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Ultrasound in Consumer Products: Perception and Safety Assessment

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Ultrasound Applications in New Consumer Products

Ultrasonic sensors are being integrated into a growing range of consumer products for applications such as proximity sensing, range finding, imaging, and long-range directional audio. Current commercial products that emit ultrasound include burglar alarms, motion detection light switches, automated vehicle sensors, fish finders, ultrasonic cleaners, automatic door openers, parametric loudspeakers, and electronic pest control devices.

Ultrasound refers to sound waves with frequencies above those typically heard by humans. This range is defined to extend above 20,000 hertz (Hz). The high frequency and short wavelength of an ultrasonic sound wave allow it to be focused into a narrow beam and propagated directionally, unlike lower-frequency sound waves. Many people are familiar with ultrasound for its use in medical imaging, which transmits at frequencies in the megahertz (MHz, i.e., 1,000,000 Hz) range via direct contact with the body. By contrast, new consumer applications use ultrasound transmitted at lower frequencies (20,000–100,000 Hz), often through air. diverse consumer marketplace.

Ultrasound Perception by Humans and Animals

The sensitivity of sound perception in humans and animals depends on the frequency (in Hz) and the loudness or pressure level (in decibels, dB) of the sound. The hearing range of humans is traditionally believed to lie between 20 and 20,000 Hz, with peak sensitivity at 1,000–4,000 Hz. As the frequency increases, the hearing threshold (i.e., the minimum sound pressure level required for detection) increases sharply. On average, humans can hear sound pressures as low as 5 dB at 4,000 Hz, although sensitive individuals can detect sound pressures down to 0 dB (defined as the minimal sound audible to humans). At frequencies of 15,000–20,000 Hz, humans typically require minimum sound pressures around 40 dB. Above 20,000 Hz, in the range classified as ultrasound, some humans can detect sound given sufficient sound pressure levels (usually 75 dB or higher).

And what about our pets? Generally, smaller mammals, such as cats, dogs, and over-ground rodents, are more sensitive than humans to high-frequency sounds. Cats have one of the broadest hearing ranges of all mammals, around 48–85,000 Hz on average, even reaching up to 100,000 Hz. For dogs, the typical hearing range is around 67–64,000 Hz. Chinchillas have the most similar audiogram to that of humans, detecting 50–33,000 Hz at 60 dB.

Ultrasound Safety and Health Risks

Ultrasound at sufficient sound pressure levels can cause hearing damage even if it cannot be heard. Potential risks of audible and non-audible ultrasound include auditory effects, thermal effects, subjective symptoms, and functional disorders (e.g., certain chronic pain syndromes and other conditions that

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impair body functions despite a normal appearance). Auditory effects are the most thoroughly studied, and include noise-induced hearing loss and temporary or permanent hearing threshold shift. Physiological risks at very high sound pressure levels include heating of the skin and other body tissues, and cavitation in blood vessels and fluid-filled organs. Subjective risks and functional disorders are less well studied, and may include fatigue, dizziness, headache, ear fullness, tinnitus, annoyance, balance disturbances, nausea, sleep disorders, and cognitive impairment. Challenges to studying these health effects include the reliance on self-reported data for symptoms in humans, the lack of validated physiological metrics, and the descriptive nature of published case reports. Even a device designed to be safe for humans may cause nuisance or harm to pets and other animals due to their extended range of hearing.

Many ultrasound devices emit airborne ultrasound. For such devices, auditory and subjective risks are the most relevant. Safety standards and guidelines have been developed with the goal of protecting against hearing damage in humans. However, the increasing use of ultrasound for consumer applications is most likely causing humans and animals to be exposed to ultrasound for longer durations than previously considered.

How Exponent Can Help

Manufacturers with ultrasound-emitting devices should understand the emission field and perform a risk analysis on the potential human exposure. In-depth analysis may be needed for devices that emit sound at relatively high sound pressure levels or for relatively long durations. Exponent can assist in several ways.

- Characterizing the sound field: Independent testing and mapping of device emissions, including comparison of sound frequencies and pressure levels with commonly accepted standards and guidelines
- Conducting hazard identification and risk assessment: Evaluating the potential for and possible scope of adverse effects from device failures in the field under normal and extreme usage conditions
- Interpreting existing scientific evidence: Reviewing and summarizing published scientific literature on sound and ultrasound perception and safety in humans and animals, including the basis for existing standards and guidelines
- Designing animal safety studies: Designing studies to assess auditory safety in humans and pets, including tests such as distortion product otoacoustic emissions, auditory brainstem response, and cochlear hair cell imaging with scanning electron microscopy
- Implementing human and animal perception and behavioral studies: Designing and conducting human and animal experimental studies of audiometric, physiological, behavioral, and subjective effects

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