# AIRCRAFT VIBRATION PERCEPTION IN A LABORATORY SITUATION

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***Abstract***. *In recent decades, air transport has shown an unprecedented growth, becoming one of the most important means of transport for passengers and cargo. This growth has been accompanied by the development of new aircraft in an attempt to satisfy stricter quality levels. These aircraft must have characteristics that attend the air companies' interests regarding issues such as performance and operation costs, as well as guarantee comfort for the passengers and crew. From the point of view of the comfort of passengers and crew in commercial aircraft, noise and vibration inside the aircraft can be highlighted as important issues and their study requires people to be interviewed whilst being subjected to the relevant stimuli. On real flights, this kind of study is costly and so the use of a simulator cabin (mock-up) fixed to the ground, able to play vibration signals recorded on a real flight with reliability, is recommended. Since the vibro-acoustic stimulus is controlled, many subjective evaluations can be made. In this study, some subjective evaluations performed in the mock-up are presented, where situations at the vibration threshold, which represents the minimum level of vibration perceived for a vibration flight signal, with and without simultaneous sound stimulus were compared. A comparison between the thresholds of the same seat in two situations, with and without vibration reference, is also discussed. The main conclusions of this paper are that the vibration perception decreases when the sound stimulus is presented and the vibration threshold does not change during the experiments. The assessment of vibratory perception thresholds (VPTs) was shown to be of great importance in studies related to the perception of aircraft comfort, as a guide for future studies, where it is necessary to study the combined effects of vibro-acoustic perception.*

***Keywords***: *vibro-acoustics, aircraft, perception, threshold*

## 1. INTRODUCTION

Interest in the human response to vibration is becoming ever more widespread and the standards, like ISO 2631-1/2 which refers to sinusoidal excitation based on vibration perception in buildings, deal with the perception thresholds of whole body vibration in all directions or equivalent comfort contours (Bellmann et al., 2004). However, the relevant literature shows significant differences in terms of the present standards and the data from the various laboratories also deviate, probably due to differences in the psychophysical measurement methods used (Griffin, 1996) and the locations where the experiments are performed.

Vibration sensation measurements have been used for several decades in the health area to identify, localize, and categorize nerve injuries (Hubbard et al., 2004) and lately they have been associated with the perception of vehicle comfort. However, there has been little information concerning the determinants of the VPT for aircraft signals, and there has been no known investigation to determine the influence of the sound stimulation on the vibration perception threshold.

Given the costs associated with carrying out this kind of study on real flights, the use of a simulator cabin (mock-up) fixed to the ground, able to play vibration signals recorded on a real flight with reliability, is recommended.

The purpose of the present study is to verify the influence of an aircraft sound stimulus on VPT and also the variation of VPT values during the experiment.

## 2. METHODOLOGY

### 2.1 Subjects

Ten volunteers participated in the experiments. Their ages ranged from 20 to 30 years. All subjects were free of injury or a history of relevant illness. The posture of the subjects was normal and they were seated comfortable in the seat, placing the entire sole of the foot on the ground.

The effects of age, sex, height, and weight on the VPTs were not considered in this study, but according to Bartlett et al. (1997) and Inami et al. (2005) subjects aged between 20 and 30 do not show large difference in terms of the VPT.

### 2.2 Apparatus and stimuli

The experiments were performed in the simulator cabin (mock-up) of the Vibration and Acoustics Laboratory at the Federal University of Santa Catarina (Fig 1).

Figure 1. Mock-up

Aircraft interior noise and vibration were recorded during a test flight using a portable binaural recording system. Stimulus from three different seats were selected for reproduction (forward, middle and aft seat), Fig. 2.

