July 2021

Active Noise Control System With Adaptive Wind Noise Mitigation

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Active Noise Control System With Adaptive Wind Noise Mitigation

ABSTRACT

This disclosure describes adaptive wind noise mitigation to provide adaptive acoustic transparency that is based on ambient wind levels. An acoustic transparency system is proposed that includes feedback and feedforward filters. The feedback filter can be dynamically throttled to mitigate low-frequency band wind noise. The feedforward filter is utilized to reduce mid-frequency band wind noise while still maintaining or enhancing high frequency acoustic transparency to enable better conversation quality. A two-microphone coherence-based metric is utilized to detect wind events and to adaptively adjust a transparency level based on the detected wind noise. Digital signal processing (DSP) control blocks are utilized to mitigate mid-and-low frequency wind noise passing into a user’s ear, while maintaining or enhancing high frequency transparency gain that enables more speech to pass through to the user’s ear, thereby improving conversational quality even in the presence of loud wind noise.

KEYWORDS

- Dynamic hear-through
- Adaptive transparency
- Acoustic transparency
- Noise tracking
- Ambient sound
- Active Noise Cancellation (ANC)
- Headphones
- Earbuds
- Sound pressure
- Wind turbulence
- Wind noise

BACKGROUND

Earbuds and headphones are commonly utilized in a variety of settings with different ambient sound levels, such as outdoors, at the gym, during travel, etc. 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.

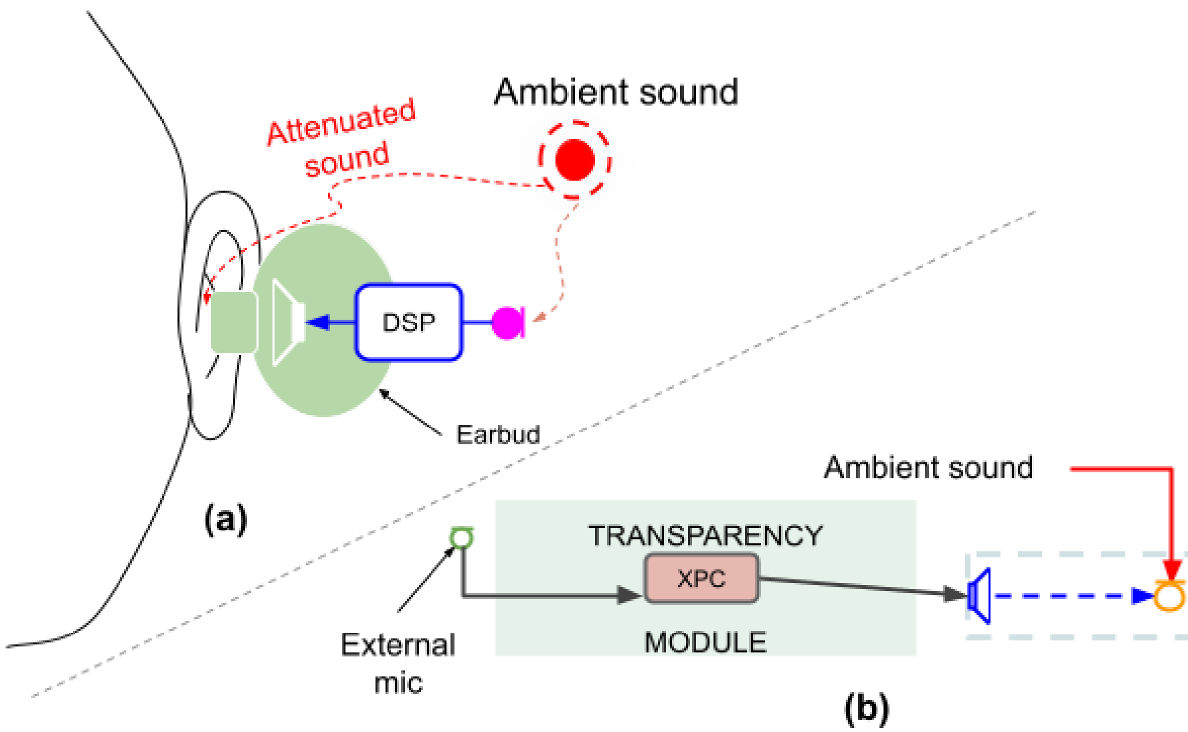

Fig. 1: Acoustic transparency enables a headphone/earbud user to listen to ambient sounds

Fig. 1(a) illustrates an example of how attenuated ambient sound reaches the ear of a user that is using earbuds/headphones 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 the 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 earbuds/headphones. The external microphone receives ambient sound, which is then processed by a transparency module (XPC), and played back into the ear canal to provide ambient awareness. However, in this configuration, unwanted wind noise picked up by external microphone is also passed through into ears causing annoyance, degrading ambient awareness and/or conversation.

