hummble Noise cancelling technology. Case studies

How active noise cancelling technology reduces heat pump tonality through the lens of noise regulation guidelines

A case study showing how integrating Hummble ANC technology into heat pumps enables manufacturers to comply with ever developing noise regulations and norms.

What is tonality?

In the realm of acoustics, we can distinguish between good and bad noise. While good noise is associated with enhancing comfort and wellbeing, the bad noise causes quite the opposite. Bad noise is not merely a matter of decibel levels; it is characterised by psychoacoustic measures of sharpness, roughness, pulsivity and tonality. Tonal noises can be particularly irritating as they draw attention and can disrupt activities like sleep or focused work.

Some examples of tonal noise sources are mosquito buzz, a siren, car engine, air conditioning units;

Tonal sources generate sounds that manifest as whining, humming, or other repetitive sounds that stand out from background noise.

Heat pumps have become an increasingly popular solution for heating and cooling in residential and commercial buildings due to their energy efficiency and environmental friendliness. One of the most commonly mentioned factors that block heat pump adoption is their noise.

When assessing heat pump **noise, regulators and standards organizations also look beyond the "loudness" alone.** They often consider not only the overall sound level but also the tonal characteristics of the noise. **Heat pump noise is full of tonal components that are a lot more noticeable and annoying to individuals, even at lower overall sound levels.**

National norms on tonality

How is heat pump tonality regulated?

Regulations and norms typically establish limits on both the overall noise level and the presence of tonal components. For example, a regulation might specify maximum allowable sound levels at various distances from the heat pump, as well as criteria for assessing tonality, such as the prominence of specific frequencies or the presence of certain amplitude modulation patterns. The national norms significantly influence decision making processes of heat pump manufacturers when designing heat pumps for a particular market.

The prominence of tones by Swiss regulation is evaluated by comparing a given 1/3 octave band to the neighbouring ones. The audibility of tones or tonal content is then split into four categories (from non-audible to strongly audible), adding 0 dB to 6 dB 'penalty' to the overall sound level of the heat pump, respectively.

Strongly audible	**+ 6 dB**
Clearly audible	**+ 4dB**
Weakly audible	**+ 2 dB**
Non-audible	**+ 0 dB**

In Germany, depending on the tonality of the source, an adjustment is made to the noise levels. There are multiple ways to determine the strength of the tonality, but all of them follow a certain selected norm. We've done our analysis in accordance with DIN 45681 and ECMA-418-1.

In practice, regardless of whether the noise immission is determined through measurement or computer-aided technique, the decibel penalty to be added is decided by the noise expert, based on numerous factors.

Determined at the discretion of a noise expert, based on the measured results.	**+ 6 dB**
	+ 3 dB
	+ 0 dB

Austrian regulation guides the manufacturer to determine whether the appliance is dominant in the low frequency region, which in heat pumps tends to be tonal.

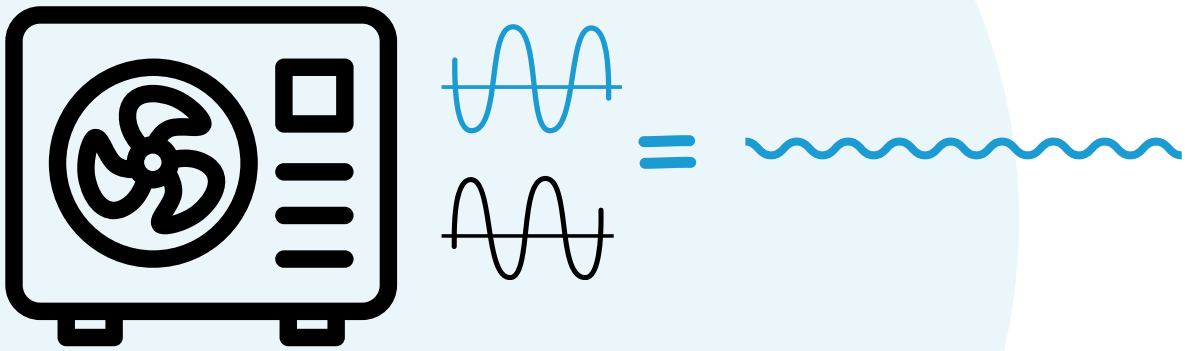
This is done by comparing the overall A-weighted level and overall C-weighted level. The A-weighting curve attenuates low frequencies more than the C-weighting curve, therefore the difference between the two curves can be a good tell tail for how much energy lies in the low frequency region.