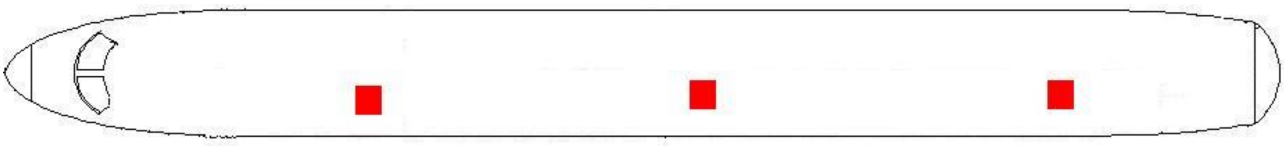

Figure 2. Location of aircraft seats selected

Sounds were reproduced using a programmable DA-converter, an equalizer from HEAD acoustics and electrodynamic headphones of the type Sennheiser HD600. Vertical aircraft vibrations were reproduced through an electrodynamic shaker (Buttkicker) which was connected to a laptop, an amplifier and communications hardware (Pulse, B&K) according to Fig 3.

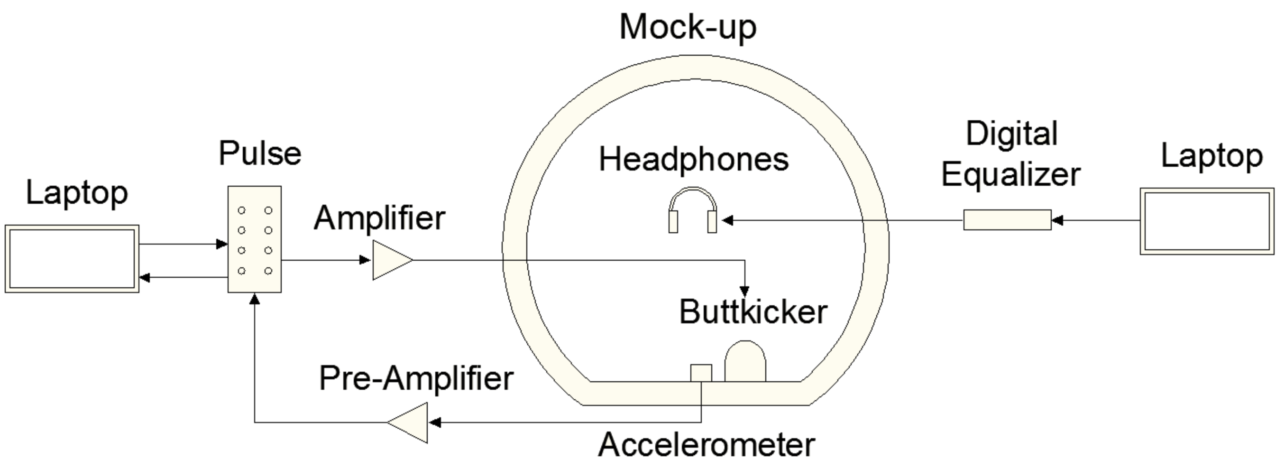


Figure 3. Setup of the experiment

### 2.3 Procedure

To verify the influence of an aircraft sound stimulus on the VPT the method of limits proposed by Fechner (1860) and well described in Gelfand (1998), was adapted. The experiment was explained to the volunteers before the test, and it was divided into two steps. In the first step the VPT was verified without the sound stimulus and in the second step with the sound stimulus. To observe the variation in the VPT during the experiment in both cases, the VPT was investigated twice for the forward seat and once for the middle and aft seats, considering that the forward seat was presented first and last. Both sets of experiments were applied to 10 volunteers. To analyze the results, statistical analysis was performed with the Wilcoxon test, which is a paired and non parametric test (Massad et al., 2004).

## 3. RESULTS AND DISCUSSION

### 3.1. Variation of VPT during the experiment

Figure 4 shows a comparison between the VPT values found for all subjects for the forward seat in the first and last presentations, without sound stimulus. The lighter lines represent the first results and darker lines represent the last results.

