Bone Conduction Hearing Device

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***Abstract*—According to the World Health Organization (WHO), almost one-thirds of hearing loss patients suffer from conductive hearing loss – a disorder either due to congenital defects in the outer and/or middle ear or due to old age [1]. A variety of hearing aids are available to solve these issues such as wearable aids, cochlear implants and Bone Anchored Hearing Aids (BAHA). Bone Conduction Technology plays a vital role in allowing these patients to hear.**

In addition to this, certain situations require the use of hearing devices which allow the user to also listen to ambient sound and not be isolated from the environment. In this project we have demonstrated two separate implementations of Bone Conduction Technology – one using specialized Bone Conduction Transducers and the other using Piezoelectric Transducer Discs. We have focused on the cost effectiveness of the latter over the former and demonstrated that Bone Conduction hearing aids can be built at much lower costs at the expense of sound quality. This report also shows how this sound quality can be improved and also focuses on various applications of Bone Conduction Technology in our day-to-day lives.

I. Introduction

Bone conduction technology has many applications in various areas. Our project is aimed at understanding those application, and analyzing and designing devices that are cost effective. We have made a bone conduction hearing band using Bone Conduction Transducers as well as one using Piezoelectric Transducer discs. We have studied the differences between varies aspects of both the implementations like cost, quality, attenuation in the signal. We have also incorporated findings of previous studies to find out the optimum positioning of transducers. Our project addresses the problem of conductive hearing loss and also mentions the usage of Bone Conduction Technology for military purposes.

II. Theory

We hear through the process of Air Conduction. Sound waves propagate by causing air particles to longitudinally vibrate. These vibrations propagate through our ear canal, until they reach the eardrum. Our ear canal is appropriately shaped to allow amplification of the sound as it travels through it. The eardrum passes these vibrations to the middle ear, which consists of three bones known as the ossicles – the malleus, incus and stapes. These bones further amplify the sound and send it to the inner ear or the cochlea. The cochlea is responsible for converting sound into electrical signals and sending these signals to the auditory nerve.

Bone Conduction Technology bypasses the outer and middle ear and sends vibrations directly to the inner ear. This is done by vibrating the temporal bone in the skull *(Fig 1)*, which conducts these vibrations and allows them to directly reach the cochlea [2]. While the exact mechanism is unknown, 8 different mechanisms have been proposed by scientists and no consensus has been arrived at [3].

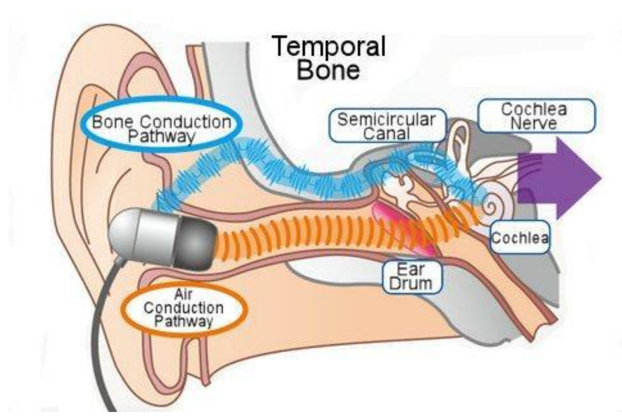

Fig 1. Bone Conduction and Air Conduction pathways [2]

The vibrations transferred through bone conduction transfer through layers of epidermis, soft tissue and even cartilage in some cases. Through bone conduction even lower frequency ultrasound can be heard. This is not possible with air conduction as our ear is evolved so as to filter vibration above 20,000 kilohertz. This property of bone conduction hearing can be used to modulate lower frequencies to ultrasound and use them to aid in the hearing of those who are suffering from hearing loss [4].

III. APPARATUS USED

A. Bone Conduction Transducer (Fig 2.)

- Dimensions: 14 mm X 21.5 mm
- Frequency response: 300 – 19,000 Hz
- Weight: 9.6 g

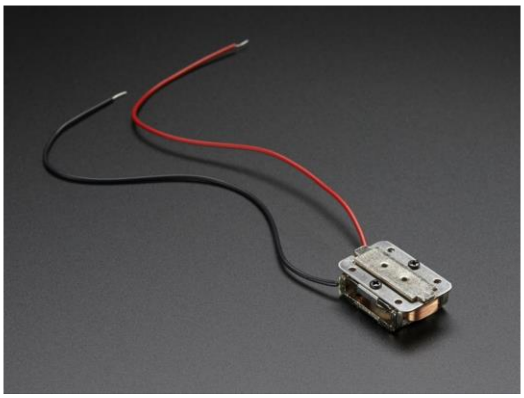

Fig 2. Bone Conduction transducer [5]

