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SUPER-COMPACT MICROPHONE/RECEIVER FOR NOISY ENVIRONMENTS

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1. Introduction

The number of mobile and personal telecommunication terminals in use is continuing to grow steadily, indicating that there is a rising demand for telecommunications for private use.

- It is desirable to reduce the size of these terminals to increase portability, but the handsets used today for picking up and reproducing voice signals are a serious obstacle toward achieving this goal. What is needed to solve this problem is a small sized acoustic transducing part which can be used in place of such handsets.
- People often find themselves wanting to use a potable terminal at the same time that their hands are otherwise occupied, e.g. when they are driving a car, typing with a keyboard in an office, or holding shopping bags. In such situations, of course, a "hands-free" terminal would be preferable.
- Potable terminals are often used in noisy environments. In such cases, an anti-noise characteristic is necessary.

A bone-conductive microphone which picks up sounds propagated to the ear canal through the facial bones has been developed for use in noisy environments[1]. Moreover, its sound quality is not as good as in microphones for ordinary consumer use.

Against this background, we have developed a super-compact microphone/receiver unit which satisfies the above-mentioned requirements for portable terminals. The signal-to-noise ratio(SNR) was taken into consideration in designing the acoustic transducing part and selecting the signal processing method. The device's effectiveness is confirmed by listening tests in various noisy environments.

2. Acoustic transducing part

The microphone/receiver unit consists of an acoustic transducing part for picking up and reproducing voice signals and a transducing signal composer to control the optimum sound quality for various noise levels.

The transducing part consists of a receiver flanked by an air-conductive microphone on the side and a bone-conductive microphone underneath. All three components are included within a single earplug-shaped case which fits easily into the user's ear.

A sectional view of the acoustic transducing part is shown in Fig. 1. When the user speaks, the voice is picked up by the air-conductive microphone and bone-conductive microphone. This method is referred to as the 'dual microphone method' in this paper, as opposed to the conventional 'single microphone method,' in which either an air-conductive microphone or a bone-conductive microphone is used.

The air-conductive microphone can pick up air-conductive sound propagated from the mouth to the ear through the air. The sound quality of the air-conductive microphone is generally good, but it is rather weak in noisy environments. The bone-conductive microphone can pick up bone-conductive sound propagated from the mouth to the ear canal through the facial bones. The sound quality of the bone-conductive microphone is generally poor, but it is fairly strong in noisy environments. The proposed 'dual microphone method' combines the advantages of both microphones by selecting the optimum mixing ratio depending on environmental noise levels. Thus the unit provides an anti-noise characteristic and sound quality suitable for telecommunications whether it is used in a low- or high-noise environment.

The conventional bone-conductive microphone unit is often subject to problems with acoustic feedback, a serious obstacle to dual-mode telecommunication. In the proposed acoustic transducing part, however, the bone-conductive microphone and the receiver are housed in separate parts which are acoustically isolated by sound- absorbent material to prevent this problem.

3. Transducing signal composer

Simulation

The two kinds of voices produced with the dual microphone method, i.e. the air-conductive voice and the bone-conductive voice are combined in the transducing signal composer to make up the transmitting voice. A block diagram of the composer's control circuit is shown in Fig. 2. The output signal of the composer comprises three band-restricted signals, i.e., low- and high-passed air-conductive voice and low-passed bone-conductive voice, with an optimum weight. Simulated characteristics of 'SNR vs. noise level' are shown in Fig. 3. The signal is that of a male voice (74 dB at the ear entrance) and the noise is Hoth noise. The low-pass and high-pass filters are 4-order Chebychev types and the frequency characteristic of both microphones is assumed to be flat. The lines of the upper group are the results obtained when the low-frequency component of the bone-conductive sound is constant and the high-frequency component of the air-conductive sound is varied from -40 to 0 dB. The lines of the lower group are those obtained when the low-frequency components of the bone-conductive and air-conductive sound are mixed with a ratio from (0:1) to (1:0) and the high frequency component of the air-conductive sound is constant.

In general, SNR is degraded as the noise level increases. In the proposed device, SNR for the low-frequency component is maintained by shifting the weight from the air-conductive sound to the bone-conductive sound and for the high-frequency component by reducing the weight of the air-conductive sound. As a means of maintaining SNR without regarding sound quality, a control method involving the levels of both the air-conductive and bone-conductive sound is considered. The bold line shown in Fig. 3 is an example of how it works. At the first step, to keep SNR at 20 dB, the low-component level of the air-conductive sound decreases and that of the bone-conductive sound level increases. At the second step, to keep SNR at 10 dB, only the high component level of the air-conductive sound decreases. In this way, SNR is kept at 10 dB at least up to a noise level of 96 dB.

