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TOUCH YOUR SOUND: A REVIEW ON HEARING BASED BONE CONDUCTION TECHNOLOGY.

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Abstract— **Humans have an amazing ability of spatializing and locating the sound. Having such ability, is a clear evolutionary advantage. The auditory system uses various cues for the location of sound source, such as time and level differences between both ears and spectral information. The vision of paper is to describe the process of reproducing a more natural stereophonic sound giving a realistic sensation despite of the influence of variances in the shapes of ears or an irregularity of the recording system or the reproducing system, through a combination of an air conduction sound produced through bone conduction by an acoustic output device. Provided is an acoustic output device having an air conduction sound providing unit configured to provide an air conduction sound and a bone conduction sound providing unit configured to provide a bone conduction sound. The bone conduction sound providing unit is positioned near the ear of an user.**

***Keywords*— Stereophonic, Bone Conduction, DSP, HRTF, SGNL.**

I. INTRODUCTION

Basically when we make calls every time, in a noisy subway or in a car, our voices are transmitted through the speakers. The problem is that anyone can hear the transmitted sound over their speaker phones, which means almost no privacy. The solution is founded by taking cues from vibration. With the development of processing capabilities of processors such as digital signal processors (DSPs), it has become possible to reconstruct spatial expansion at the time of acoustic listening using a headphone by convoluting an audio signal with a head-related transfer function (HRTF). The air conduction sound is a sound that directly reaches both human ears. The bone conduction sound is a sound that reaches the ears through the inside of the human body.

Generally, the headphone system includes a signal generating unit, a speaker unit, and a vibration unit. The signal generating unit includes an air conduction signal generating unit and a bone conduction signal generating unit. The air conduction signal generating unit generates the audio signal (air conduction signal) to be the output to the speaker unit using the audio signal output from the audio device. The bone conduction signal generating unit generates the audio signal (bone conduction signal) to be output to the vibration unit using the audio signal output from the audio device. The realistic sensation is further improved without depending on complicated signal processing by providing the bone conduction sound that reaches the ear through the inside of the human body in addition to the air conduction sound that directly reaches both of the human's ears[1].

II. HEAD-RELATED TRANSFER FUNCTION (HRTF)

HRTFs capture sound localization cues created by how sound reflects, diffracts, and is generally filtered by the geometry of a person's head, face, Re-imagining Music for an Immersive, Interactive Listening Experience and pinna (external part of the ear) before entering the ear canal. Even though general geometric models can capture most of the filtering effects for the HRTFs, small variations of the pinna can produce large changes in the HRTFs. The Centre for Image Processing and Integrated Computing (CIPIC) database consists of many HRTF responses with diverse ear and head measurements that can be used to match an individual. HRTF captures transformations of a sound wave propagating from the source to our ears. Some among the transformations include diffraction and reflections on the parts of our bodies such as our head, pinnae, shoulders and torso. As a result, with both of these functions we can create the illusion of spatially located sound. HRTF is a form of Fourier transform for a head-related impulse response (HRIR). We can emphasize that it is a complex function defined for each ear, having both information about the magnitude and the phase shift [2]. The HRTF is very much dependent on the location of the source of sound relative to the listener, which is a main reason for able to locate the sound source.

The impulse responses are denoted for the left and the right ear in the time domain as $h_L(t)$ and $h_R(t)$, respectively. In the frequency domain we can denote the responses by corresponding capital letters - $H_R(\omega)$ and $H_L(\omega)$.

Let the function x(t) be the pressure of the sound source and let functions xL(t) and xR(t) describe the pressure at the left and the right ear, respectively. According to the time domain, the pressure at the ears can be written as a convolution of the sound signal and the HRIR of the corresponding ear:

$$x_{L,R}(t) = h_{L,R}(t) * x(t) =_{\infty} \int^{-\infty} h_{L,R}(t-\tau)x(\tau)d\tau. \tag{1}$$

According to the frequency domain, convolution is transformed into multiplication:

$$X_{L,R}(\omega) = F(h_{L,R}(t) * x(t)) = H_{L,R}(\omega)X(\omega). \tag{2}$$

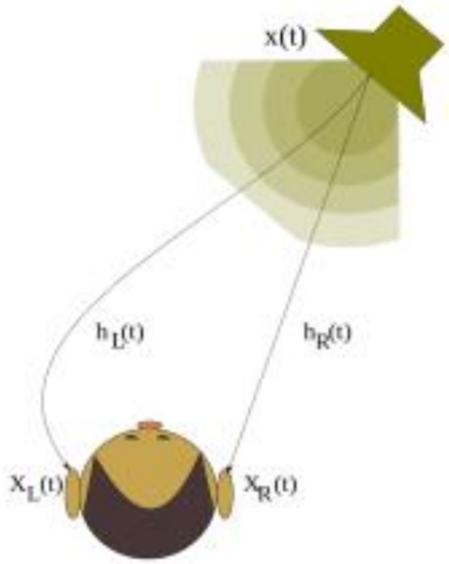

Figure 2.1: shows the filtering of a signal $x(t)$ by two separate transfer functions $h_L(t)$ and $h_R(t)$.