Small difference means there is little energy in the low end, meaning that no penalty is added. If the difference is >20 dB, this means that the heat pumps noise is dominant in the low frequency region, therefore a 5 dB penalty is added to the measurement.

> 20 dB difference	**+ 5 dB**
< 20 dB difference	**+ 0 dB**

The following documents will provide more insight into the topics discussed in this case study:

1. A whitepaper published by the EHPA on heat pumps and sound
2. Tonality explained
3. National heat pump noise regulation overview summarized by the HPT TCP Annex 51 group of researchers



Patent pending.

Active noise cancelling technology can remove tones from the frequency spectrum, reducing annoyance of heat pump noise. It is the only technology that can effectively achieve this performance at low frequencies.

Our approach to this case study

The primary objective of this case study is to assess the effectiveness of using Hummble Active Noise Cancelling technology for tonality reduction in heat pumps. Additionally, we are presenting the effect in the context of national heat pump noise reduction norms.

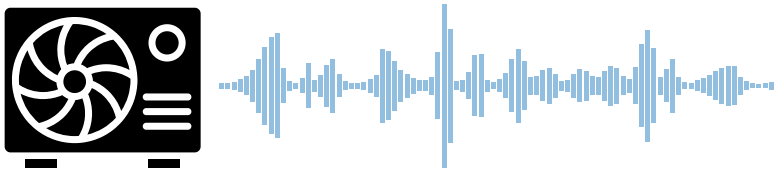
The way that tonality is applied in norms from Switzerland, Austria and Germany appears most defined, insightful, and systematic, compared to other countries.

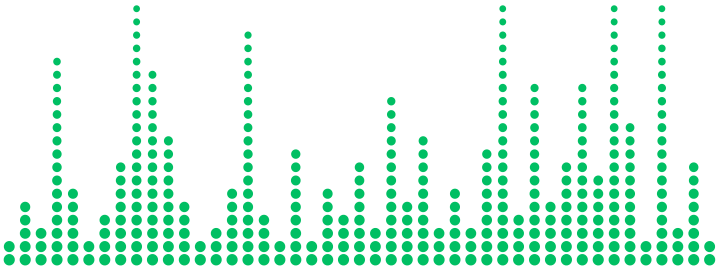
Hence, we have chosen to analyse the strength and significance of the tone reduction effect achieved with Hummble through the norms applied in these three systems.

For this case study, we have selected datasets from different types of heat pumps for domestic use. We have made sure to include a good balance of heat pumps that are produced in Europe, and those imported from eastern countries. Due to confidentiality agreements with our customers, we have anonymized the heat pump specimen.

Heat pump	Energy Source	Power (kW)
A	Air	12
B	Air	15
C	Water/Brine	12
D	Water/Brine	10
E	Air	8.5
F	Air	45

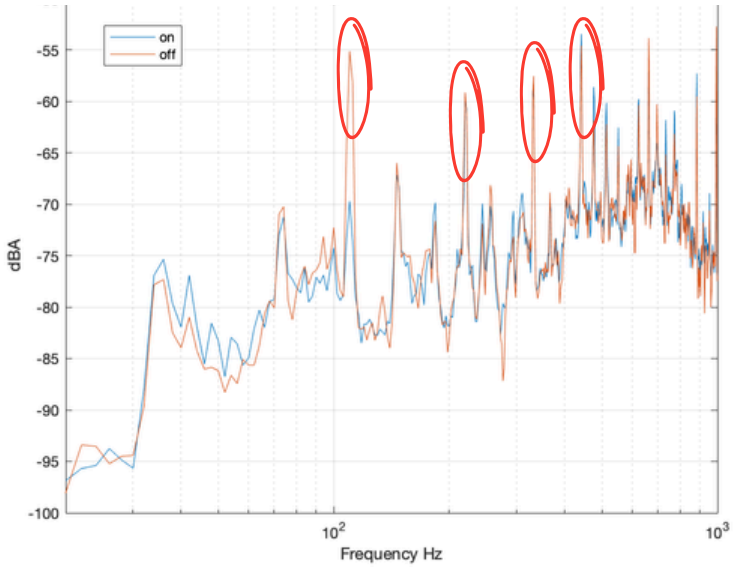
How to analyse and treat tonality?