From the viewpoint of sound quality, however, the air-conductive sound is more significant. The relationship between SNR and sound quality is determined by both simulated results and listening test results.

The system can estimate environmental noise level automatically by integrating the air-conductive sound as the noise level. Using the characteristic that the bone-conductive sound includes a little noise compared to the air-conductive sound, it estimates whether an air-conductive sound level is voice or noise.

Analysis & tests

The frequency characteristic of the mixed sound is shown qualitatively in Fig. 4. When noise level is low, the frequency characteristic is almost the same as the air-conductive sound and the sound quality is good. When noise level is high, the frequency characteristic includes few high frequency components and this contributes to improved the sound quality.

The results we obtained in SNR vs. Hoth noise level experiments are shown in Fig. 5. At SNR of zero, the noise level is 20 dB more than an ordinary air-conductive sound. The same results were obtained in the listening tests. The conclusion is that the anti-noise capability of the mixed sound is the same as that of the ordinary bone-conductive sound. However, the advantage of this method is that it can realize optimum sound quality in both quite and noisy environments.

The shape of the acoustic transducing part resembles the shape of an earplug and enables the user to hear the incoming voice sounds. The noise levels at which telecommunication is feasible with this method and with the ordinary air-conductive microphone method are shown in Fig. 6. The effectiveness of the proposed method was confirmed by listening tests using a wide variety of noises, among them street, traffic and railroad noises.

4. Conclusion

A super-compact microphone/receiver unit comprising a bone-conductive microphone and air-conductive microphone and a sound control method for mixing sounds from both microphones according to noise level is proposed. It was determined that the unit's sound quality is better in both quite and noisy environments than that obtained in using only a bone-conductive microphone and that the unit makes telecommunication feasible in an environment 20 dBA noisier than the noisiest environment in which an ordinary air-conductive microphone can be used.

Test results verify that our proposed method is very promising for use in mobile telecommunications for users who are on foot on a noisy street, driving their car, or otherwise are in the midst of high-noise environment.

Reference

[1] Y. Maruya, "Evaluation of a bone-conduction microphone," Tech. Rep. Applied Acoust. Jpn. EA 95-56 (1995).

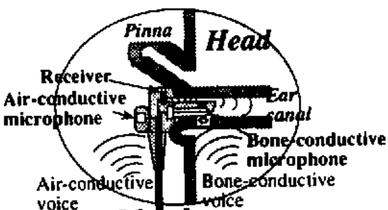

Fig. 1 Configuration of acoustic transducing part

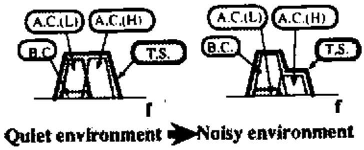

Fig. 4 Frequency band characteristics of mixing voice
B.C.: Bone-conductive voice,
A.C.: Air-conductive voice,
H:HPF, L: LPF,
T.S.:Transmitting voice

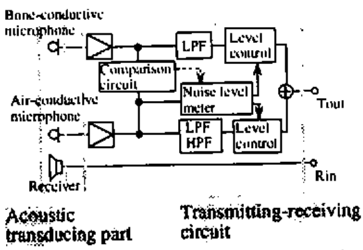

Fig. 2 Block diagram of control circuit

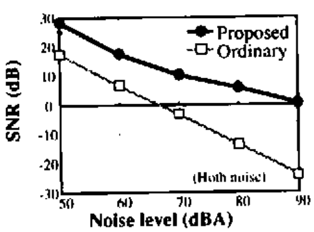

Fig. 5 SNR dependance on noise level

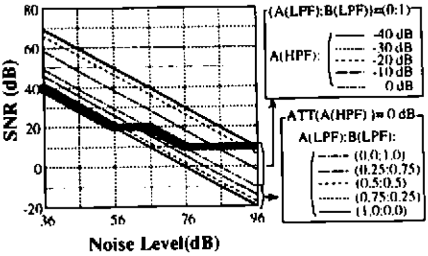

Fig. 3 Optimum SNR vs. environment noise (Hoth noise)

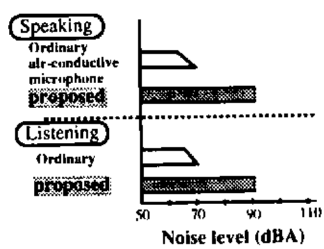

Fig. 6 Feasibility of telecomunication