Infrasound and ultrasound

Risks and the means of protection

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The human ear is exposed to a significant amount of various sounds and noises on a daily basis, over a wide spectral range extending beyond the frequency limits of human hearing defined between 20 Hz and 20 kHz. Although our hearing aids transmit only frequencies between these limits to our brain, our organization is potentially subject to such frequencies.

Although these infrasound and ultrasound frequencies are not perceived by the ear, they can have an impact on our hearing.

This document aims to simply explain the nature of these frequencies and the environments we are generally exposed to, to discuss their potential dangers, and finally to provide some solutions to protect ourselves.

Protection against noise
E-131.1

Table of contents

1 Infrasound

1.1 Introduction

Infrasound is defined as sound oscillating from 1 to 20 times per second (frequency of 1 to 20 Hz, Figure 1). By definition, they have a long wavelength (from 17 meters at 20 Hertz up to 340 meters at 1 Hertz) Hertz)[1].

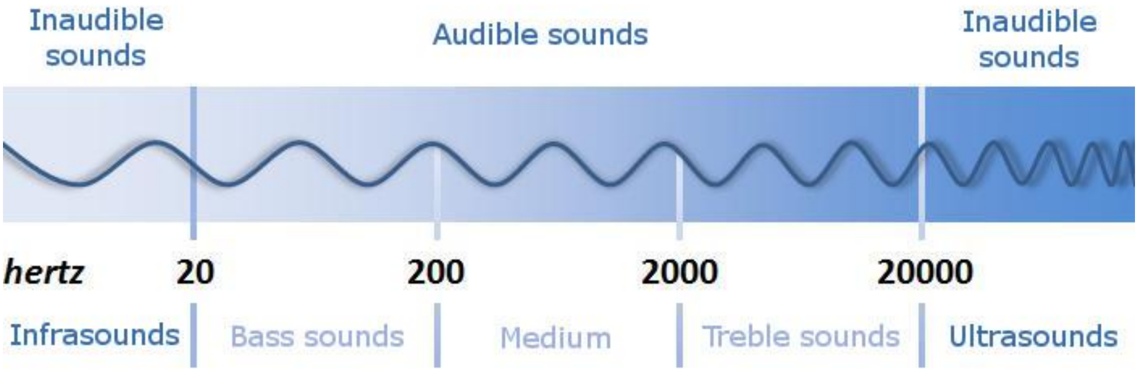

Figure 1: Categorization of frequencies that are audible and inaudible to the human ear.

A number of noise sources that are encountered naturally (large sea waves, wind, thunder, earthquake, volcanic eruption, etc.) or artificially (usually related to industrialization: rotating machines, punching machines, transportation, or explosions) are sources of infrasound [3].

Several species (elephants or whales for example) use the properties of infrasound to communicate over long distances. These waves, because of their lengths, travel greater distances before attenuating, and are reflected or absorbed with great difficulty due to their dimensions with regard to the obstacles they face.

Studies such as that of MØLLER [4] show that infrasound is not actually inaudible to humans, but that we possess perception thresholds for these frequencies that are too high to be met by natural sources. Moreover, it is possible to perceive these frequencies in mechanical or vibrotactile ways through organs other than the auditory system (skin, bone, eyeballs, organs, etc.).

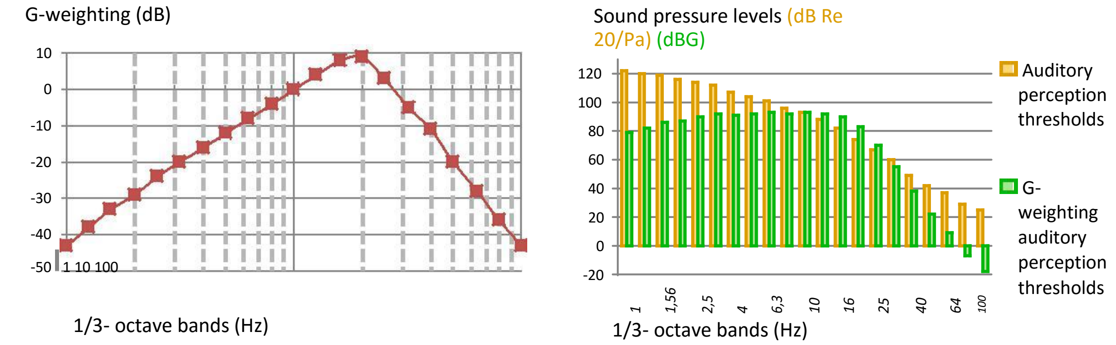

Figure 2: G-weighting (left) and threshold of perception per 1/3- octave band between 1 and 100 Hz, with and without G-weighting (right).

Thus, G-weighting was created. It was defined in 1995 in ISO 7196 standard [5], supplementing A-weighting and thus characterizing low frequencies and infrasound in a more precise manner (1 Hz to 100 Hz, see Figure 2).

1.2 Danger

Since we can feel them or hear them, infrasound can have adverse effects on our health [1] [3]. We will incorporate these effects in terms of three levels of infrasound:

- Before the hearing threshold is reached or vibrotactile sensation is felt (less than 100 dB), the danger is minimal and few adverse effects are felt. Disturbances or discomfort may still occur, such as fatigue, stress, difficulty in concentration, sensitivity to vibration, confusion, headache, decreased respiratory rate, sleep deterioration. These physiological effects could be due to the vibration of the digestive, cardiovascular, respiratory organs, or eyeballs.
- Beyond the hearing thresholds (above 100 dB), one or more issues and disturbances mentioned above are experienced and/or are amplified.
- Finally, at extremely high levels (above 140 dB), infrasound can damage hearing, especially in the audible frequency band of infrasound.

