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Dynamic Acoustic Transparency Control System

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ABSTRACT

A dynamic acoustic transparency control mechanism for audio devices such as headphones or earbuds is described. The acoustic transparency level for the device is adjusted based on ambient sound detected using an external microphone. In some configurations, an automatic gain control (AGC) block is utilized in the signal path to automatically boost ambient sound to a designed level. In some configurations, a sound pressure level (SPL) is determined based on sound received at the external microphone and a lookup table is utilized to determine a gain based on the received SPL. In some configurations, the applied gain is determined based on an audiogram associated with the user, obtained with user permission. The acoustic transparency system as described herein is implemented in a low-latency signal path and is well-integrated with feedback noise cancelling system to alleviate occlusion effects. The described techniques can enable users to maintain an awareness of their surroundings while wearing headphones or earbuds.

KEYWORDS

- Dynamic hear-through
- Adaptive transparency
- Audiogram
- Noise tracking
- Background noise
- Active Noise Cancellation (ANC)
- Headphones
- Earbuds
- Sound pressure
- Occlusion

BACKGROUND

Earbuds and/or headphones are commonly utilized in a variety of settings such as outdoors, at the gym, etc. that have different ambient sound levels. Some earbuds and headphones include active noise cancellation features that cancel ambient noise and provide users with a superior listening experience. However, cancellation of ambient noise can also lead to the user feeling aurally isolated from the environment. To mitigate this, many headphones and earbuds offer audio transparency.

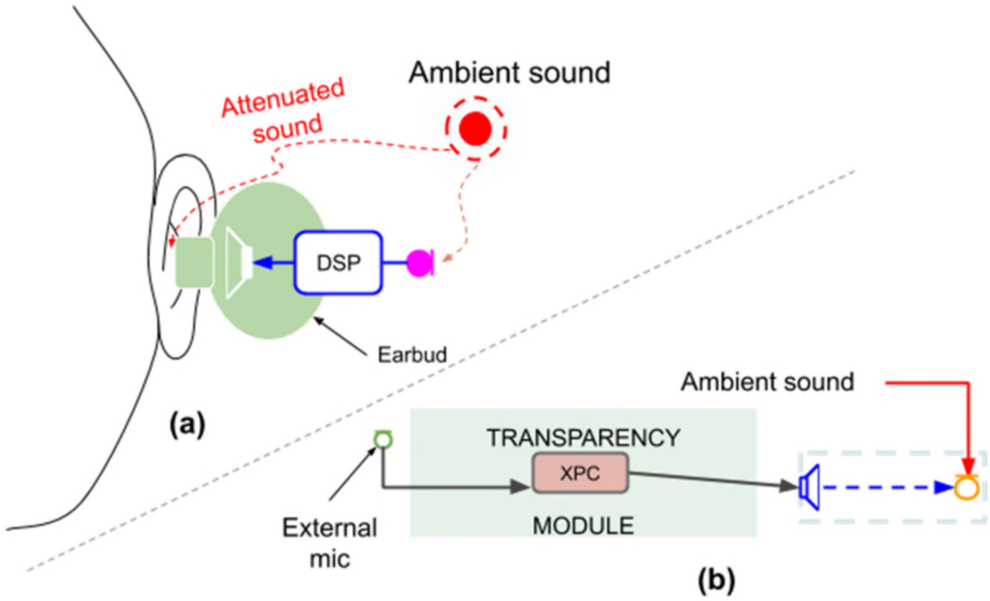

Fig. 1: Acoustic transparency enables a headphone/earbud user to listen to ambient sounds

Fig. 1 illustrates example utilization of acoustic transparency. As depicted in Fig. 1(a), only attenuated ambient sound reaches the ear of a user utilizing an earbud/headphone via leakage, e.g., gaps between a headphone/earbud and the ear. Acoustic transparency (pass through) is commonly utilized to mitigate user isolation and enable a user to maintain some awareness of ambient sound.

Fig. 1(b) depicts an example implementation of acoustic transparency. As depicted in Fig. 1(b), an external microphone is placed outside the earbud/headphone. The external microphone receives ambient sound, which is then processed through a transparency module

(XPC), and played back into the ear canal to provide ambient awareness. However, most solutions utilize a fixed filter topology and do not adapt to different sound environments.

DESCRIPTION

This disclosure describes a dynamic acoustic transparency control system that is adaptive to ambient sound environments. Per techniques of this disclosure, a dynamic transparency control (XPC) mechanism is utilized to adjust an acoustic transparency level depending on the ambient sound level. The detected ambient audio signal is processed in a low-latency digital signal processing (DSP) path and well-integrated with feedback active noise cancelling system to alleviate occlusion effects. The features enable natural perception of sounds, with automatic books being applied to the ambient sound to achieve a designed level.

