BONE CONDUCTION TELEPHONE FOR THE HEARING IMPAIRED

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ABSTRACT In order to realize the function of human interface of telecommunications whose objective is to interchange useful information among persons, we developed a bone conduction telephone with which hearing impaired persons with conductive or noise-induced hearing loss and presbycusis can communicate with each other without any other additional devices such as hearing aids. The bone conduction telephone we developed has chatacteristics as follows : (i) a hearing impaired person and a normal hearing person can communicate by bone and air conduction hearings, respectively, using only this telephone set because, as its receiver, it uses a bone conduction vibrator with which we can realize such function with the voice coil and damper of a small speaker unit, the vibrating plate, etc.; (ii) it has tone control function compensating hearing losses of hearing impaired persons according to their hearing loss/frequency chatacteristics. Using the tone control function together with a received volume control, it has the received volume range of 20dB in loudness rating; and (iii) it has the function of three emergency calls and a bell lamp as the visual display of a received call.

1. INTRODUCTION

The ultimate purpose of communication is to interchange useful information perfectly between human beings, which means, in the case of telecommunication, realizing the function of human interface from the viewpoint of users. This purpose coincides with that of informationized society and benefits from that society are to be no exception for the handicapped. But, recently, the population of the hearing impaired, including those of noise-induced hearing loss and presbycusis, has been increasing and the telephoning is an indispensable means of communication for anyone. Nevertheless, for the hearing impaired, it is not easy to communicate with a telephone, which is a fundamental means of telecommunication, and although it may be not always impossible it is very difficult without any other additional devices.

To solve the problem mentioned above, many kinds of telephone sets for the hearing impaired have been developed[1][2]. And SG 12, one of the study groups of ITU-T, made a recommendation P.37 including magnetic coupling method of telephone receivers to hearing aids and characteristics of telephone sets with additional receive amplification of 25dB intended to aid the hearing impaired[3]. There are also many international standards about magnetic field strength criteria around telephone receivers to couple to hearing aids and its measuring method such as Section 68.316 of FCC, RS-504 of EIA and IEEE std.1027.

In this paper, we desribe the bone conduction telephone set, we developed, with which hearing impaired persons with conductive or noise-induced hearing loss and presbycusis can communicate with each other without any other additional devices such as hearing aids.

2. TELEPHONE COMMUNICATION METHODS FOR THE HEARING IMPAIRED

The grades of hardness of hearing can be classified into 5 categories like Table 1 according to the difficulties to communicate with a telephone[4]. In Table 1, we also represent the ISO classification.

Table 1. The grades of hardness of hearing

grades	hearing loss(dB)	telephone communication	ISO classification(dB)
A	below 23	no problem	normal limits(10 ~ 26)
B	24 ~ 34	not serious	mild(27 ~ 40)
C	35 ~ 54	possible if normal speech level	moderate(41 ~ 55)
D	55 ~ 89	impossible without additional devices	moderately severe(56 ~ 70)
			severe(71 ~ 90)
E	above 90	impossible with any other additional acoustic devices	profound(91 ~)

Telephone communication methods for hearing impaired persons are considered to be several from the viewpoint of the amount of hearing losses and the origin of hearing difficulty, but from the viewpoint of with/without a hearing aid, they can be classified like Table 2[5][6][7].

Table 2. Telephone communication methods

with/without a hearing aid	methods or equipments	
without	a telephone with built-in amplifier a bone conduction telephone	
with	direct coupling	acoustic/magnetic coupling
	coupling with an adaptor	- magnetic coupling - acoustic coupling - electric coupling to telephone line - direct connection to a receiver terminal
	handset with built-in telecoil	magnetic coupling

In general, from Tables 1 and 2, only those with mild hearing losses will use a telephone receiver or one with built-in amplifier without a hearing aid. Some people with moderate to severe hearing losses can cope reasonably well with acoustic coupling to the phone(or with built-in amplifier) and can understand considerable amounts of speech. Many with severe or profound hearing losses prefer to use their hearing aids on telecoil input, because this electromagnetic link provides better speech perception for them[8]. These methods, i.e., use of a telephone handset with built-in amplifier or a hearing aid, are useful for some of the hearing impaired, but for those with conductive hearing loss, who have a defection on air conduction path of outer and middle ears, they are not, because a telephone receiver is an air conductive receiver of a loudspeaker.

There are, generally, two kinds of hearings, an air conduction hearing and a bone conduction hearing, as shown in Fig. 1. The former means that a sound can be heard when transmitted through the air to the ear and the latter that it can be heard through a bone vibrator pressed against the skull. Therefore, those who have a hearing impairment on the conductive system of hearing mechanism, as can be seen in Fig. 1, can perceive speech with a bone conduction hearing, if their sensorineural system is not or slightly impaired. A telephone with a bone vibrator as a receiver is meant to be a bone conduction telephone[1][5].