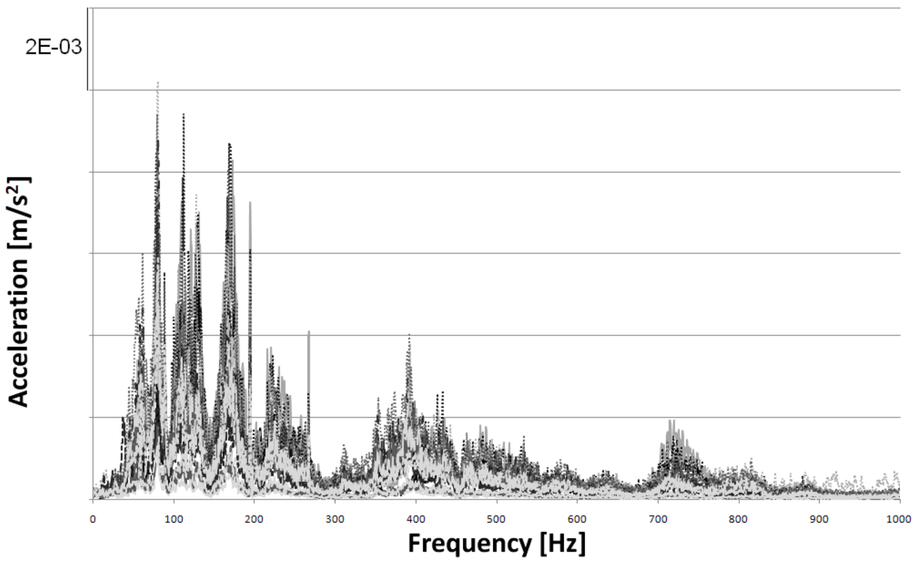


Figure 4. VPT for ten subjects with and without reference

Statistical analysis was performed to observe the variation in VPT during the experiment and the mean of thresholds are presented in Fig. 5.

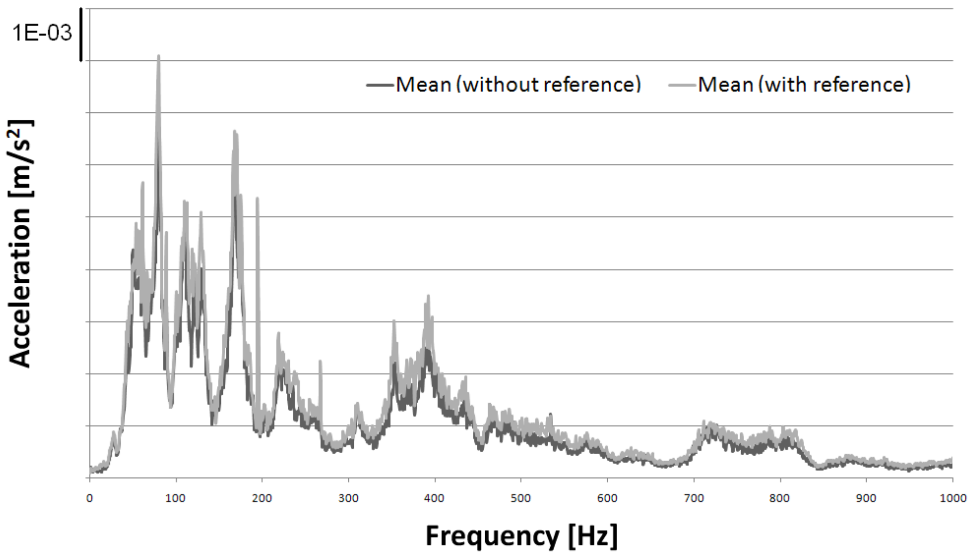


Figure 5. Mean VPT values for ten subjects without (first evaluation) and with (last evaluation) reference without noise stimulus.

The statistical analysis showed no significant difference (Wilcoxon, 95% significance), which reveals that the response for the VPT does not change over the experiment. The same results were found in the tests with a simultaneous acoustic stimulus.

### 2.2. Influence of sound stimulus on VPT

The VPT results for the forward seat with and without sound stimulus are given in Fig. 6. The lighter lines represent with sound and darker lines represent without sound.