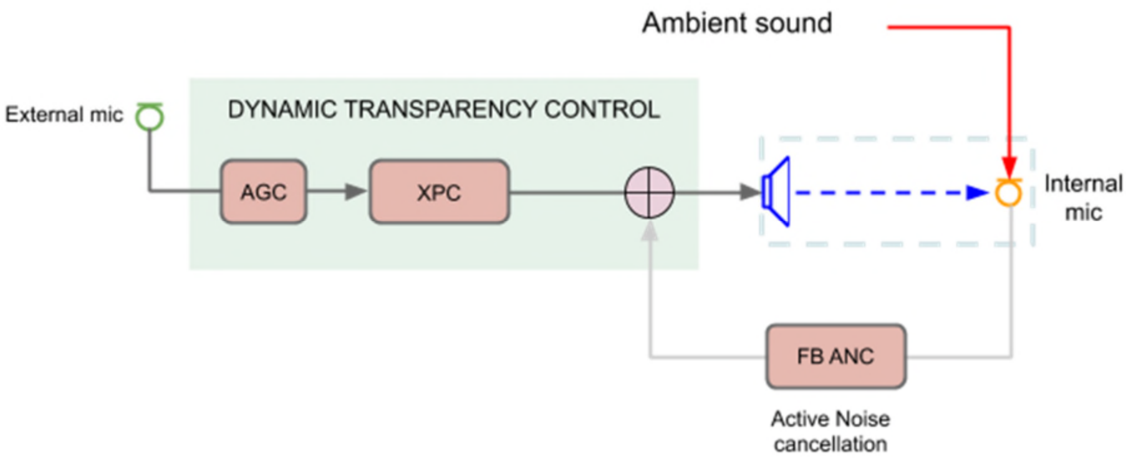

Fig. 2: Automatic gain control (AGC) based acoustic transparency

Fig. 2 illustrates a first example implementation of acoustic transparency, per techniques of this disclosure. In this example, acoustic transparency is enabled by inclusion of an Automatic Gain Control (AGC) block in the signal path. An external microphone placed on an exterior surface of the headphone/earbud is utilized to receive ambient sound. A feedback active noise cancellation (ANC) path is utilized to cancel ambient noise. An internal microphone is utilized to measure ambient sound that is received in the ear via leakage. Based on a particular sound level that is set for ambient sounds, the AGC block automatically boosts ambient sound to the designed level.

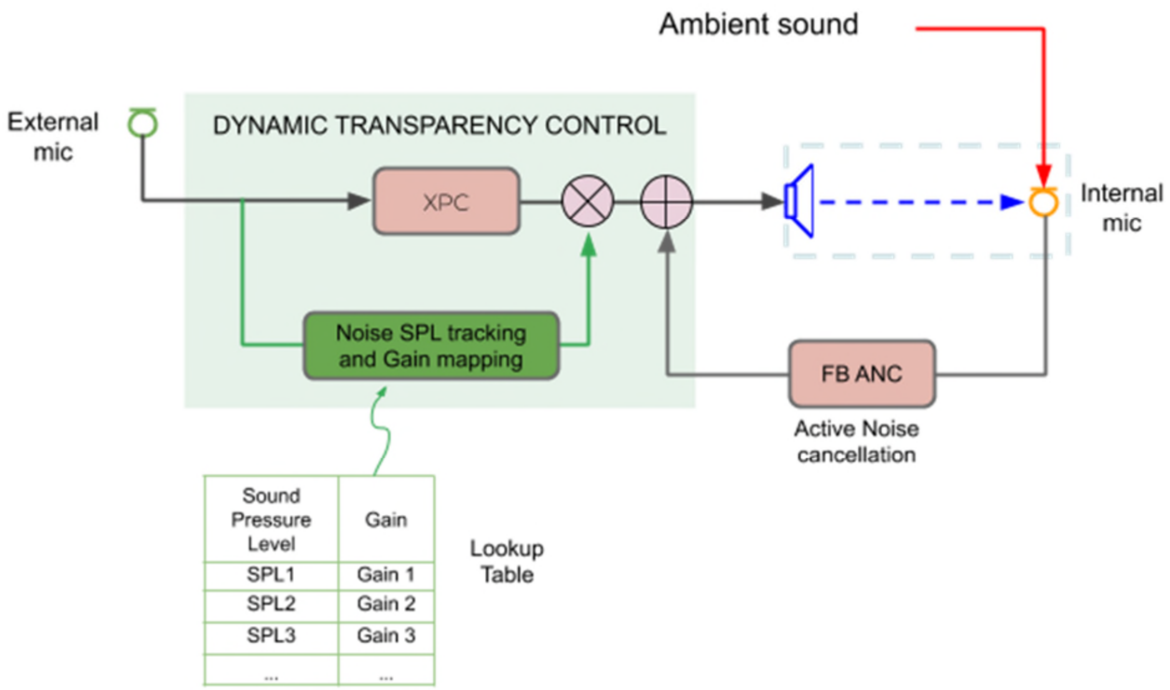

Fig. 3: A dynamic gain is applied based on background noise levels

Fig. 3 illustrates a second example implementation of acoustic transparency, per techniques of this disclosure. In this example, acoustic transparency and hearing protection is enabled by providing ambient sounds to the user at a sound level based on gain that is determined from measured background noise (sound) levels.

