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TEMPORAL INTEGRATION AT THRESHOLDS AT VERY LOW AND INFRASONIC FREQUENCIES

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ABSTRACT

The human ear can perceive sound well below 20 Hz, i.e. infrasound, provided that the levels involved are high enough to be heard. It is also known that below a critical duration, the shorter the sounds are, the higher their intensity must be to be detected. Furthermore, this duration seems to increase with decreasing frequency. While most studies about hearing at infrasonic frequencies mention the necessity to use stimuli of sufficient length to be above the critical duration, to our knowledge only one study has actually measured the critical duration for a couple frequencies below 20 Hz and showed that at 4 Hz, the critical duration would be above 4000 ms. The presented work aims at bringing more precision to the measurement of the critical duration. In this paper, we will present the experimental setup built in order to reproduce infrasound at audible levels and the test procedure that we will use to measure the critical duration at different durations and frequencies below 63 Hz.

Keywords: *Hearing thresholds, Infrasound, critical duration.*

1. INTRODUCTION

While infrasonic frequencies are not a part of everyday communication in human, the human ear is still actually capable of hearing them and as such will still be a carrier of information. When speaking of audible sounds, infrasonic frequencies are often not accounted for because it is not a type of sound that we are often exposed to. Nowadays, however, infrasound sources are becoming increasingly common. Examples include road traffic, power transformers, heavy vehicles vibrations transmitted to buildings via solid-borne pathways, noise from rail traffic, etc. Furthermore, as the size of machines increases, so does the amount of infrasound they produce, as in the case of wind turbines, whose noise level increases with their size.

It is also worth noting that infrasound is indeed perceived primarily by the ear. Behler and Uppenkamp [1] for example have observed activity of the central auditory system through fMRI when exposed to infrasound. They also have shown considerable variation between listeners regarding perceived loudness and unpleasantness.

Thus, several studies have aimed to study infrasound perception by measuring features such as hearing thresholds, loudness function or spectral integration ([2]–[4]). A common aspect to all those studies is the attention brought to the length of the stimuli. Indeed, it is known that the absolute threshold tends to decrease with increasing stimulus duration. The limit above which the thresholds does not decrease anymore is called the critical duration. The critical duration tends to increase with decreasing frequency as shown by Watson & Gengel [5].

However, to our knowledge, only one paper has specifically studied this aspect in infrasonic frequencies. Jurado *et* al [6] measured critical duration at 32, 16 and 4 Hz and has shown that for 32 and 16 Hz the critical duration is about 1000 ms while at 4 Hz the absolute thresholds was still decreasing for a stimulus duration of 4000 ms (which was their longest duration evaluated). Here, we will use a room designed specifically to broadcast infrasonic frequency to study temporal integration below 32 Hz.

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2. EXPERIMENTAL SETUP

2.1 Testing facility

Infrasonic frequencies have absolute thresholds so high that it is a difficult task to just broadcast them at sufficient levels. To do so, a specific room has been designed at the Laboratory of Mechanics and Acoustics (LMA) to reach the needed levels with minimal harmonic distortion as this would alter measured threshold. Indeed, as shown by Møller & Pedersen [3], hearing thresholds increase very quickly with decreasing frequency below 20 Hz, as such, harmonic distortion occurring at higher frequency that the one tested will have a much lower hearing threshold and thus might be heard instead of the frequency of interest.

To broadcast infrasonic frequencies the room is equipped with 32 subwoofer speakers on opposite walls (see Fig. 1) that allows to reach the needed levels to make these frequencies audible. The room is able to reach significant level while keeping distortions levels lower than their associated hearing thresholds as shown in Fig. 2. A more thorough description of the room is proposed by Pachebat *et al* [7] (in French).

Figure 1. Picture of the room for broadcast of infrasonic frequencies. The room is equipped with 32 subwoofers speakers (f ≤ 40 Hz), 40 low frequency speakers (40 < f ≤ 3000 Hz) and 6 medium frequency speakers(3000 < f ≤ 17000 Hz).

2.2 Listeners’ hearing thresholds

To ensure that harmonic distortions will indeed not be heard by the listeners, their hearing thresholds at higher frequencies, corresponding to the harmonics, will be measured before undergoing the infrasonic thresholds measurements.

2.3 Test procedure

A 2-interval forced choice procedure with a 2down-1up rule will be used to measure the absolute thresholds of frequencies at and below 63 Hz and for different duration. Based on the results of [6], a maximum duration of 1500 ms will be used for frequencies down to 16 Hz. Below that, longer durations will be used.

Starting level will be around 10 dB above the hearing thresholds for infrasounds [2]. This depend on the tested frequency as loudness has been shown to increase faster at very low frequencies [2] As such, special care will be taken to ensure starting levels not too loud for the listeners.

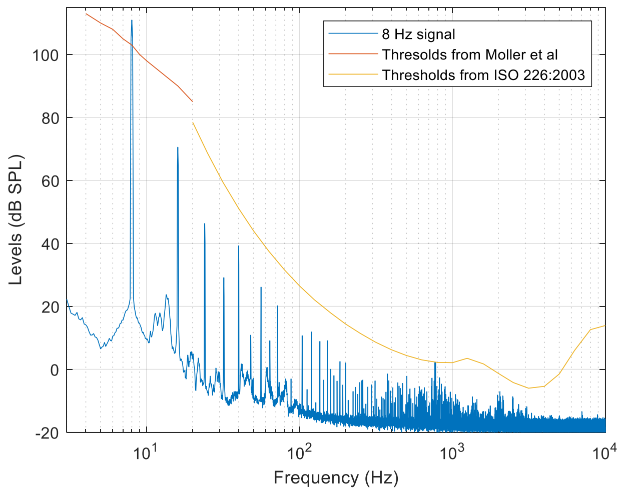

Figure 2. Example of 8 Hz signal measured in the room. A level of 111 dB (8 dB above expected threshold from [3]) is reached while all harmonics distortions’ levels are below the standardized thresholds from ISO 226:2003.

3. RESULTS

Results will be presented at the 2023 Forum Acusticum convention.

4. ACKNOWLEDGEMENT

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