DESCRIPTION

This disclosure describes adaptive wind noise monitoring and mitigation to provide adaptive acoustic transparency that is based on ambient wind levels. Per techniques of this disclosure, an acoustic transparency system includes a feedback Active Noise Cancellation (ANC) filter and a feedforward transparency filter. The feedback filter can be dynamically throttled to mitigate low-frequency band wind noise (disturbances).

The feedforward filter is utilized to reduce mid-frequency band wind noise while still maintaining or enhancing high frequency acoustic transparency to provide good conversation quality. A two-microphone coherence-based metric is utilized to detect wind events and to adaptively adjust an acoustic transparency level based on the detected wind occurrences and/or speeds. The acoustic transparency levels are adjusted by applying different gains and filters.

A total of three microphones are utilized, where one of the microphones is utilized for the transparency path, and the other two microphones are utilized for wind noise detection, which is performed in parallel.

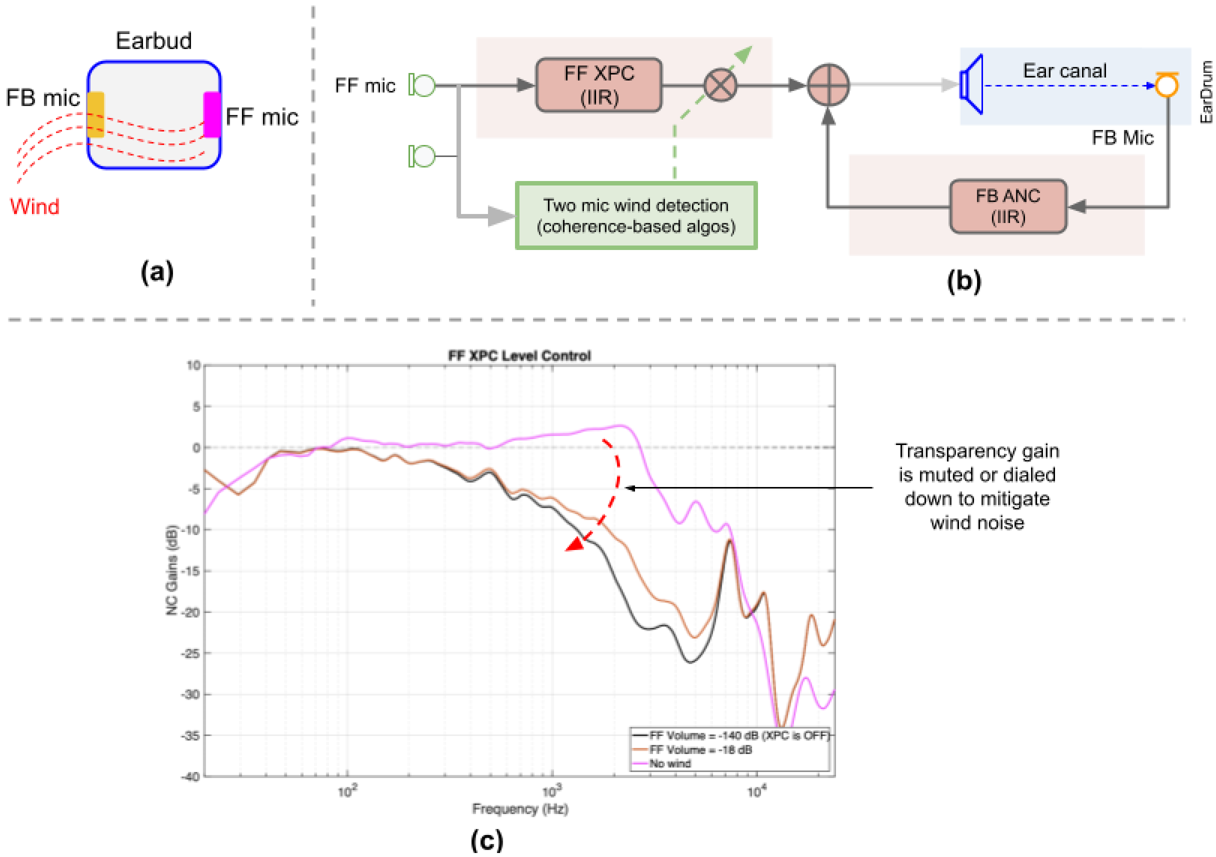

Fig. 2: Conventional: transparency gain is reduced to mitigate effects of wind noise

Fig. 2 depicts an example of a conventional acoustic transparency system that can be utilized to mitigate effects of wind noise by adjusting the transparency. Fig. 2(a) depicts an example earbud that includes a feedforward (FF) microphone and a feedback (FB) microphone located on its exterior surface. Fig. 2(b) depicts components of the acoustic transparency system.