A sound pressure level (SPL) is determined based on sounds received at the external microphone. A lookup table is utilized to determine a gain based on the received SPL that is applied to the ambient sound before being transmitted to the user. In this example, a larger gain is applied when users are in a relatively quiet environment and a lower gain is applied when the user is in louder environments.

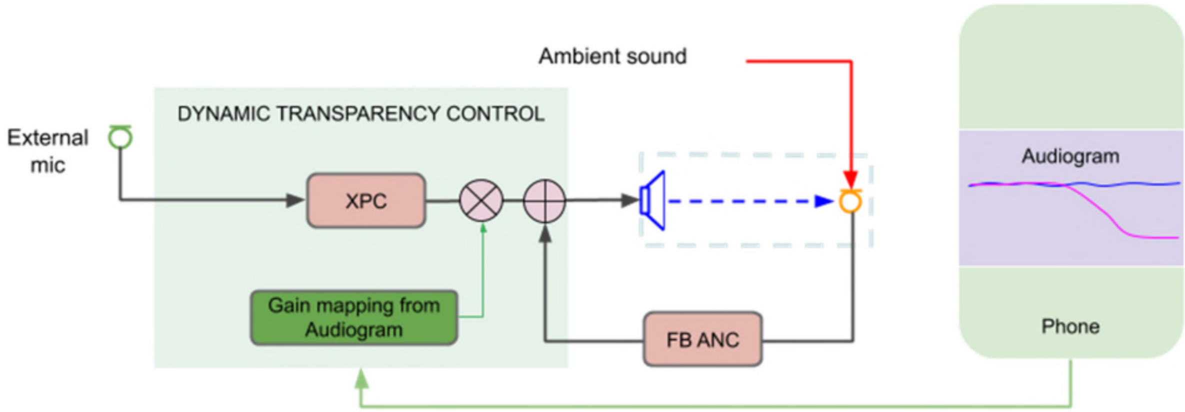

Fig. 4: A dynamic gain is applied based on user specific audiograms

Fig. 4 illustrates another example implementation of acoustic transparency, per techniques of this disclosure. In this example, acoustic transparency is enabled by applying a gain to ambient sound based on an audiogram associated with the user, obtained with user permission. An audiogram is indicative of a user's ability to hear sounds at different frequencies. For example, an audiogram can represent a user's degrees of hearing loss across different sounds frequencies.

In this example, based on the measured ambient sound, a gain is determined based on a user's response to frequencies based on an audiogram. The audiogram is stored locally, for example, on a user's mobile device, based on a previously conducted hearing test. The determined gain is applied to suitably compensate for a user's reduced response to certain frequencies, e.g., low frequency sounds, and enables better user perception of ambient sounds. If no audiogram is available, a default (non-personalized) audiogram can be used, or the adjustment can be made according to the configurations of Fig. 2 or Fig. 3.

The various examples of adjusting for ambient sound level can enable users to maintain an awareness of their surroundings while wearing earbuds or headphones. Specific implementations can be particularly useful for users that are hearing impaired.

Further to the descriptions above, a user is provided with controls allowing the user to make an election as to both if and when systems, programs or features described herein may enable collection of user information (e.g., information about a user's hearing ability or an audiogram for the user, a user's preferences, ambient sound levels, a user's location), and if the user is sent content or communications from a server. In addition, certain data may be treated in one or more ways before it is stored or used, so that personally identifiable information is removed. For example, a user's identity may be treated so that no personally identifiable information can be determined for the user, or a user's geographic location may be generalized where location information is obtained (such as to a city, ZIP code, or state level), so that a particular location of a user cannot be determined. Thus, the user may have control over what information is collected about the user, how that information is used, and what information is provided to the user.

CONCLUSION

A dynamic acoustic transparency control mechanism for audio devices such as headphones or earbuds is described. The acoustic transparency level for the device is adjusted based on ambient sound detected using an external microphone. In some configurations, an automatic gain control (AGC) block is utilized in the signal path to automatically boost ambient sound to a designed level. In some configurations, a sound pressure level (SPL) is determined based on sound received at the external microphone and a lookup table is utilized to determine a gain based on the received SPL. In some configurations, the applied gain is determined based on an audiogram associated with the user, obtained with user permission. The acoustic transparency system as described herein is implemented in a low-latency signal path and is well-integrated with feedback noise cancelling system to alleviate occlusion effects. The described techniques can enable users to maintain an awareness of their surroundings while wearing headphones or earbuds.