3. CONFIGURATION AND CHARACTERISTICS OF THE TELEPHONE

3.1 The bone conduction vibrator

As a bone conduction vibrator, in general, converts an acoustic input signal into a vibration, when it is used as a receiver of a telephone set, the hearing impaired with conductive hearing loss can communicate by bone conduction hearing. Especially, with the vibrator developed, not only hearing impaired persons but also normal hearing persons can perceive speech signal using bone

and air conduction hearings, respectively, because it was designed to realize such function with the voice coil and damper of a small speaker unit, the vibrating plate, etc. unlike the vibrators the other made.

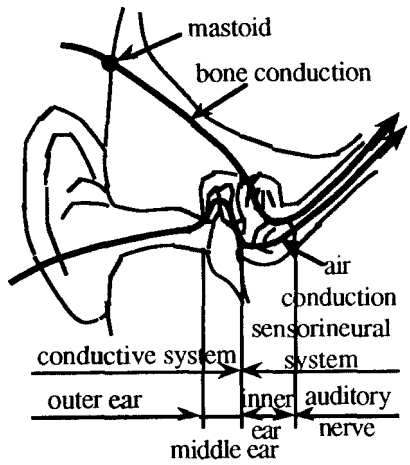


Fig. 1. Paths of air and bone conductions

The configuration of this vibrator designed to realize the fact mentioned above is given in Fig. 2. When the acoustic signal is applied to (2), the voice coil converting this signal into variation of magnetic field, through (10), the terminal, the magnetic field generated by the induced current in (2) and the field by (1), the magnetic circuit and magnet playing the role of fixed magnet, push and pull each other and the bobin around which the voice coil is wound vibrates upwards and downwards in the gap of (1). Then, (3), the vibrating plate which is pasted on the top of the bobin and designed as 'cross' type, vibrates together with bobin and the motion of the additional vibrating plate (8) is added. When the vibrating motion takes place, the cusion (5), the cover (6), and the additional cusion (7) keep it to be safe and it is transfered to the direct contacting part (9) through the fixing pin (4). Therefore, contacting (9) on the mastoid, which is the best hearing position of bone conduction on human head and placed about 3cm behind the ear entrance point, the hearing impaired can perceive the speech signal. And from the motion of the bobin mentioned above, the damper of (2) vibrates in air and reinforces the total motion of the vibrator itself stronger, so normal hearing persons can also perceive the signal.

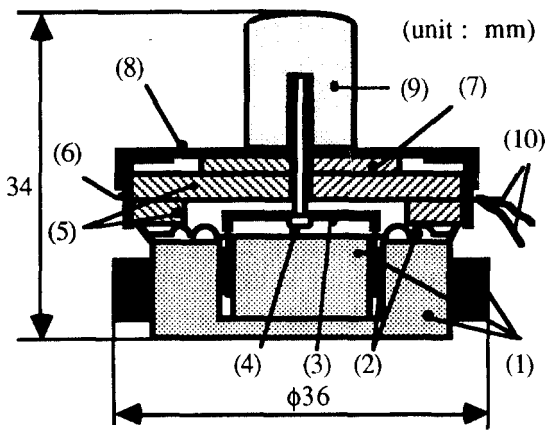


Fig. 2. The configuration of the bone conduction vibrator

The electric and receiving characteristics of bone/air conductions of the vibrator were measured. The nominal and maximum input powers are decided to be 1watt and 1.5watts, respectively. The measured nominal impedance was about 8.4ohms at one of the frequencies between 1.09 and 1.30kHz and the minimum frequency of resonance is in the range of 0.97 ~ 1.15kHz. The sensitivity/frequency characteristics, in the range of frequencies between 0.29 and 3.45kHz, was (114.5 ± 6.5)dB relative to 20μm/s^2 for bone conduction when measured with an artificial mastoid(B&K Type 4930), and (92 ± 11)dBSPL for air conduction when measured with an artificial ear(B&K Type 4128). Finally, the percentage of total distortion including the 3rd harmonic, in the range of frequencies between 125Hz and 4kHz, was below 1.34% for the nominal input and below 2.62% for the maximum input.

3.2 The bone conduction telephone

Because the bone conduction telephone set uses, as its receiver, the bone conduction vibrator mentioned above, it has a merit that hearing impaired and normal hearing persons can communicate by bone and air conduction hearings, respectively, using only this telephone set. It has also the function of three emergency calls for the aged and also a bell lamp as the visual display of a received call.