Based on wind noise detected by the two microphones, a transparency path gain of the transparency module is dialed down or muted to mitigate effects of wind noise. This leads to reduced effects of wind noise; however, the user also loses awareness of high-frequency sound in their ambient environment.

Per techniques of this disclosure, additional digital signal processing (DSP) control blocks and a finite impulse response (FIR) filter are utilized to mitigate mid-and-low frequency wind noise passing into a user's ear, while maintaining or enhancing high frequency transparency gain that enables more speech to pass through to the user's ear. These techniques thereby improve conversational quality even in the presence of loud wind noise due to turbulence.

Dynamic Gain Control

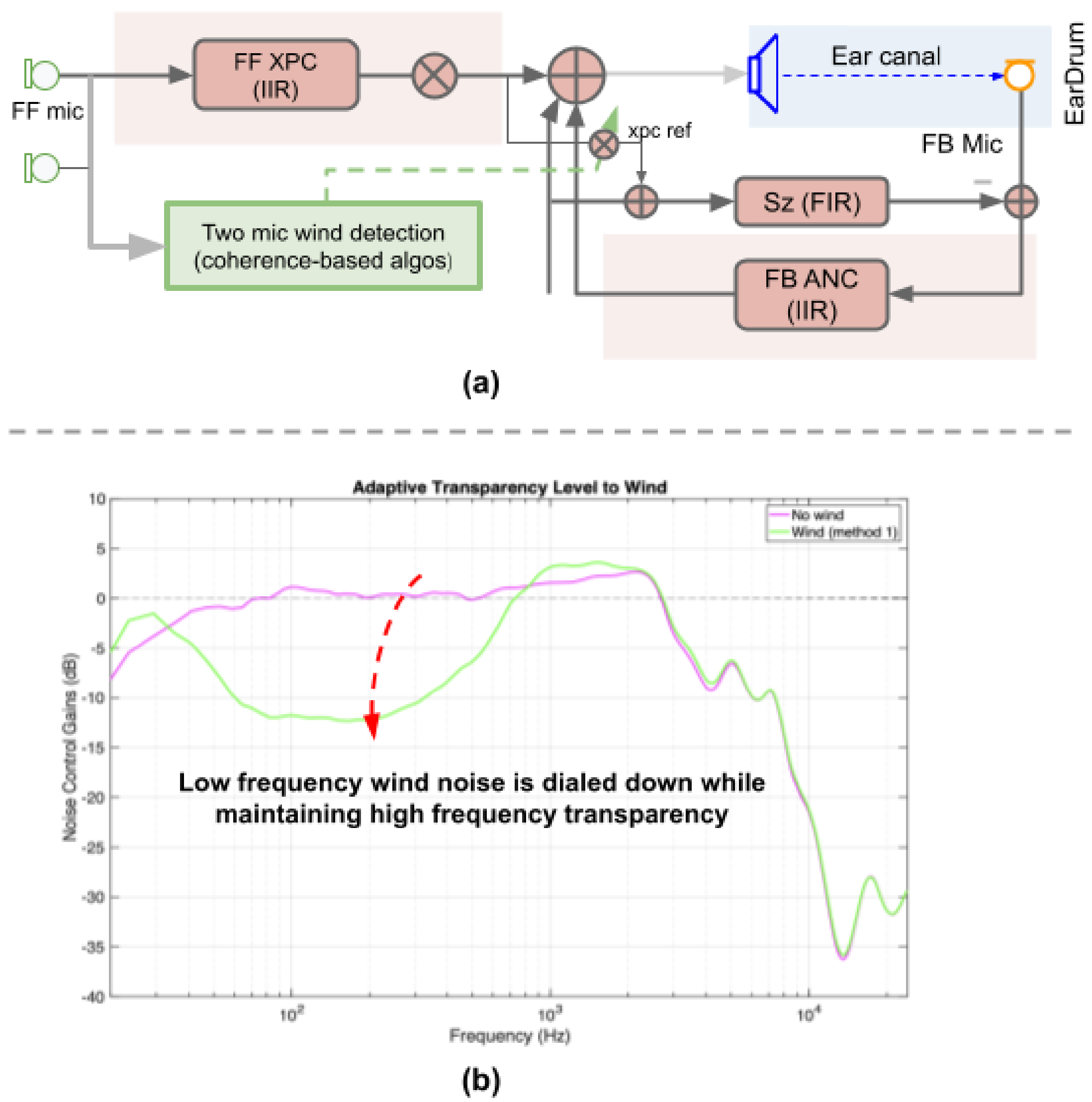

Fig. 3: Wind effects are mitigated while high frequency transparency is maintained