B. PAM8403 Stereo Amplifier (Fig 3.)

- Functions with power supply of 2.5V – 5V
- 85% amplification efficiency
- Dimensions: 1.85 cm X 2.11 cm

Fig 3. PAM8403 Stereo Amplifier [6]

C. LP053048 LiPo Battery (Fig 4.)

- 3.7 V output
- 700 mAh capacity

Fig 4. LP053048 Li-Po Battery [7]

D. TP4056 Li-ion Lithium Battery Charging Module (Fig 5.)

- 1200 mAh charge current
- 5V input

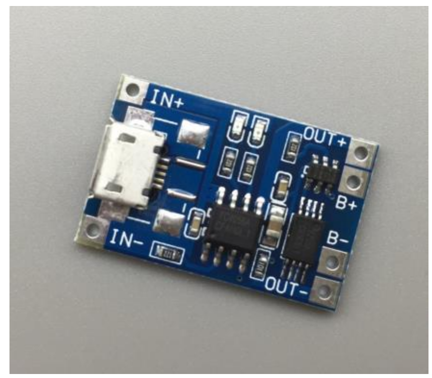

Fig 5. Battery Charging Module [8]

E. Piezoelectric Transducer Disc (Fig 6.)

- 25 mm diameter
- Material : lead zirconate titanate-piezoelectric ceramic material
- Weight : 18g per disc

Fig 6. Piezoelectric Transducer Disc [9]

F. *Samsung Bluetooth Module (Fig 7.)*

Fig 7. Samsung Bluetooth Module [10]

IV. DESIGN AND WORKING

In this section we speak about our two designs – The Bone Conduction Transducer Model and the Piezoelectric Transducer Model.

A. *Circuit Diagram*

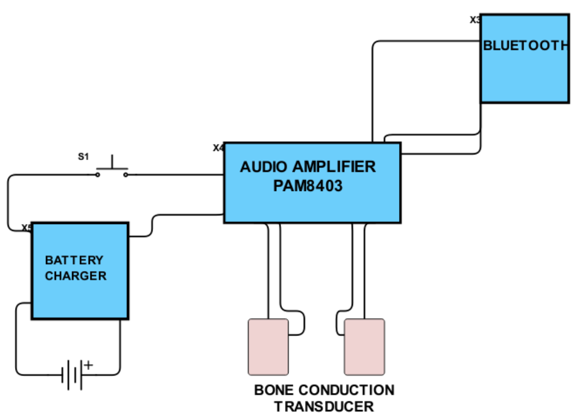

Fig 8. Bone Conduction Transducer Circuit

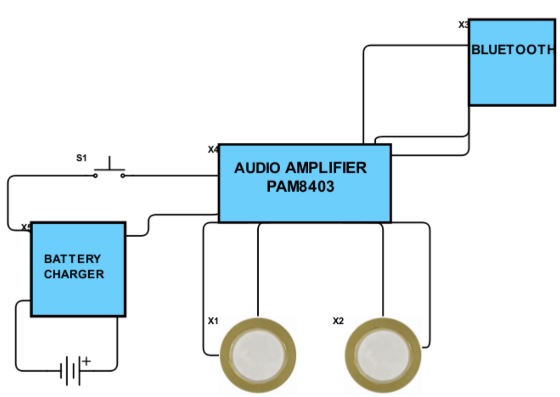

Fig 9. Piezoelectric Transducer Circuit

Both these circuits are exactly the same except that they consist of different transducers. In our model we used Bluetooth to send audio signals in the Bone Conduction Transducer Circuit *(Fig 8, 10.)* and an audio jack to send audio signals in the piezoelectric transducer circuit *(Fig 9, 11.).*

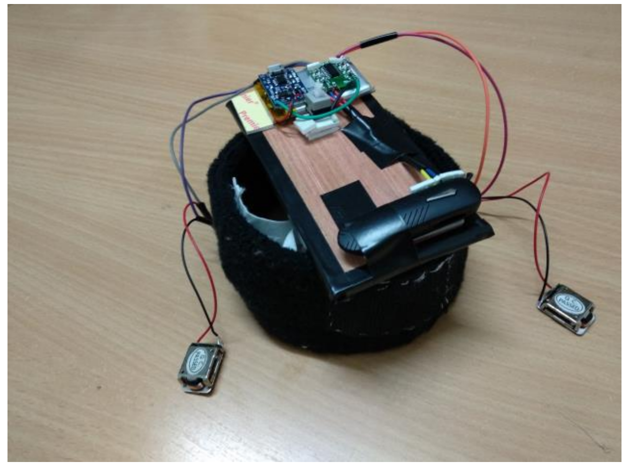

Fig 10. Our Bone Conduction Transducer Model

The Bluetooth device receives signals from the mobile phone. This is converted into electric signals and passed on to the amplifier. This signal is subsequently amplified and it travels to the Bone Conduction / Piezoelectric Transducer which converts these signals into mechanical vibrations. In the case of the Bone Conduction Transducer, it is the vibration of the metallic plate due to varying magnetic fields. In the case of the piezoelectric disc it is the vibration of the piezoelectric material.