Figure 2.1 shows thoroughly the propagation of a sound wave from the source to the ears with the conventional notations for filtering functions and pressure impulses.

III SPATIAL HEARING

Spatial hearing is the important aspect of auditory perception. It allows humans to orient themselves in space and also suppress the sound reflections from walls of the room that interfere with the direct sound. The position of the source of the sound can be specified with three variables: the azimuthal angle φ in equatorial plane also called the left/right dimension, the polar angle θ also called the vertical dimension and distance r from the listeners head to the sound source.

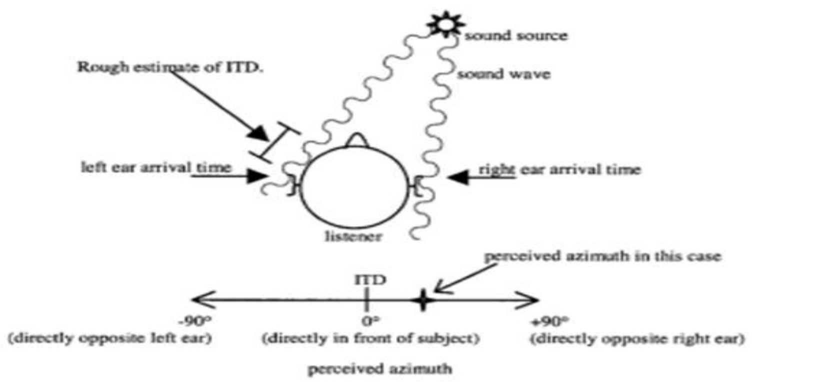

Figure 3.1: shows basic concept of interaural time differences (ITD).

Various psychoacoustic experiments have shown that the following cues contribute to the spatial localization of the sound source:

- The interaural time difference (ITD) is the time difference of the arrival of sound waves at left and right ear canals. This cue is dominant for frequencies below 1.5 kHz. Figure 2 shows the basic concept of the ITD caused by the sound waves coming from a specific azimuthal angle.

- The interaural level difference (ILD) is the pressure level difference between left and right ears. This cue is important for frequencies above 1.5 kHz.

- The spectral cues encoded in the shapes of our pinnae. This cue is important for frequencies above 5 to 6 kHz. The frequency below which the ITD cue is dominant (νc) can be estimated from the average diameter of the head (d) and the speed of sound (c): νc = c d ≈ 1.5 kHz, where we used c = 340 m s and the average diameter of the human head d = 25 cm.

IV. BONE CONDUCTION

Ludwig van Beethoven was a famous 18th century composer, who was almost deaf discovered bone conduction that is, a way to hear music through his jawbone by biting a rod attached to his piano [6]. Usual sound waves are actually tiny vibrations in the air and these vibrations travel through the air to our ear drums. The ear drums in turn vibrate, decoding these sound waves into a different type of vibrations that are received by the Cochlea, also known as the inner ear. The Cochlea is connected to our auditory nerve, which transmits the sounds to our brain.