1.3 Prevention and protection

No national or European laws or regulations have been published to date. However, health organizations in several countries have expressed some recommendations with regard to infrasound (Table 1.1) [1].

Country	United States	New Zealand	Denmark	Switzerland
Organizations	*ACGIH*	*NZOSHS*	*DEPA*	*EKAS*
Limit Level Pulsed	below 145 dB 1/3- octave (1 to 80 Hz)	less than 120 dB for 24 hours integrated from 1 to 16 Hz	less than 85 dBG integrated from 1 to 20 Hz	less than 135 dBA for 8 hours
Limit Level Pulsed	less than 150 dB	-	-	150 dBA

Table 1.1: Precautions regarding the average levels and pulsed infrasound, by various countries.

To measure the average level of infrasound, care must be taken to use the proper equipment [1] [6]:

- A microphone with a uniform frequency response from 0.25 Hz to 160 Hz.
- A measurement channel (preamplifier, sound level meter, frequency analyzer) adapted to this microphone. An accuracy of 1 dB is desired on the whole measurement channel.

From 10 seconds to 1 minute, we integrate 1/3-octave bands corresponding to infrasound when the referring body has not specified a frequency range or an integration time.

When this level exceeds the recommended level, we will choose either to isolate the machine by a formwork using absorbent materials at very low frequency, or reduce the exposure time of persons. The rule regarding exposure time which reduces an exposure level by 3 dB if the exposure time is halved, applies to both infrasound and the audible spectrum.

2 Ultrasound

2.1 Introduction

Ultrasound, just as infrasound, includes frequencies that are inaudible to humans.

In contrast, they are caused by much more rapid oscillations than infrasound: more than 20,000 oscillations per second (or 20,000 Hz, Figure 1) [1] [7] [8]. They have very short wavelengths (less than or equal to 17 mm). They are thus rapidly absorbed into the air and more easily reflected when they encounter obstacles, which are the waves from the audible spectrum.

We find few of these frequencies in nature, unless they are created by other species such as bats, dolphins, birds, etc. Various industrial applications include infrasound (cutting, welding, cleaning, machining, detection), which form important activities in our profession [1] [7] [8].

2.2 Danger

With regard to use for control and detection, the frequencies used (in megahertz) cause little or no danger to humans. This is the case of ultrasound for example. It has had no adverse biological or physiological effect so far.

For industrial applications where medium frequency ultrasound is used (40,000 Hz to 100,000 Hz) - in the case of welding, cleaning, or cutting with ultrasound - where the intensity of these waves is selected to heat, cut, or destroy particles of plastic, metal, or other materials, adverse effects may occur when the human body comes into contact with these waves. There are two means of transmission of these waves:

- Direct contact: Energy here is defined in Watt per square centimeter (W/cm^2) and the danger level is high. Burning is the only recorded effect. It occurs immediately or after some time, is localized on the surface because the tissues under the skin can sometimes be affected, causing some serious injury when contact is prolonged. This is why the frames of industrial machines generally protect users of sonotrode or cleaning tanks during ultrasonic pulses [1] [8].

- Contact through air: in addition to overheating and burns that have already been mentioned, other problems may be caused when the ultrasound levels are high. Fatigue, headache, nausea, loss of balance, and tinnitus are the most commonly reported issues [1] [7] [8].

  At very high levels (above 120 dB), temporary hearing loss can occur at high frequencies (4-20 kHz).

2.3 Prevention and protection

As with infrasound, so far there are no real national or European laws or regulations, but only recommendations issued by health organizations in several countries [1]. INRS, based on these recommendations, proposes limit values for each 1/3-octave band from 8 to 50 kHz that must not be exceeded over a period of 8 hours of exposure.
(Table 2.1) [1].

1/3-octave band in: (kHz)	8	10	12,5	16	20	25	31,5	40	50
Limit values for 8 hours of exposure (dB)	75	75	75	75	75	110	110	110	110

Table 2.1: Maximum levels by octave band recommended by INRS [1]

To measure the average level of ultrasound, the necessary equipment is substantially the same as for audible frequencies. However, using the manufacturer's information, we must ensure that the frequency response at very high frequencies is not reduced to around 50-63 kHz.

The measurement is performed at the estimated position of the head of the user and other items that may be present in the room. [7]

If the level of one of the octave bands exceeds that prescribed by INRS, several solutions are possible:

- Isolate the machine in a dedicated room.
- Provide a hood or a formwork in addition to the machine frame; simple materials like Plexiglas or wood are sufficient to stop the transmission of ultrasound.
- Keep the user station away from the machine. The absorption of ultrasound in air is very fast, and sometimes, a distance of 1 meter is equivalent to several dB of attenuation.
- Finally, provide operators with suitable hearing protection. The attenuation level of the octave band centered at 8 kHz (APV_{8000}) generally corresponds to the attenuation that we also get at the following 1/3-octave bands (from 8 kHz to 50 kHz).

3 Bibliography

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