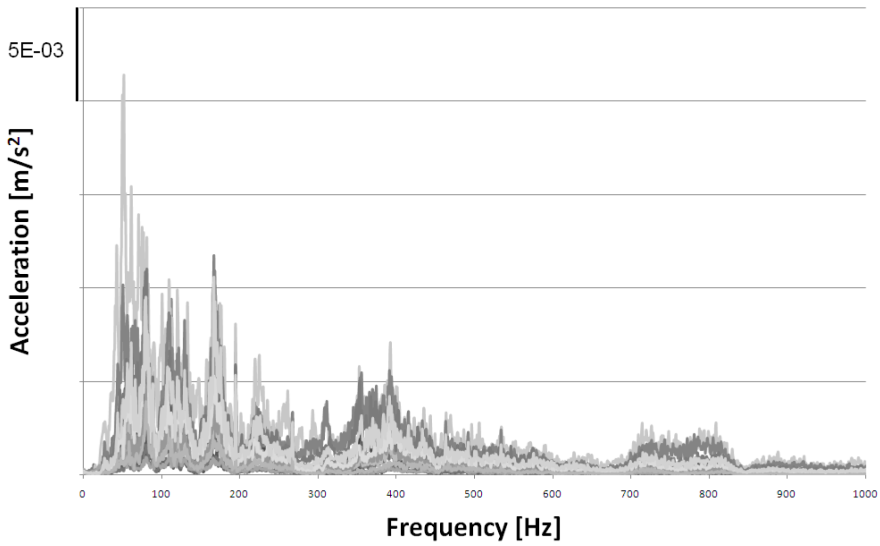


Figure 6. VPT for all subjects with and without noise

The spectrums show that there is a difference in the VPT results with and without noise. The lighter line which represents the results with sound stimulus shows higher threshold values. To verify whether this difference is significant, statistical analysis was performed and the mean of thresholds with and without noise for the forward seat are presented in Fig. 7.

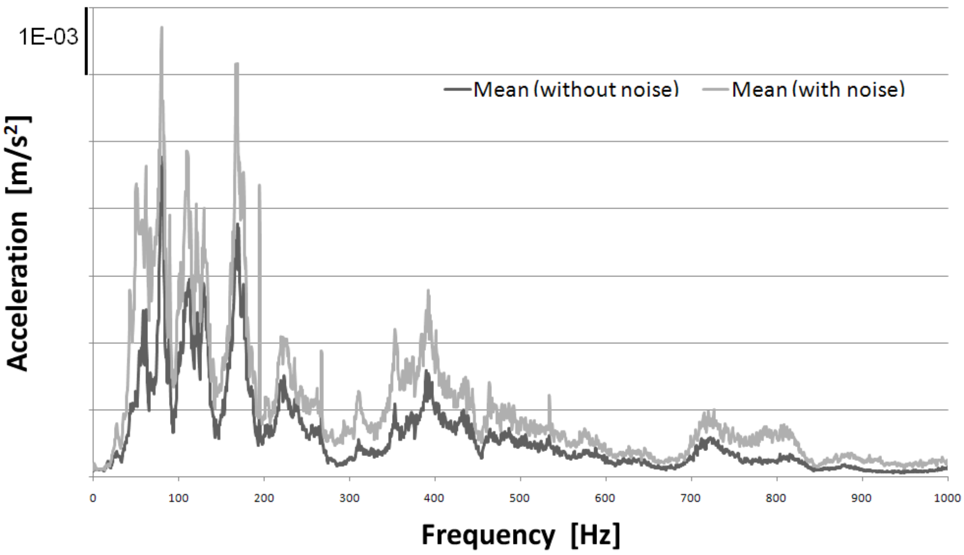


Figure 7. Mean VPT values with and without noise for forward seat

The statistical analysis showed that there is a significant difference (Wilcoxon, 95% of significance), which reveals that the response for the VPT changes with simultaneous noise stimulation. The same results were found for the middle and aft seats (Figs. 8 and 9). These findings are in agreement with those of Griffin (1996) who stated that people hear vibration before feeling it.