The circuit configuration of the telephone set is given in Fig. 3. It consists of the speech IC circuit, the tone control and selection circuits, the power amplifier, the DC power supply circuit and the handset with the vibrator, etc. The speech circuit has functions of switching and dialing with emergency calls. The tone selection circuit has 3 frequency characteristics, designed using variable resistors, such as flat, high 1 and high 2, compensating hearing losses of hearing impaired persons and maximizing articulation scores according to their hearing loss/frequency chatacteristics, which can be selected by a switch. The tone control circuit controls speech tone from the speech circuit using a commercial IC according to the selected frequency characteristic of the tone selection circuit. The power amplifier amplifies speech signal from the tone control circuit and controls the loudness of received sound, and the power supply circuit supplies power enough for the power amplifier to activate the vibrator from an external adaptor. The handset consists of the bone conduction vibrator, as the receiver, and the transmitter of a general microphone. As the result of the configuration of the power amplifier with the tone control and selection circuits, the telephone set has about 20dB control range of RLR(Receive Loudness Rating), that is, it has a similar effect to that which a telephone set with built-in received amplifier has.

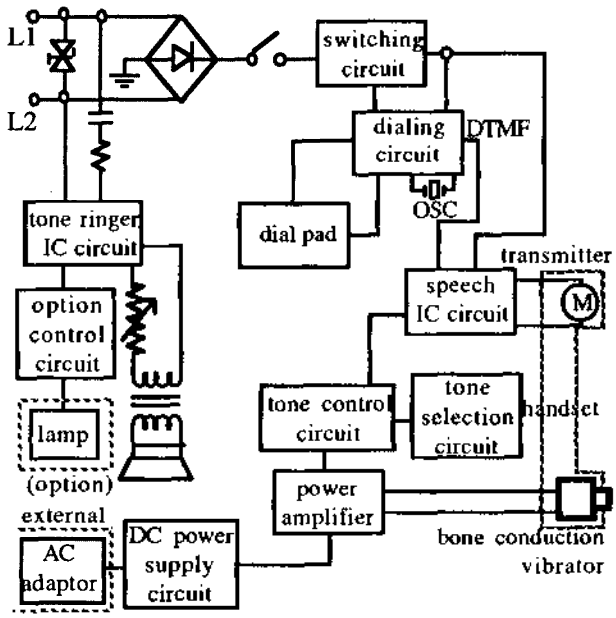


Fig. 3. The circuit configuration of the bone conduction telephone

Now, we describe the measured characteristics of the bone conduction telephone. The sensitivity/frequency characteristics was measured using the configuration of Fig. 4. A sound source, pink noise, was fed into the telephone through a telephone interface(B&K Type 5906) which includes high pass filter with cutoff frequency of 200Hz, low pass filter with of 4kHz, and feeding bridge. Then, the input level to the telephone line was selected to be -15dBm each over the measured range of frequencies, which was the mean level considering that the actual input level of speech signal to the line was in the range of -10 ~ -20dBm during a phone call. The sensitivity/frequency characteristics for bone conduction was measured as acceralation level with an artificial mastoid and for air conduction as sound pressure level with a head and torso simulator, like the case of the vibrator.

The measured results for bone conduction, when at the maximum position of the power amplifier, were (110.5 ± 6.5)dB for the flat frequency characteristic of the tone control function, (112 ±

10)dB for the high 1 of the function, and (114 ± 8)dB relative to 20μm/s^2 for the high 2 of the function, in the range of frequencies between 0.29 and 3.45kHz. And it was (96 ± 9)dBSPL between 0.4 and 3.45kHz for air conduction. We represent the measured results in Fig. 5.

