 2 \cdot 10^{-5} Pa$).

The reference value for sound intensity is defined in such a way that the same level values result for sound pressure and intensity, when measured in the free sound field, in the direction of propagation.[2]

[1] For example, the range of values of the sound pressure between the hearing threshold and the pain threshold extends over several powers of ten.

[2] Theoretically, the values are not exactly equal, as the reference values given are rounded. The actual difference depends on the acoustic impedance of the medium in which the sound propagates. For the medium air, however, this deviation is usually negligible, unless the measurement is made at high altitude above sea level.

However, free field conditions are rarely encountered, resulting in a more or less large difference between sound pressure level and sound intensity level.

Doubling the distance to the sound source (in free field) halves the sound pressure (measured in the direction of propagation), thereby reducing the sound pressure level by 6 dB. Doubling the distance reduces the sound intensity to a quarter of the original value, thus the sound intensity level is also reduced by 6 dB. The sound power level is independent of the distance to the sound source.

Proceed to the second application note on sound power providing information on why and with which measurement methods sound power is measured.