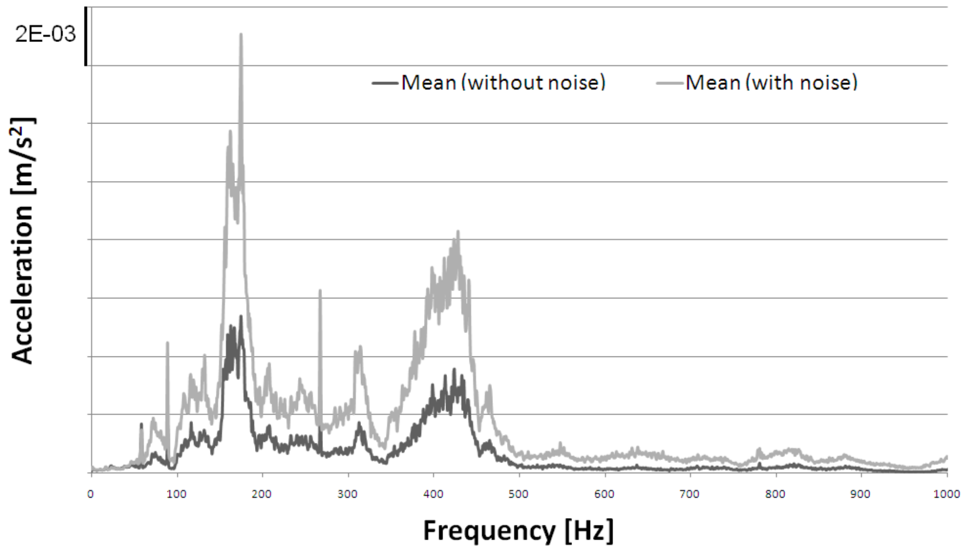


Figure 8. Mean VPT values with and without noise for the middle seat

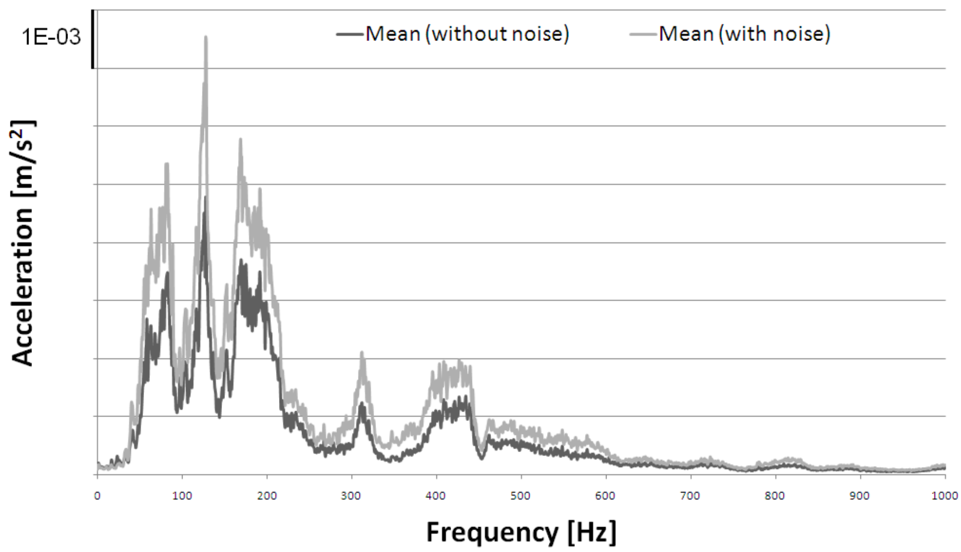


Figure 9. Mean VPT values with and without noise for the aft seat

## 4. CONCLUSIONS

From the results of this study it can be asserted that the response of the volunteers in terms of VPT did not change during the experiment and that the sound affects this threshold, the perception decreasing when the sound stimulus is present. The assessment of vibratory perception thresholds was shown to be of great importance in studies related to the perception of aircraft comfort, acting as a guide for future studies, where it is necessary to study the combined effects of vibro-acoustic perception.

## 5. ACKNOWLEDGEMENTS

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