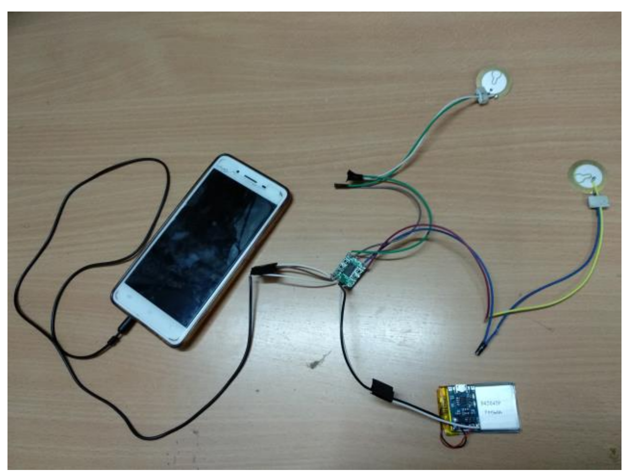

Fig 11. Our Piezoelectric Transducer Model

B. Location of Bone Conduction Device on Skull

According to research done by scientists in Maryland, USA the best location for the hearing device is the condyle bone, situated close to the front side of our ear. As it is near the ear canal, sound conduction also takes place by air conduction. The next best places are the jaw angle and the mastoid bone. Although the jaw angle allows good bone conduction, it is not suitable for placing bone conduction devices as maintaining the device position would be difficult while the user speaks. We have designed our headband such that the Bone Conduction Transducers are at the condyle position [11].

C. Comparison between Bone Conduction Transducer and Piezoelectric Transducer

In Bone Conduction Transducer, when current is passed through its coil, the magnetic field causes vibration in the metal piece and when it is pressed against a flat surface or against bone, it produces sound, whereas in piezoelectric transducer, when electric field is applied, it will cause the material to deform. The sound production is not based on a magnetic field but it depends on a special crystal that moves when an electric pulse is given to it.

The main advantage in using bone conduction transducer is that it produces high quality sound and with very less noise as compared with the Piezo transducer which produces less quality sound. But the noise produced in the piezo transducer can be minimized by using filters and noise cancellation circuit and piezo requires more amplification as compared with Bone Conduction Transducer. The main reason of using the piezoelectric transducer is its very low price which is approximately 20 ₹ per disc as compared to the price of Bone Conduction Transducer which is about 600 ₹ per transducer. The total cost of the Bone Conduction Transducer Model *(Fig 10.)* came to about 2500 ₹, whereas the total cost of the Piezoelectric Transducer Model *(Fig 11.)* came to about 500 ₹.

V. Applications of Bone Conduction Devices

A. Hearing Aids for Hearing Loss Patients

Bone Conduction Technology is a boon for people suffering from conductive hearing loss. There are a variety of hearing aids available including wearable aids, cochlear implants and BAHA (Bone Anchored Hearing Aids).

B. Underwater Communication

Bone Conduction Technology has enabled scuba divers and swimmers to communicate in water. Swimmers can listen to music while swimming. Bone Conduction Technology is useful wherever the medium of air is not present for conduction.

C. Reduction of Ambient Noise in daily use

Bone Conduction Technology is not limited to hearing aids or underwater communication. It is can be used to listen to music. Although quality of sound is still not quite as good as in-ear headphones, it is still more than sufficient for everyday use. It is very helpful for cyclists and runners as their ears will be open to ambient noises and hence they can avoid getting hit by a passing vehicle.

D. Military Applications

Bone Conduction Technology has been utilized in military communication devices. Military personnel operating under stealth mode or in close counter combat situations need to communicate with their team members as well as take into account ambient sounds from the environment.

VI. Improvements

A. Miniaturization

The whole setup can be packed into a band, which one can wear on his head and able to hear the sound through bone conduction. The band should be lightweight and easy to wear.

B. Sound Amplification

By reducing the thickness of piezoelectric discs, the amplification of sound can be increased, as it is easier to vibrate thin piezoelectric disc even at lower input voltages.

C. Noise Cancellation

Noise cancellation in Bone conduction hearing devices is a major challenge. Attenuation in the signal can be tackled using filter circuits.

VII. Conclusions

We have successfully implemented Bone Conduction Technology in two different ways. We have shown how cost can be reduced by using piezoelectric transducer discs. This implementation can give many more hearing loss patients access to this technology so their problems can be solved.

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