The Influence of Hearing-Aid Microphone Location and Room Reverberation on Better-Ear Effects

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Introduction

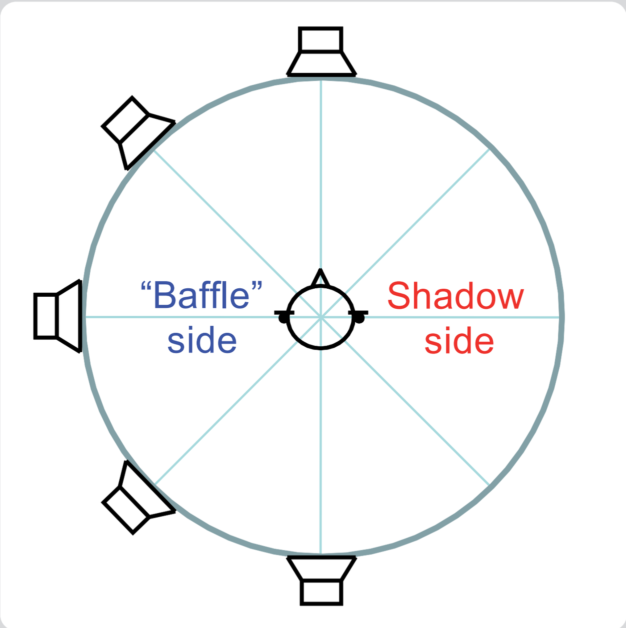
In situations with competing noise sources, listeners are known to improve their speech recognition by exploiting so-called better-ear effects (BEEs; e.g. Bronkhorst & Plomp, 1988). These effects are due to the directional properties of the human head and pinnae. They can give rise to ear-specific signal-to-noise ratio (SNR) changes when the head and pinnae filter a target and masker signal differently, e.g. when the target is located in front and the masker to one side of a listener.

Given the large proportion of hearing-aid wearers using behind-the-ear (BTE) devices, it is of interest to find out to what extent picking up the sound above the pinna – rather than at the ear-canal entrance – leads to modified BEEs. Furthermore, most listening can be expected to take place in reflective environments, and so it is also of interest to find out to what extent BEEs are affected by the presence of reverberation.

Measurement and Analysis Methods

MEASUREMENT SET-UP

- Acoustic manikin (B&K HATS) fitted bilaterally with omnidirectional microphones (Knowles FG series) placed at positions representative of completely-in-the-canal (CIC) and BTE hearing aids.
- Loudspeakers with directional properties similar to those of human talkers (Genelec 8030A) placed at five source azimuths (0°, 45°, 90°, 135° and 180°).
- Two acoustic environments:
  - Anechoic chamber
  - Auditorium (volume ≈ 560 m^3, T_{60} ≈ 0.7 s): For each source azimuth, four source distances (1 m, 1.9 m, 2.5 m and 4.1 m) were tested to vary the relative amounts of reverberation at the receiver.



BEE ESTIMATION

- Measure the transfer function, H(ω), for each combination of microphone, source azimuth and source distance.
- Filter an arbitrary input signal with each H(ω) and estimate the resultant signal output levels in one-third octave bands.
- Define various spatial target-masker constellations and calculate the resultant SNRs using the same input signal for both target and masker (corresponding to a free-field SNR of 0 dB).
- Compute the inner product of these SNRs and the articulation index (AI) weights (ANSI, 1997) to obtain single-value SNR estimates, AI-SNRs, indicative of the intelligibility advantages offered by the various BEEs.

ESTIMATION OF RELATIVE LEVEL OF REVERBERATION

- For each H(ω) measured in the auditorium, find the room impulse response, h(t), and compute the corresponding direct-to-reverberant sound ratio (DRR) as follows:

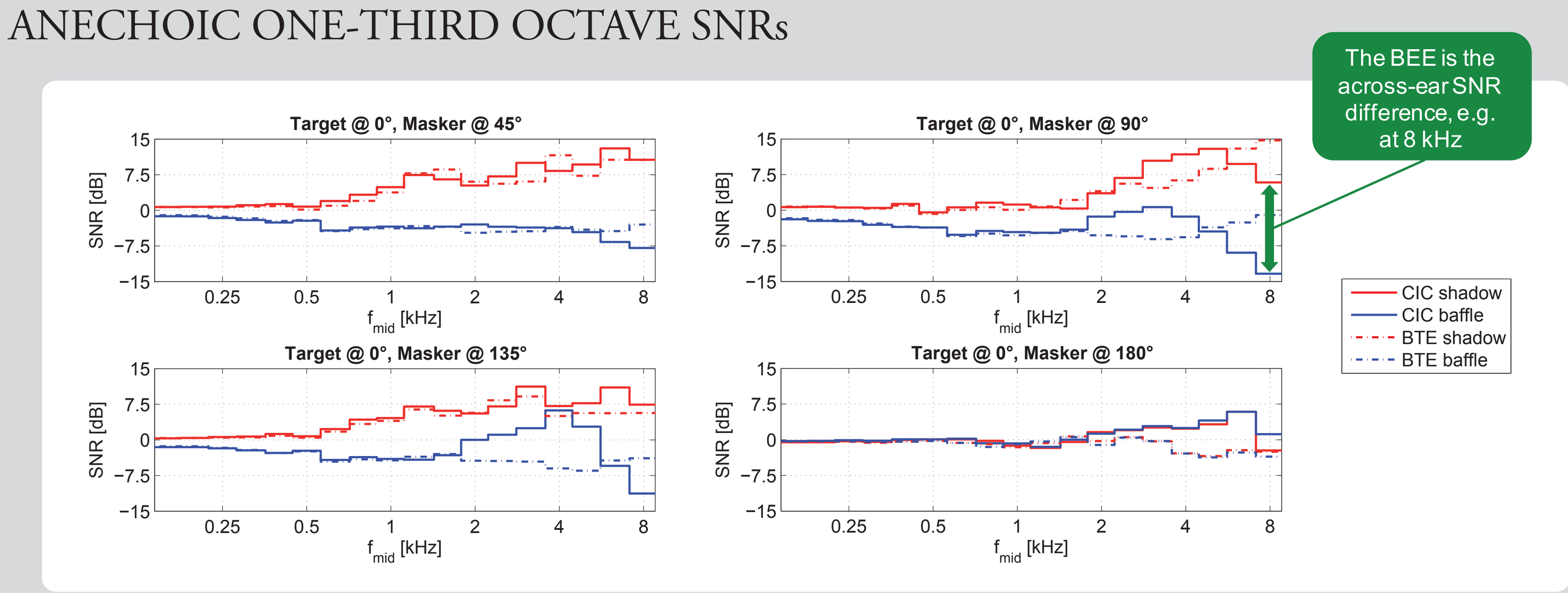
$$DRR = 10\log\left[\int_{0ms}^{2ms} h^2(t) \Big/ \int_{2ms}^{\infty} h^2(t)\right],\ dB$$

References

- Bronkhorst A.W. and Plomp R. (1988), "The effect of head-induced interaural time and level differences on speech intelligibility in noise," J. Acoust. Soc. Am., 83: 1508-1516.
- ANSI (1997), "Methods for calculation of the speech intelligibility index," American National Standard, ANSI S3.5-1997.

Results

ANECHOIC ONE-THIRD OCTAVE SNRs



→ For a masker azimuth of 45°, the CIC and BTE locations lead to very similar results.

→ For masker azimuths of 90° and 135°, the BTE location leads to substantially smaller SNRs between 2-5 kHz, most notably so on the baffle side.

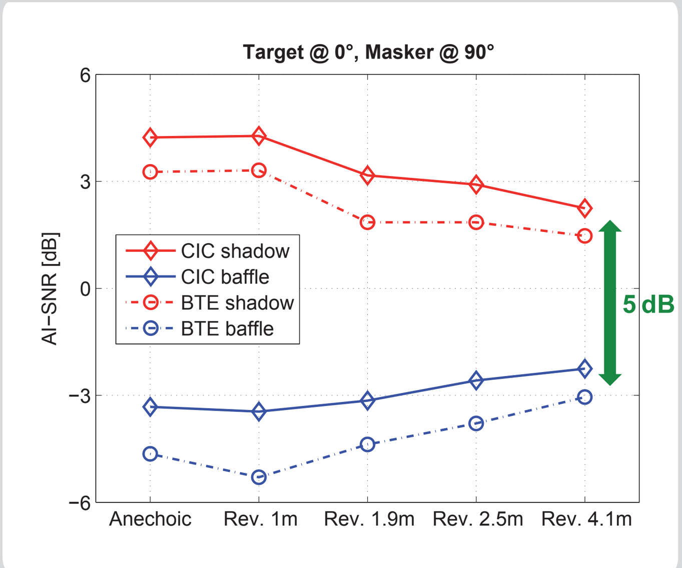
→ For a masker azimuth of 180°, the BTE location leads to smaller SNRs above ca. 2 kHz owing to the lack of pinna-shadowing.