Fig. 3(a) illustrates a first example implementation (Method 1) of adaptive acoustic transparency, per techniques of this disclosure. A gain of the FIR filter is adjusted based on detected wind noise. In this example, at low frequencies, the acoustic transparency is reduced, thereby mitigating effects of wind noise, while mid and high frequency components are unaffected, thereby providing superior voice quality. Fig. 3(b) depicts a graph that illustrates an example of performance of this implementation.

Dynamic Gain and Filter Control

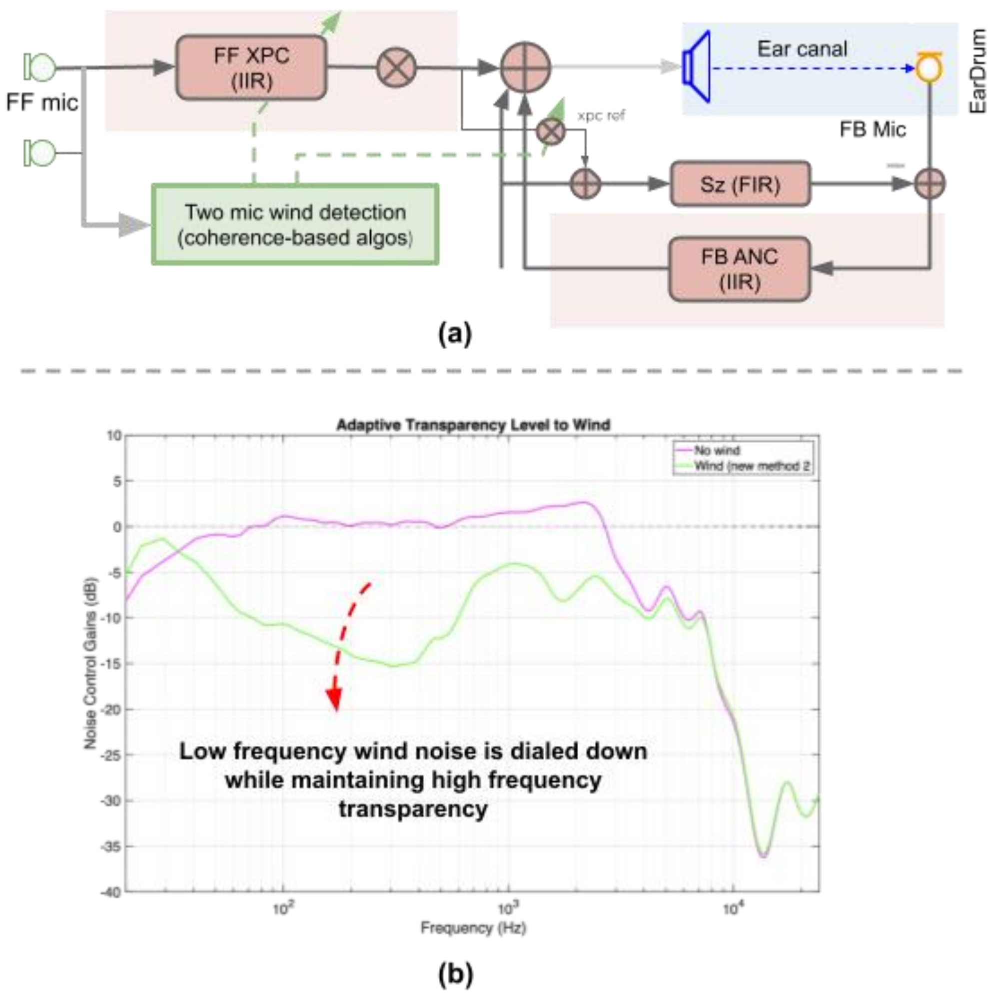

Fig. 4: Gain of an FIR filter is adjusted based on detected wind noise

Fig. 4(a) illustrates a second example implementation (Method 2) of adaptive acoustic transparency, per techniques of this disclosure. In this implementation, gain of the transparency (XPC) infinite impulse response (IIR) filter is also adjusted based on the detected wind noise. This provides additional flexibility and control over the filter performance, and provides superior performance in high wind (1-2 kHz) conditions. Fig. 4(b) depicts a graph that illustrates an example of performance of this implementation.

