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Embodied Sound: Full Frequency Vibrotactile and Vibroacoustic Sensation for Reduced Volume Multimodal Music Experience

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ABSTRACT

Prolonged exposure to constant signal often leads to auditory fatigue in audio engineers and music enthusiasts, resulting in a cycle of increasing volume and further auditory degradation (hearing loss). The concept of "Embodied Sound" proposes using the body's capacity to sense vibrations as a method for interpreting sound, shifting the focus from the ears to the body. Early results of an embodied sound system showed a detectable frequency range of ~11Hz-17kHz. Despite as large variation between frequencies, this system provides a reliable auditory and tactile experience for both hearing and hard-of-hearing individuals. Future research should focus on capture and signal processing workflows to accommodate a broader usable frequency range.

1 Introduction

Audio engineers in post-production sound stages or music studios often experience prolonged exposure to constant signal which leads to fatigue. This often results in the need to increase volume to clearly differentiate between various sources. Even for music enthusiasts: as their hearing worsens, they often amplify audio devices for a better experience. This inadvertently exacerbates the deterioration of their auditory capabilities, leading to a vicious cycle of increasing volume and further auditory degradation. Evelyn Glennie, a percussionist, is recognized for her barefoot performances on stage. The standard (usually wooden or hollow) concert hall floor allows her to perceive vibrational sound energy through her feet, enabling her to keep time with other performers. She proposes utilizing the body's capacity to sense

vibrations as a method for interpreting sound:

"For some reason we tend to make a distinction between hearing a sound and feeling a vibration, in reality they are the same thing...If we can all feel low frequency vibrations why can't we feel higher vibrations?" [1]

2 Gaps in Literature

Existing literature shows that most experiments on bodily frequency detection focus on easily-perceptible lower frequencies. They often overlook the higher frequency range, which contains nuanced harmonic details. Glennie's hearing loss in early adolescence, coupled with her later experience as a musician, may explain why Glennie believes she can perceive a broader range of frequencies through tactile perception than what current literature

suggests. Previous attempts to use the body for perceiving acoustic information include Maria Karam's Emoti-Chair [2], NXT's excitation and Distributed Mode Loudspeaker (DML) technologies [3], Tectonic's Balanced Mode Radiator (BMR) technologies [4, 5], and a variety of tactile solutions from makers like Subpac, Woojer, and AuraSound. Emotichair and similar research efforts are highly specialized, requiring proprietary signal processing chains and hardware. Despite their advancements, Directivity Modulated Loudspeakers (DMLs) and Balanced Mode Radiators (BMRs) only engage the user's ears. Furthermore, nearly all tactile solutions address only low-frequency, easily-detectable vibrations.

3 Possible Solution

An ideal solution would be a full-frequency multimodal experience leveraging tactile transducers. This approach would require the fewest drivers, cost less, and be compatible with existing acoustic infrastructure. Since the whole class of tactile transducers includes both low-frequency bass-shakers and high-frequency excitation technology, a single system with multiple actuators would ideally be capable of producing the entire frequency range due to the combined bandwidth. This sensation should be experienced across the body to maximize signal transmission. This shifts the focus of interpreting sound from the ears to the body, embodying the sound for a user. I aim to share these defining characteristics under the moniker "Embodied Sound". Embodied Sound is defined as a full-frequency multimodal vibrotactile and vibroacoustic sensation. It is adjusted for the resonant frequencies of the embedded substrates and further calibrated for a synchronous, equalized perceived frequency response across the available frequency range.

4 Methods and Results

Early results of an encompassing embodied sound system powered by 4 units of prototype model showed an average frequency response ± 30 dB from 30Hz-11kHz (2021). More recent tests show ± 30 dB from 20-12kHz from an individual unit, with installed systems powered by multiple units showing ± 15 dB from 20-13kHz with a maximum detectable frequency range of ~ 11 Hz-17kHz (2023).

5 Conclusions

Despite the large variation in frequencies, which is usually unacceptable in a critical listening environment, the chaotic and emanative nature of installed systems offers a highly forgiving and reliable monitoring solution for hostile and untreated environments. Additionally, it provides a reliable dual-mode auditory and tactile experience for both hearing and hard-of-hearing individuals at much lower overall SPL. In practice, the barrier to enhancing the user experience often occurs earlier in the signal pathway. Future research should address capture and signal processing workflows to accommodate the availability of a broader usable frequency range. This is particularly important given the direct nature of experiencing Embodied Sound, as devices will be directly connected to the body.

References

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