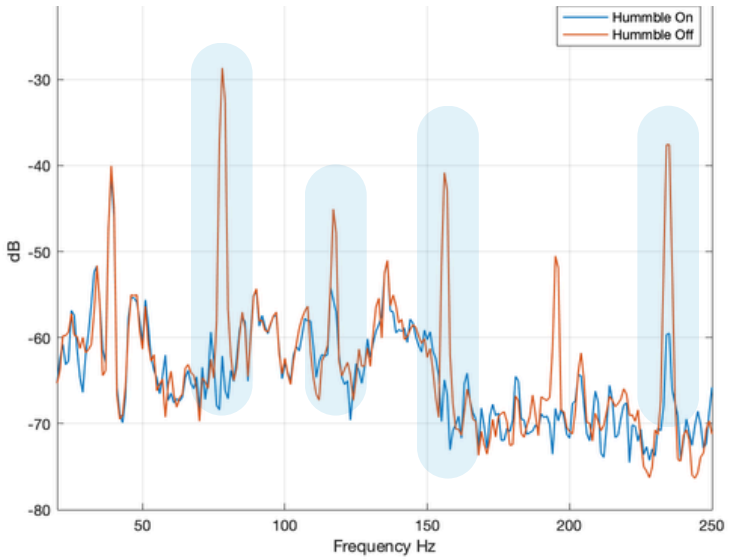


Record heat pump noise

Perform frequency analysis



Look for spikes in the narrow-band spectrum



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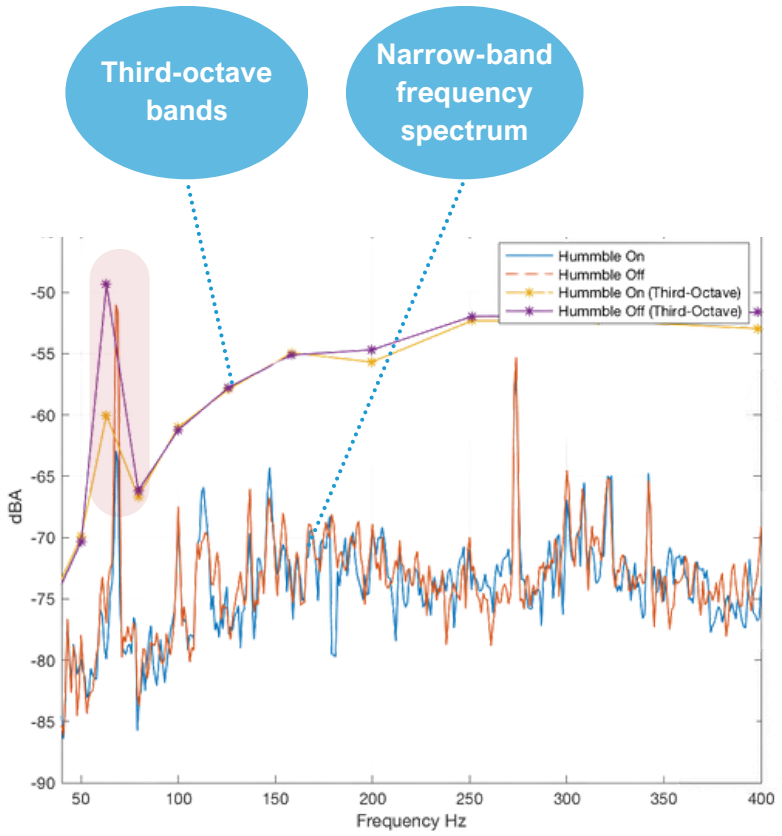
Use active noise cancelling technology to notch the spikes down into the broadband noise level.

The data analysed in this case study was collected over a period of 6 months, mostly measured on-site or on a factory floor, at a listening position 1-3 m away from the pump. When evaluating the effect of Hummble ANC technology, an uncalibrated sound pressure level was recorded. **Hummble ANC is switched on and off repeatedly, to obtain recorded data for the "before/after" effect quantification. The performance of the Hummble ANC system can be measured by calculating the difference between noise spectra captured with and without the system enabled.**

Looking at the controlled tonal frequencies, the (external) noise reduction performance that Hummble can achieve is typically >10 dB. The diagram shows narrow-band frequency spectrum, as well as third-octave band spectral analysis of the effect with Hummble system switched ON or OFF. This analysis was performed on all specimen.