Dynamic Filter Control

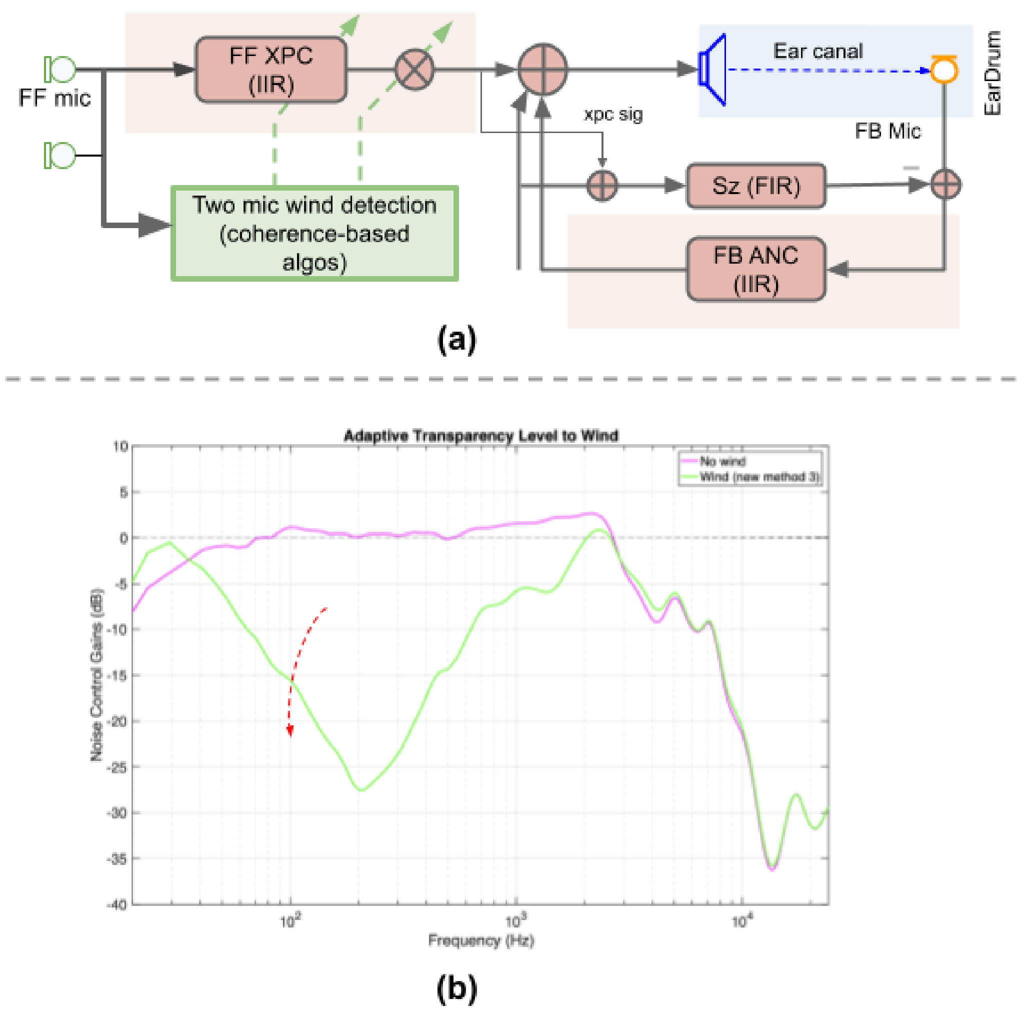

Fig. 5: Gain of the XPC filter is adjusted based on the detected wind noise

Fig. 5(a) illustrates a third example implementation (Method 3) of adaptive acoustic transparency, per techniques of this disclosure. In this example implementation, the gain of the XPC filter path is adjusted based on the detected wind noise. Fig. 5(b)depicts a graph that illustrates an example of performance of this implementation.

The different variations of the implementations described herein enable various degrees of flexibility and adaptability of acoustic transparency based on detected wind noise.