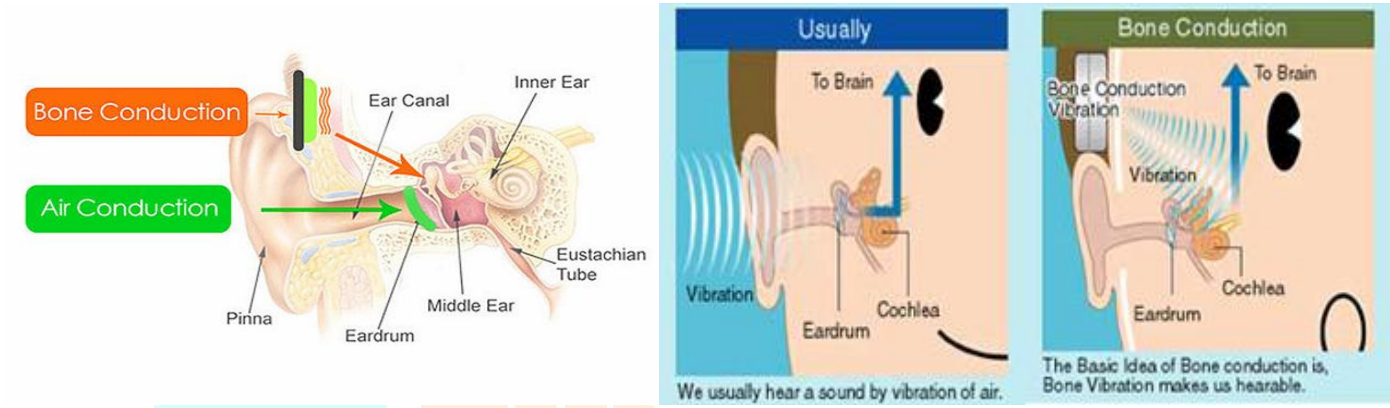

Figure 4.1: Comparison of normal and Bone conduction.

Bone Conduction bypasses the eardrums and makes us hear the sound. In one of the application of bone conduction hearing, the headphones perform the role of your ear drums; Audio Bone headphones decode sound waves and convert them into vibrations that can be received directly by the Cochlea without involving the ear drum. Initial attempts at the bone conduction resulted in fairly poor sound quality. But Audio Bone has developed a technology which decodes the sound waves in high fidelity, stereo quality sound. But this technology relies not only on bone, but also on tendons, ligaments, and other tissue to pass the vibrations from your wrist, through your fingers to your ear.

An acoustic output device, consisting of an air conduction sound providing unit which is configured to output an air conduction sound, similarly a bone conduction sound providing unit configured to output a bone conduction sound. The bone conduction sound providing unit is positioned on a area other than near an ear of a user. Sometimes Bone conduction makes person's voice sound different when it is recorded and played back because of the skull conduction at lower frequencies, which is better than air. People recognize their own voices to be lower and fuller than others do, and a recording of one's own voice frequently sounds higher than one expects it to sound.

V. APPLICATION (SGNL)

Signal Genetics, Inc. is symbolized as SGNL which is considered under Health Care sector of Medical Specialities industry. SGNL is a wristband that allows hearing phone calls by using your body as a conductor. There's no human user, one who never lost his\her earphone in their lifetime. With SGNL, cell phone can be kept in the pocket and simply by using hand we can answer a phone call without carrying any extra headset or earphone. Wonderfully sound will be transmitted by removing background noise, when you place your finger to your ear. We can hear very clear voice in loud places without worrying about other people listening in.

Figure 5.1: Working of SGNL

Hearing your caller's voice simply by placing your fingertip on your ear as you speak through a microphone included in the SGNL strap. As we had discussed about another device Audio bone headphones, instead of gaffing around sending vibrations through the air like a damn clown, these headphones take a more direct route sending vibrations straight into the top of your jaw and from there to your inner ear and brain. It is a funny idea that's mostly worse than using regular headphones, but can't help liking it all the same. Add together all these factors and despite their futuristic, mandible-vibrating promise, bone conduction headphones don't really cut it against the regular cousins, at least not in day-to-day use. The main benefit of bone conduction is that it keeps your ears free. Without any plug in the ear canals, people can hear the rest of the world just like they would normally.

In SGNL Bluetooth is used to receive voice signal from your phone. When a voice signal is received by SGNL, vibrations will be generated by Body Conduction Unit (BCU) which is transmitted through the hand to fingertip. As the transmission will be made through vibrations, there will not be any risk or harm to the human body. When the fingertip is placed beside our ear, the vibrations were made to echo and create amplified sound within the closed space of your ear [9]. With SGNL, answering calls becomes direct and removes background noise also. There is no need to struggle through your bag when your phone rings, or carry around extra headsets or earphones. Simply SGNL can be tapped to answer the calls and in the noisiest of the surroundings, calls can be heard very clearly. As sound is contained within the ear , only you can hear the voice ensuring privacy. Though, it is designed to fit in all sorts of classic and smart watches with its specially designed lug adapter, so it is called as a wearable smart strap, or a watch companion.

CONCLUSION

The present invention makes users to operate the phone without carrying earphone or headset. Bone conduction isn't likely to remove whole traditional sound hardware completely, especially when very few people use headphones for better sound quality and to escape noisy environments. The limitation is that, bass doesn't do so well and can easily get drowned out in environments containing a lot of external noise. The main advantage is reliability, because when we keep our finger on ear it blocks other background noise and makes the voice loud and clear and privacy is also maintained. This invention also provides a method for improving hearing perception in patients. Even musicians can use bone conduction devices while using tuning stringed instruments like tuning fork. After the fork starts vibrating, placing it in the mouth with the stem between the back teeth ensures that one continues to hear the note via bone conduction, and both hands are free to do the tuning.

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