

[0038] A vented loudspeaker system may be provided that can create an air flow in vicinity of a vent. Bass reflex loudspeaker boxes are acoustic systems comprising an electro-acoustic transducer, acoustically loaded at the back by a volume of air and a port (vent) opening the box to the outside (often in the shape of a tube).

[0039] The air inside the box may be compressible and may act as an acoustic spring. The air inside the vent may act as an acoustic mass and can move inside and outside of the box. When the loudspeaker is operated at frequencies near or below the so-called box resonance (defined by the spring mass system just described), the vent may act as an exhaust pipe and may produce a strong air flow, which can be felt if the user places his or her hand or face or any other sufficiently sensitive body part in front of the vent. This effect may be particularly strong as the airflow from the vent is turbulent.

[0040] A multi-sensory excitation (a synchronous excitation of several senses) is a way to enhance or multiply the perceived magnitude of a (monosensory) stimulus.

[0041] In other words, a perceived effect of a "stimulus 1" plus a synchronous "stimulus 2" may be larger and/or better than the "stimulus 1" plus an asynchronous (i.e. not synchronous) "stimulus 2"

[0042] Based on the above considerations and recognitions, an audio-haptic excitation mechanism may be provided according to an exemplary embodiment of the invention. According to an exemplary embodiment of the invention, a synchronous tactile one may strengthen an auditory experience. This may be obtained by directing the airflow of an acoustic vent (or port) towards a part of the body of the user which is sensitive to air flow. Therefore, preferably a naked part of a body may be used. Examples for parts of the body, which are specifically sensitive for tactile stimuli, are the hands or the wrists. This may be used particularly in case of handheld devices.

[0043] Natural time synchronization and complementary spectrum coverage of the tactile (also named haptic) and auditory stimuli may be obtained by the very properties of the vented acoustic system. The combination of audio and touch may result in an increased awareness of the bass present in the reproduced signal.

[0044] In a listening test performed by the inventor with a handheld prototype using a 30 mm diameter driver, five subjects out of five reported that they had the impression of a bigger, more powerful sound system, when they were subjected to the air flow onto their hands, in addition to listening to the audio only.

[0045] In the following, some aspects regarding a theoretical basis for embodiments of the invention will be explained.

[0046] In a vent acoustic system, two regimes may be distinguished:

[0047] above a box resonance frequency: high sound pressure level is produced, little air flow

[0048] below a box resonance frequency: high air flow is produced, little sound.

[0049] The sound pressure level response of a vented loudspeaker may be a forth-order high pass filter. The main flaw of these systems may be the very limited sound output below the box resonance frequency. Embodiments of the invention may provide the user with the information that is not conveyed acoustically, as a tactile feedback.

[0050] In music, which often has harmonic content distributed on both sides of the box resonance, the complete audio spectrum can therefore be conveyed to the user, by the sum of

acoustic and tactile contributions. The mechanical action may be synchronous with the acoustical one because the music signal itself is spread over the "acoustic" and "mechanical" regions.

[0051] The haptic excitation may be selective. In other words, provision may be made that the excitation may be switched on or off or may be adjusted quantitatively under control of a machine or a user. It may also cover the feature of an excitation that varies over time.

[0052] Next, further exemplary embodiments of the device will be explained. However, these embodiments also apply to the methods, to the program element and to the computer-readable medium.

[0053] The haptic excitation generation unit may be adapted for generating the haptic excitation of the specific body part, wherein this body part differs from an ear of the user. Specific parts of the human body may be more sensitive with regard to an air stream than the ear that is adapted by nature to be sensitive to an audio stimulus. However, other parts of the human body like a hand, a wrist, a neck, a finger and a face may be appropriate targets for the air stream so as to generate, in a timely synchronized manner, a combined ear based audio perception and other body part based tactile stimulus. Moreover, the entire perception may be more intense when the target of the audio stimulus and the target of the tactile stimulus are different.

[0054] The haptic excitation generating unit may be adapted for generating the haptic excitation of the specific body part of the user by directing the air flow onto the specific body part. In other words, a guiding mechanism like a correspondingly curved tube or any other air streaming conduit may be provided to transport the (moving or even accelerated) air flow or air stream to the desired location, and to selectively apply the tactile sensation to this body part.

[0055] The haptic excitation generation unit may be adapted for generating the haptic excitation of the specific body part of the user by generating a turbulent airflow. By not only generating a laminar air flow, but for instance a non-linear air stream having a sufficiently high velocity, a sufficient air pressure level and/or eddies, an ecstatic feeling may be generated at the user's skin. Such a turbulent property may be promoted by a fan, a ventilator or any other air acceleration mechanism (for instance by a specific tapering geometry of a conduit forming the vent). In fluid dynamics, turbulence or turbulent flow is a flow regime that may be characterized by low momentum diffusion, high momentum convection and/or rapid variation of pressure and velocity in space and time. A turbulent airflow may be present when the fluid streamlines break into eddies and complex changing patterns. This can cause (desired) unstable forces on the target body part.

[0056] The haptic excitation generation unit may be adapted for generating the haptic excitation of the specific body part of the user by generating the air flow through the vent in accordance with a bass portion, particularly exclusively with a bass portion, of the audio signal to be reproduced. Particularly in portable and other small sized audio playback devices, it may be difficult to generate a high quality bass performance. If, selectively for such bass frequencies, an additional haptic excitation is added, this may improve the feeling of the user in this specific frequency range. "Bass" frequencies may be audible frequencies below a predetermined threshold frequency that may be in the range of essen-