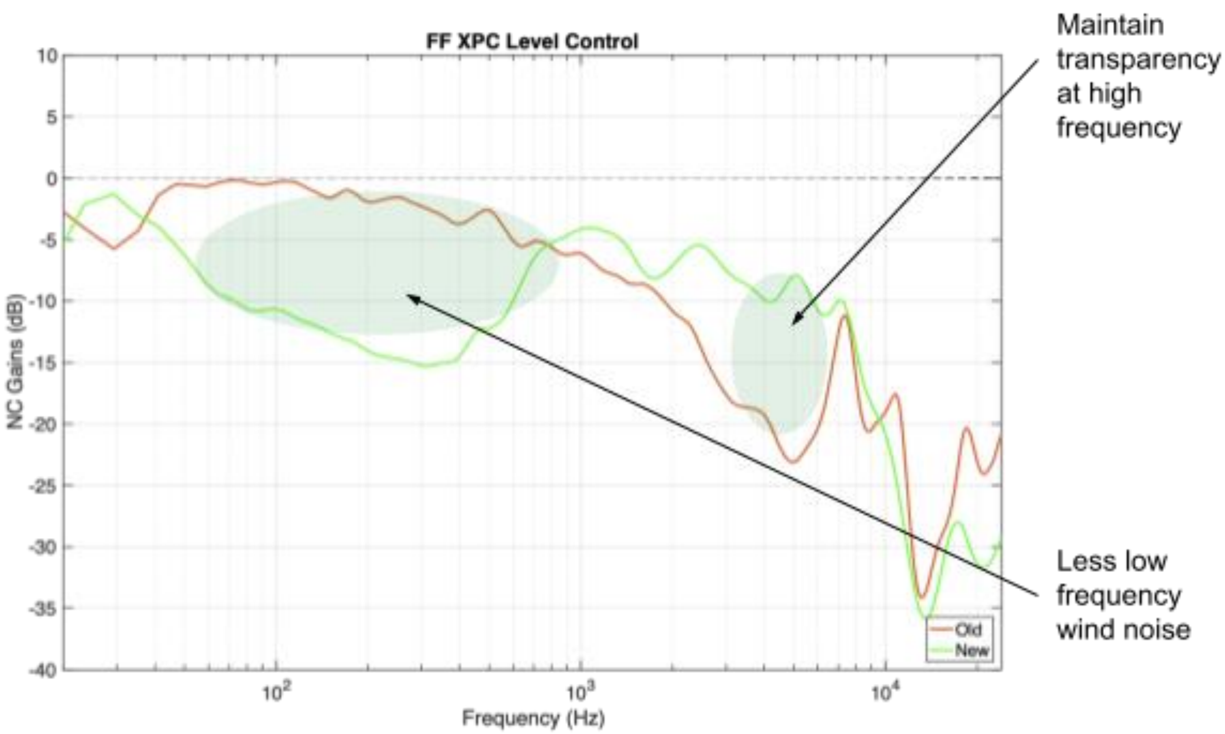

Fig. 6: Acoustic performance comparison

Fig. 6 depicts a comparison of acoustic performance of conventional wind mitigation techniques and techniques described herein. As can be seen from Fig. 6, techniques (e.g., Method 2) described herein enable maintenance of acoustic transparency for high frequency components (speech, etc.) while mitigating effects of low frequency wind noise, and can provide superior conversational quality.

CONCLUSION

This disclosure describes adaptive wind noise monitoring and mitigation to provide adaptive acoustic transparency that is based on ambient wind levels. An acoustic transparency system is proposed that includes feedback feedforward filters. The feedback filter can be dynamically throttled to mitigate low-frequency band wind noise. The feedforward filter is utilized to reduce mid-frequency band wind noise while still maintaining or enhancing high frequency acoustic transparency that enables better conversation quality. A two-microphone coherence-based metric is utilized to detect wind events and to adaptively adjust a transparency level based on the detected wind noise. Digital signal processing (DSP) control blocks are utilized to mitigate mid-and-low frequency wind noise passing into a user's ear, while maintaining or enhancing high frequency transparency gain that enables more speech to pass through to the user's ear, thereby improving conversational quality even in the presence of loud wind noise.

REFERENCES

1. Sun, Guohua; Ooi, Leng; and Lee, Jae, "Dynamic Acoustic Transparency Control System", Technical Disclosure Commons, (December 14, 2020), https://www.tdcommons.org/dpubs_series/3881, accessed on 14 June 2021.