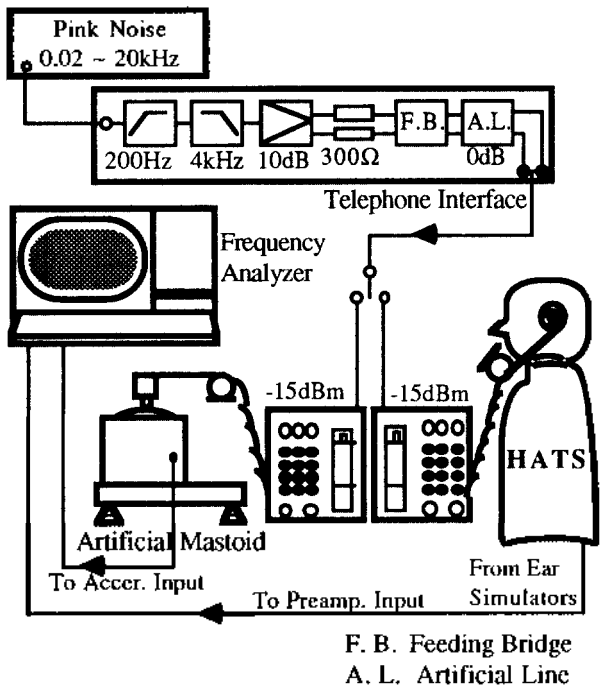
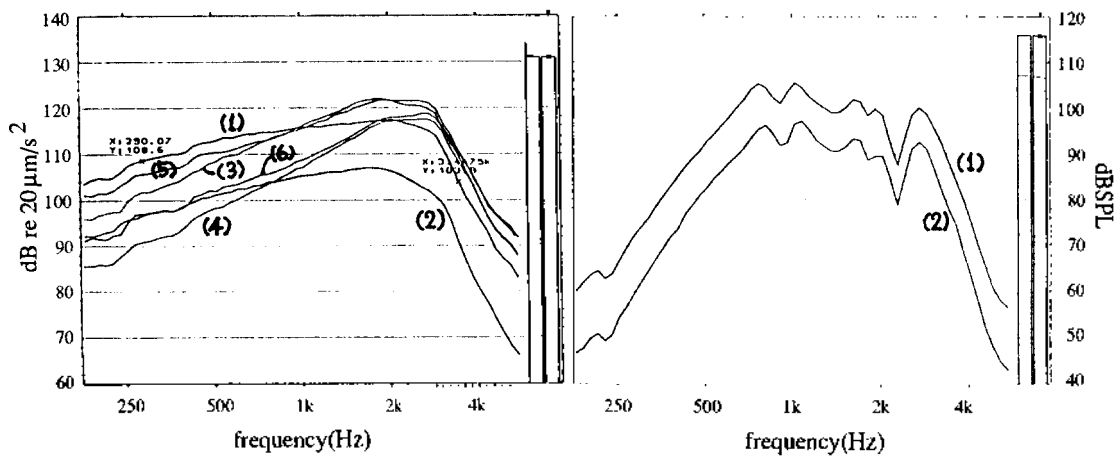


Fig. 4. Measurement configuration for the sensitivity vs. frequency characteristics of the telephone

The percentage of total distortion including the 3rd harmonic for bone conduction, when at the flat frequency characteristic of the tone control function, was below 3.54% in the range of 0.3 ~ 3.4kHz and for air conduction below 5% in the range of 0.6 ~ 3.4kHz.

The measured RLR was minimum -18.9dB when at the high 2 frequency characteristic of the tone control function and the maximum received loudness and maximum 1.6dB when at the flat of the function and the minimum loudness, so it is clear that the telephone set is designed to have 20dB, it is 20.5dB from the mesured result, control range of RLR as the result of the configuration of the power amplifier with the tone control function.



(a) characteristics for bone conduction

(1) power amp. at max.;tone ctrl. at flat
(2) power amp. at min.;tone ctrl. at flat
(3) power amp. at max.;tone ctrl. at high 1
(4) power amp. at min.;tone ctrl. at high 1
(5) power amp. at max.;tone ctrl. at high 2
(6) power amp. at min.;tone ctrl. at high 2

(b) characteristics for air conduction

(1) power amp. at max.;tone ctrl. at flat
(2) power amp. at min.;tone ctrl. at flat

Fig. 5. Measured sensitivity/frequency characteristics of the telephone

4. DISCUSSIONS AND CONCLUSION

Up to now, we described all the characteristics of the bone conduction telephone set which was developed to help the telephone communication for persons with conductive hearing loss. The telephone has a merit that hearing impaired and normal hearing persons can communicate by bone and air conduction hearings, respectively, using only this telephone set. And it has tone control function compensating hearing losses of hearing impaired persons. Using the tone control function together with the received volume control of the power amplifier, it has the control range of the received volume of 20dB in loudness rating. It has also the function of emergency calls and also a bell lamp as a visual display.

The development of the bone conduction telephone set has a meaning that persons with conductive hearing loss including noise-induced hearing loss and presbycusis would participate in the telephone communication because very few studies have been done to help the telephone communication for the hearing impaired and the aged. It can be applied, we guess, to public telephones and mobile telephones for personal. An articulation test with a syllable or an intelligibility test with a sentence for the actual users of this telephone set, the hearing impaired, has not done yet because of their lack to understand a language and the difficulty to select subjects, but it should be done to clarify persons to have a benefit from this telephone set, we guess. Of course, it is not all, but a starting point. From now on, we must be interested in some kinds of equipments to help the impaired to work as members of our society.

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