November 07, 2017

Notch filters for removing common noise frequencies

Robin Lundberg

Notch filters for removing common noise frequencies

ABSTRACT

A microphone for picking up speech in an enclosure typically also picks up noise from nearby equipment. A common approach to reduce such noise is to first estimate the noise and then to remove it, e.g., through cancellation or frequency sub-band damping. Noise cancellation typically involves additional hardware, e.g., additional microphone(s) to estimate noise, cancellation circuitry, etc.

Observing that noise from equipment typically present in conference rooms, e.g., computers, fans, etc., have a sharp noise spectral density, techniques of this disclosure employ notch filters, e.g., filters with sharp V-shaped reject-frequencies, to remove noise. Notch filters, having narrow reject-frequencies, effectively cut down noise and produce an audio signal that improves audio quality in audio calls.

KEYWORDS

- Notch filter
- Noise rejection
- Audio conferencing
- Noise estimation

BACKGROUND

Rooms or offices used for audio calls often include equipment that generates noise that is picked up by a microphone. For example, such equipment includes computers, fans, air conditioners, other ventilation equipment, etc. Besides sources of mechanical noise, there is also 50 or 60 Hertz hum that originates from electrical lines and is picked up inductively by

audio circuitry. Such noises, when picked up by a microphone used during an audio call, reduce audio quality of the call.

Noise in audio systems is traditionally reduced by noise-cancellation circuitry. The circuitry typically senses ambient noise and adaptively transforms sensed noise so that it is a near-negative of the noise present at the listener end (e.g., a headphone of a listener). A requirement of noise-canceling technology that is not always met is to place the noise-sensing microphone close to the source(s) of noise. Aside from the difficulty of placing a microphone such that it acquires only (or mostly) noise, noise-cancellation technology also requires the use of additional hardware, e.g., microphones, cancellation circuitry, communication lines between noise-sensing and speech-sensing microphones, etc. Once estimated, noise can be suppressed using filters, but this leads to some listeners perceiving speech as somewhat muffled.

DESCRIPTION

Noise sources within common locations where audio calls are conducted, e.g., conference rooms, offices, etc., typically have sharp power spectral density. For example, a power-line hum in the United States is a 60-Hertz wave and its harmonics, while in the European Union and some other locations, it is a 50-Hertz wave and its harmonics. Computer hard-drives typically generate noise at 120 Hertz and harmonics thereof. Since noise experienced in conference rooms is essentially narrow band, it can be rejected by use of narrow-band filters that target just the noise frequencies and allow unaltered passage of all other frequencies that carry speech.