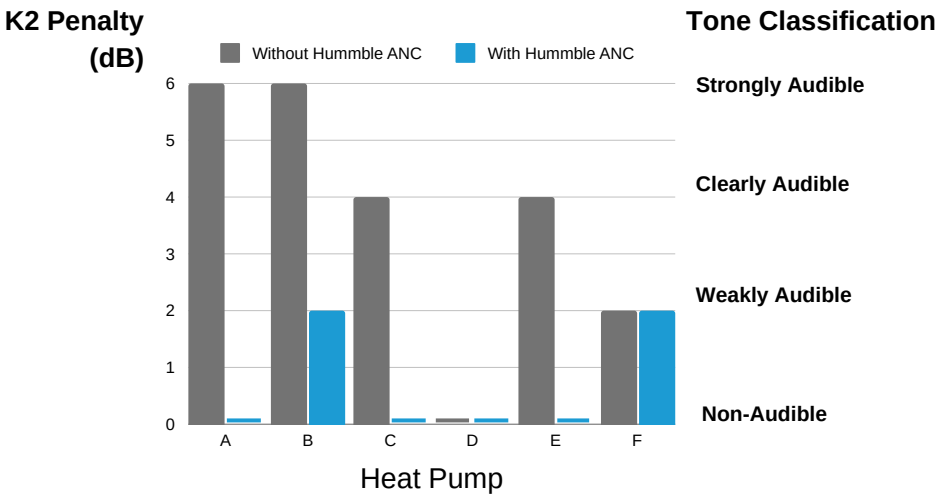
Heat Pump	Narrow-band reduction (dB)	Third-octave band reduction (dB)
A	17.0	15.1
B	11.4	10.0
C	11.5	11.2
D	13.1	12.5
E	12.0	7.8
F	15.0	13.1



Results in the context of national regulation

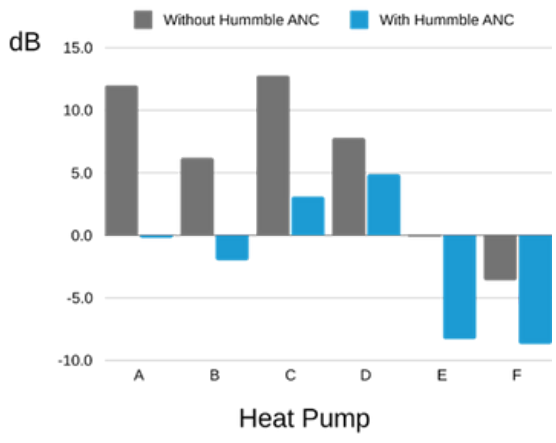
In Switzerland, according to the Noise Abatement Ordinance (NAO 2016), an adjustment factor should be added to the noise levels predicted or measured to account for the tonality of the source. The appropriated adjustment factor is determined based on the comparison of each third-octave bands to the levels seen in their neighbouring bands. The level difference (Lbi) is then translated into the tone classification matrix, that determines how audible the tone is (non-audible to strongly audible).

The audibility matrix directly determines the K2 coefficient penalty that has to be added to the sound power metric because of high tonality (0, 2, 4, or 6 dB).

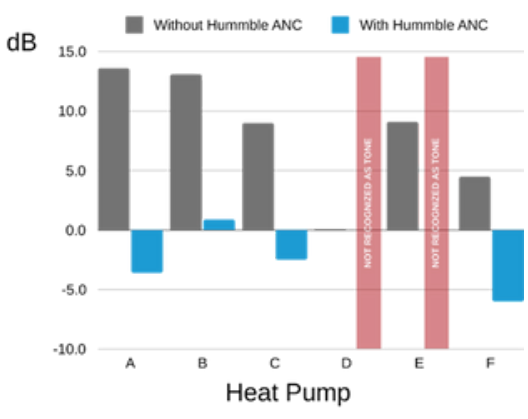


The **ECMA-418-1 norm** quantifies the significance of the presence of tones in a noise through **Prominence** and **Tone-to-Noise Ratio**. The prominence evaluates the entire critical frequency band where a tone is present and compares it's magnitude to the neighbouring bands. Hummble has enabled to bring the level of generated tones down into the average noise level. With the system enabled, both the Tone-to-noise ratio and the prominence of the tone in the noise signature is significantly reduced. Even if the reduction in overall sound pressure level is modest with Hummble, the tonality results show that the system has a significant impact on the heat pump's noise signature.

