Human hearing covers a range of 20 to 20,000 Hz, but is most sensitive in the region of 2,000 to 5,000 Hz, with a peak sensitivity in the region of 3,700 Hz, due to the resonance of the ear canal.

ISO 226:2003 [1] provides equal loudness curves, which demonstrate the sensitivity of human hearing to different frequencies. Each curve is calculated for a Phon, a measure of loudness. The sound pressure level, in decibels, for each frequency on each curve indicates that the sound will be perceived at the same volume.

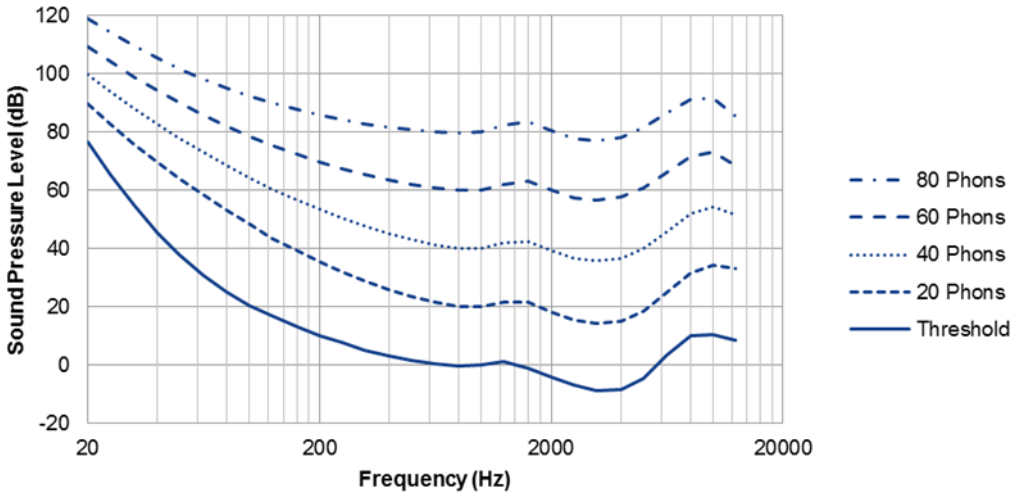

Figure 1 - Loudness curves for human hearing sensitivity

As can be seen from the above chart, in the region where the human ear is most sensitive, 3,700 Hz, a lower sound pressure level is required compared to, for example 1,000 Hz where the hearing is less sensitive, for the sound to be perceived at the same volume.

Taking the curve for 40 Phons as a reference, and recalculating the sound pressure level to a relative sensitivity (%) more clearly demonstrates the sensitivity of human hearing across the frequencies.

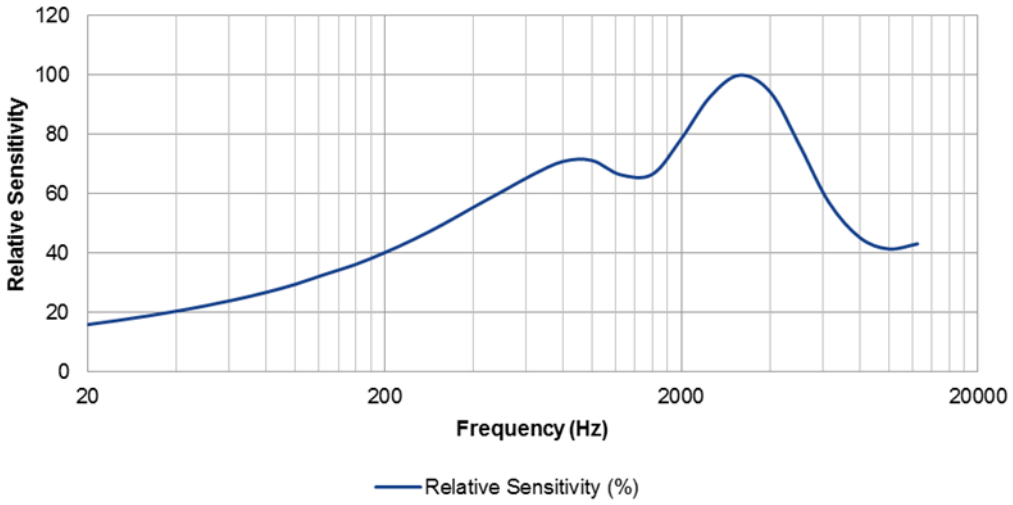

Figure 2 - Human hearing sensitivity across the audible frequency range

PERCEPTION OF CHANGES IN SOUND

The decibel scale for sound pressure levels is logarithmic. As such, a double in the decibels will not result in a doubling of sound pressure. Instead, a change in sound pressure level can be defined by:

$$\frac{P_2}{P_1} = 10^{A/10}$$

Where, P_2/P_1 is the ratio of increased or decreased sound pressure to original sound pressure and A is the change in decibels. As can be seen from Table 1, an increase in 3 dB is required for the sound pressure to be doubled.

Table 1 - Perception of sound pressure level changes

Decibel Level Change (dB)	Relative Sound Pressure Level (%)	Relative Loudness (%)	Awareness
+10	1000	200	Twice as Loud
+5	316	141	Noticeable
+3	200	123	Barely Perceived
+1	126	107	Insignificant
0	100	100	No Change
-1	79	93	Insignificant
-3	50	81	Barely Perceived
-5	32	71	Noticeable
-10	10	50	Twice as Loud

The perception of a change in sound pressure is a defined by psychoacoustics, and can often be roughly be equated to the change in decibels by the below equation:

$$\Delta_{Loudness} = 2^{\Delta_{dB}/10}$$

Based on this, and as indicated in Table 1above, it is generally accepted that a change in 3 dB is required for a change in volume to be perceived. A change of 10 dB equates to a doubling of the loudness [2].

PERCEPTION AND TOLERANCE OF SOUND

Table 2, below, adapted from documents produced by the European Commission and Occupational Safety and Health Administration [3, 4], shows typical sound pressure levels and associated sources and observation conditions.

Table 2 - Perception and sources for sound pressure levels

Sound Pressure Level (dB)	Observer/Source	Perception
140		Pain Threshold
130		
120	Aircraft Taking-Off (Close)	Unbearable
110		
100	Construction Site	Extremely Loud
90		
80	Road Traffic	Very Loud
70		
60	Normal Speech	Loud
50		
40		Quiet
30	Whispering in Ear	
20	Leaves	Barely Audible
10		
0		Hearing Threshold

REFERENCES

[1] International Organization for Standardization, *ISO 226:2003 - Acoustics - Normal equal-level-loudness-level contours,* ISO, 2003.

[2] V. Bradshaw, The Building Environment: Active and Passive Control Systems, Wiley, 2010.

[3] Occupational Safety & Health Administration, *OSHA Technical Manual - Noise,* United States Department of Labour.

[4] SCENIHR, *Potential health risks of exposure to noise from personal music players and mobile phones including a music playing function,* European Commission, 2008.