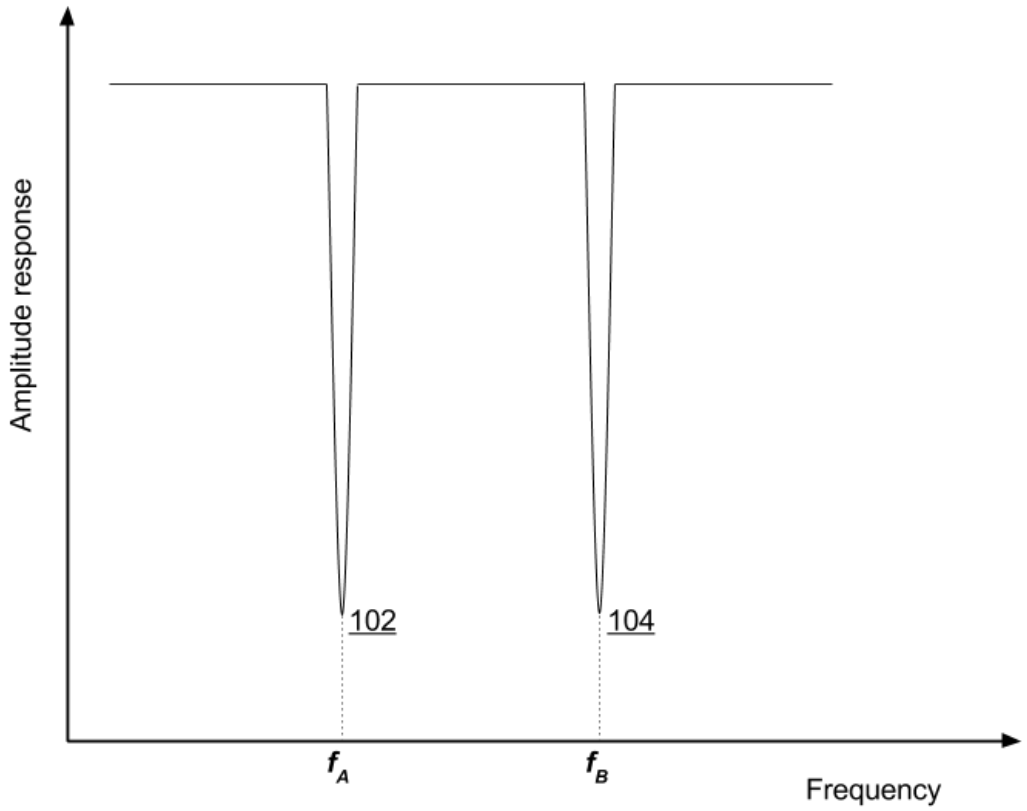

Fig. 1: Response of a notch filter

Fig. 1 shows an example of amplitude response of a notch filter. A notch filter can have one or more notches, e.g., narrow, V-shaped regions (102, 104) within which the gain of the filter is low (rejection is high). At notch frequencies, e.g., f_A and f_B in Fig. 1, an incoming signal experiences high rejection, whereas at all other frequencies, the incoming signal experiences almost no change, e.g., frequency response is flat outside of the notches.

Per techniques of this disclosure, one or more notch filters, with notches at noise frequencies commonly found in conference rooms (e.g., 50Hz, 60Hz, 100Hz, 120Hz, etc.), are applied to the signal captured by the microphone. Due to the narrow width and precise placement of notches, the speech signal quality is unaffected while noise is reduced.

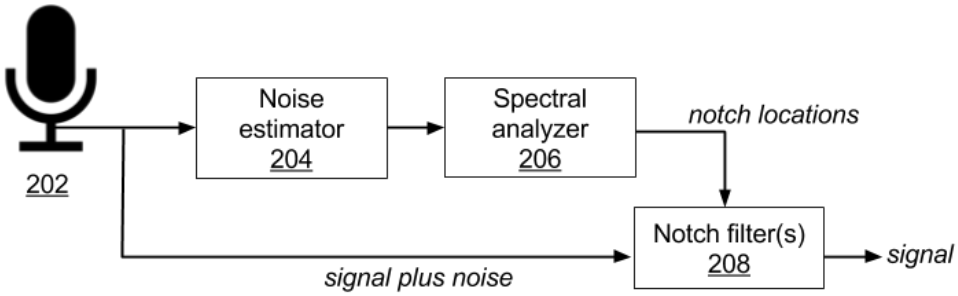

Fig. 2: Placement of notches in notch filter

In some implementations, the notches of the notch filter can be placed adaptively based on the spectrum of the narrow-band noise present in the conference room. Fig. 2 is an illustration of such adaptive notch placement. A microphone (202) picks up signal as well as ambient noise. A noise estimator (204) determines frames that contain only or mostly noise. For the purpose of noise estimation, frames with low total energy are deemed as speech-free or noise-only frames.

A spectral analyzer (206) estimates the power spectral density (PSD) of ambient noise by applying standard spectral estimation procedures to noise-only frames. The output of the spectral analyzer contains peaks that correspond to noise frequencies. For example, if a noise source is 60-Hz electrical hum, then the output of the spectral analyzer reveals a peak at 60 Hz and lesser peaks at harmonics, e.g., 120 Hz, 180 Hz, etc. These peaks correspond to notch locations for the notch filter(s) (208).

The notch locations for filter(s) 208 can be placed using standard filter-design techniques. A single filter can include multiple notches corresponding to noise peaks, or multiple notch filters may be used, each with one or more notches. With notches placed, filter 208, when fed with the microphone output, produces a noise-free signal, or closely so.

CONCLUSION

Techniques of this disclosure reduce the types of noise most commonly found in conference rooms and other locations where audio calls are conducted. The techniques make advantageous use of the narrow-band nature of noise in such locations. Notch filters, with notches set at the spectral peaks of noise, are applied to the microphone output. In this manner, noise is effectively removed from microphone output, while speech is allowed to pass largely unaltered.