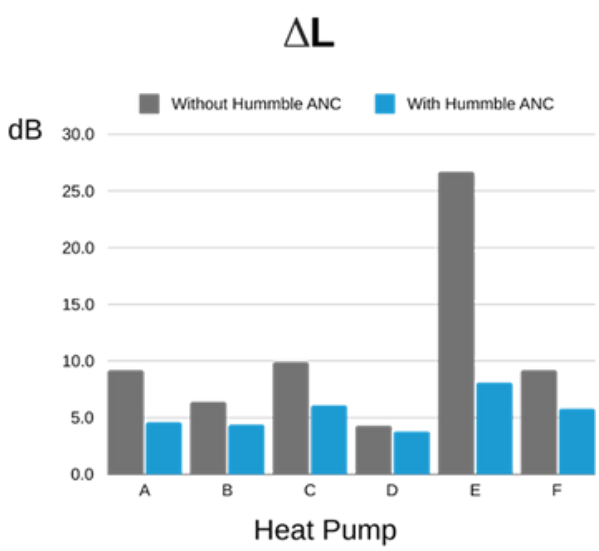
Prominence

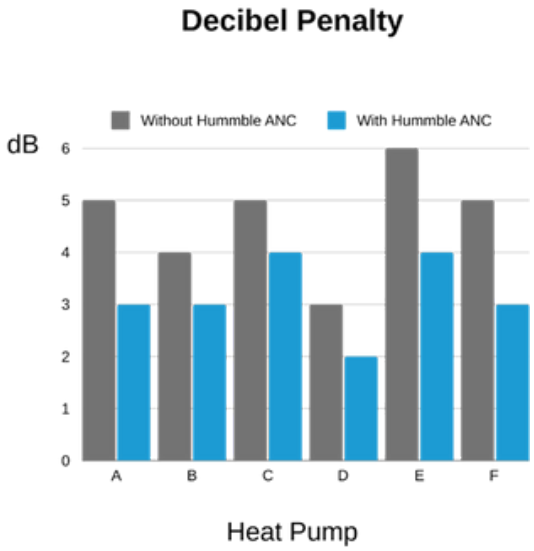


Tone-to-noise ratio



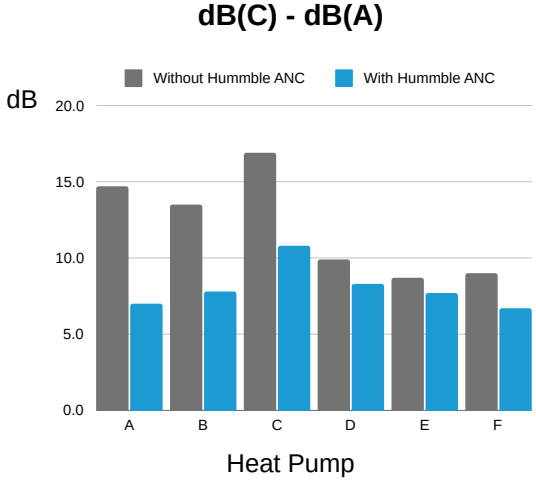
The DIN 45681 norm describes a method to detect and classify tonal components in a noise spectrum. To do so, the level difference ΔL between a tonal peak level and the surrounding background level is calculated, taking into account the frequency dependent auditory masking effect. Depending on the difference found in each case, the tonality adjustment factor can be determined based on the norm. The ΔL determines the decibel penalty to be applied to the heat pump sound power level. The applied decibel penalty and how it changes by adding Hummble ANC technology, is shown in the graph below.





The graph below shows the **difference between the C-weighted and A-weighted levels** that determines whether the **noise signature of the heat pump is dominated by low frequencies**. The results show that all, but particularly the first three specimen emit significant amount of low frequency energy. In all cases, the Hummble Active Noise Control system successfully and often significantly reduced the difference making the noise signature of the heat pumps more manageable and less annoying. Out of the 6 specimen analysed in this study, it looks like none would classify as low-frequency-dominant (the difference would need to be >20dB), however this has to be taken with caution as the measurements were not done according to the laboratory standards.

The graph shows that in all cases, we have managed to reduce the low frequency dominance.



Conclusion

In national regulations, the consideration of heat pump tonality reflects an acknowledgment of the importance of addressing both the volume and quality of noise generated by these systems. This ensures a comfortable and harmonious environment for residents and communities.

Over a long time, low frequency tonal content of heat pump noise can have a significantly negative effect on people's health and wellbeing.

In our case study, we evaluated the effectiveness of the Hummble Active Noise Cancelling system in six heat pump specimens through the lens of noise regulation in three different countries. **The results showed a significant reduction in tonal noise levels in all heat pumps, and the manifestation of the effect being visible in the regulatory framework.**

How can we improve?

All measurements considered in this case study were done by Hummble staff. We're working with field experts on 3rd party analysis of the results, to maximize the objectivity of the output.

All measurements in this study were uncalibrated and recorded in a non-standardized setting, however this does not dramatically influence the quality of output as we're merely comparing two signals between one another.

The noise was recorded at a position near the heat pump, which is not where people typically are when they are affected by heat pump noise. This study could be augmented by recording and analysing the heat pump noise inside living and working spaces.

The findings of this case study support the use of the Hummble ANC system as an effective solution for addressing tonality issues in heat pump installations, with positive outcomes in various regulatory environments.

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