ANECHOIC AND REVERBERANT AI-SNRs

- Exemplary data: Target at 0°, masker at 90°

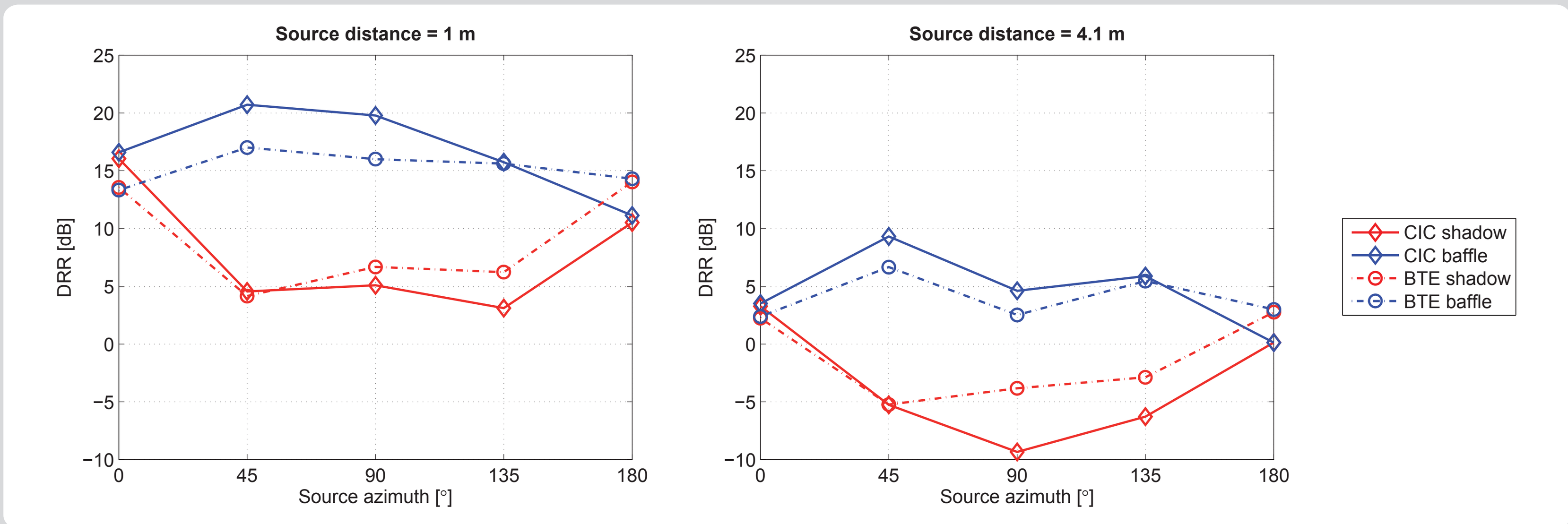
→ The BEEs at the "conversational" distances of 1 m and 1.9 m are largely unaffected by reverberation. Even at a distance of 4.1 m, an AI-weighted BEE of ca. 5 dB remains!

→ Despite giving rise to similar BEEs, the BTE location generally leads to smaller AI-SNRs than the CIC location, in line with the results above.



DRRs

- Exemplary data: Source distances of 1 m and 4.1 m



→ Results confirm the expected relative increase in reverberation with source distance.

→ The head and pinna's directionality also affects how much reflected sound is present in a given microphone signal. Consequently, a larger dependency of the DRR on source azimuth is apparent for the CIC location than for the BTE location.

Conclusions

- The ear-specific SNR changes brought about by head and pinna filtering are generally more favourable at the CIC location than at the BTE location.
- The directional properties of the head and pinnae also affect the ratio of direct to reverberant sound contained in a given ear-input signal, especially at the CIC location.
- Although reverberation reduces their magnitude, considerable BEEs can be expected to be available in the listening situations experienced by typical hearing-aid users.

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