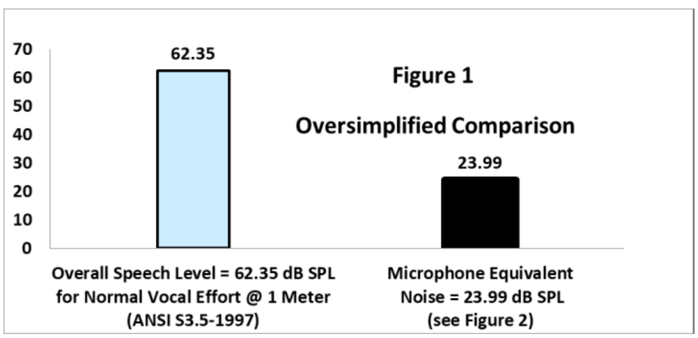
Understanding Microphone Equivalent Noise

Dean R. G. Anderson and
Dean G. Anderson, M.D.

Abstract: The effects of microphone equivalent noise on speech intelligibility have been obscured by oversimplified comparisons. A detailed analysis of the effects of microphone equivalent noise on speech intelligibility is provided along with a reference to a potential solution.

Microphone equivalent noise or microphone self-noise is always present and impacts speech intelligibility. A typical comparison of microphone equivalent noise to overall speech level is shown in Figure 1. This comparison shows the microphone equivalent noise level appearing far below the overall speech level. However, Figure 1 oversimplifies and obscures the effects of frequency and distance on speech intelligibility.

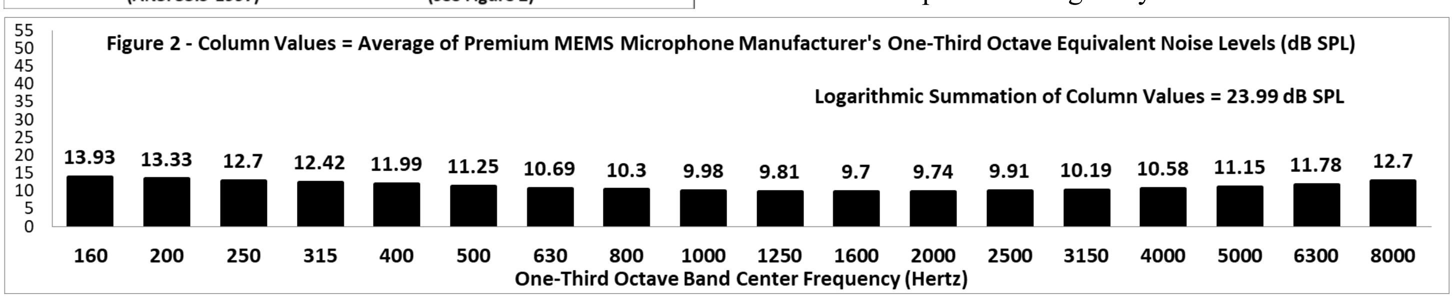


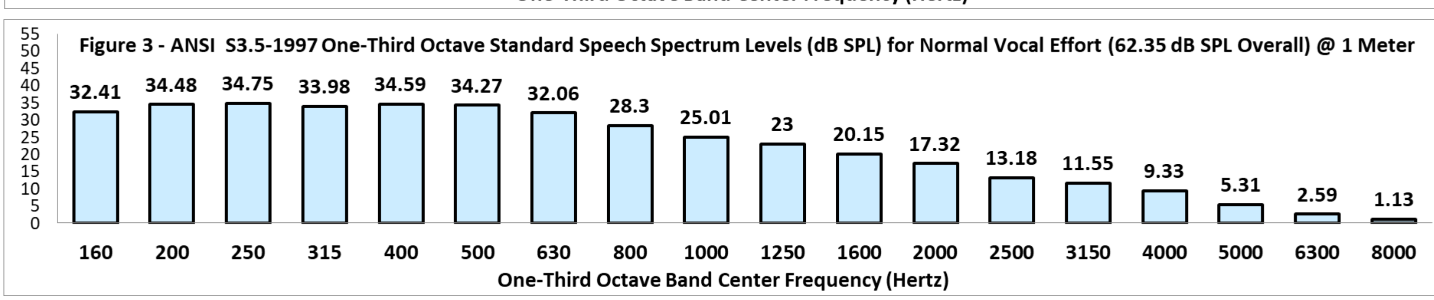
One-Third Octave Equivalent Noise:

In Figure 2 we present an expanded description of the microphone equivalent noise from the first figure. Figure 2 depicts microphone equivalent noise values for each of the 18 one-third octave frequency bands which affect speech intelligibility. The 18 one-third octave equivalent noise levels are based on an average of one-third octave equivalent noise levels for two exemplary MEMS microphones from two premium manufacturers. Thus, the 23.99 dB SPL *overall microphone equivalent noise* in Figure 1 is the logarithmic summation of the 18 one-third octave equivalent noise levels from Figure 2.

One-Third Octave Speech Levels:

Figure 3 shows the 18 one-third octave standard speech levels for normal vocal effort at one meter from ANSI S3.5-1997 *Methods for Calculation of the Speech Intelligibility Index*. These 18 one-third octave standard speech levels for normal vocal effort at one meter are designed for comparison with one-third octave noise levels from any source when evaluating the Speech Intelligibility Index (SII). The 18 one-third octave standard speech levels for normal vocal effort are measured at one meter directly in front of the speaker's lips and are averaged across a large number of adult male and female talkers. Furthermore, the measurements were made in quiet, in a free sound field, and include pauses between words which occur during an utterance pronounced in a normal, connected manner. The overall 62.35 dB speech level used in Figure 1 is also defined in ANSI S3.5 and is derived from the square of the time-mean-square speech pressure. These ANSI S3.5 definitions are distinct. For example, the logarithmic summation of the 18 one-third octave standard speech spectrum levels for normal vocal effort in Figure 3 *does not equal* the overall 62.35 dB speech level in Figure 1. These distinctions illustrate how the oversimplified comparison in Figure 1 can result in a significant underestimation of the effect of microphone equivalent noise on the Speech Intelligibility Index.





Distance Distinctions

It is important to note that one-third octave microphone equivalent noise levels are constant. They do not vary with distance. One-third octave normal vocal effort speech levels vary with the lips-to-microphone distance according to the Inverse Square Law. This means that doubling the lips-to-microphone distance diminishes sound levels by 6.02 dB. Halving the lips-to-microphone distance increases sound levels by 6.02 dB.

Frequency Distinctions

Each of the 18 one-third octave frequency bands contributes in *unequal* proportion to the total number of speech cues available to the listener. For example, the 160 Hz band contributes less than 1% of the total speech cues where the 2000 Hz band contributes almost 9%. ANSI S3.5 lists the contribution made by each one-third octave frequency band. Note that frequency bands from 1000 Hz to 8000 Hz contribute 70% of the total speech cues.

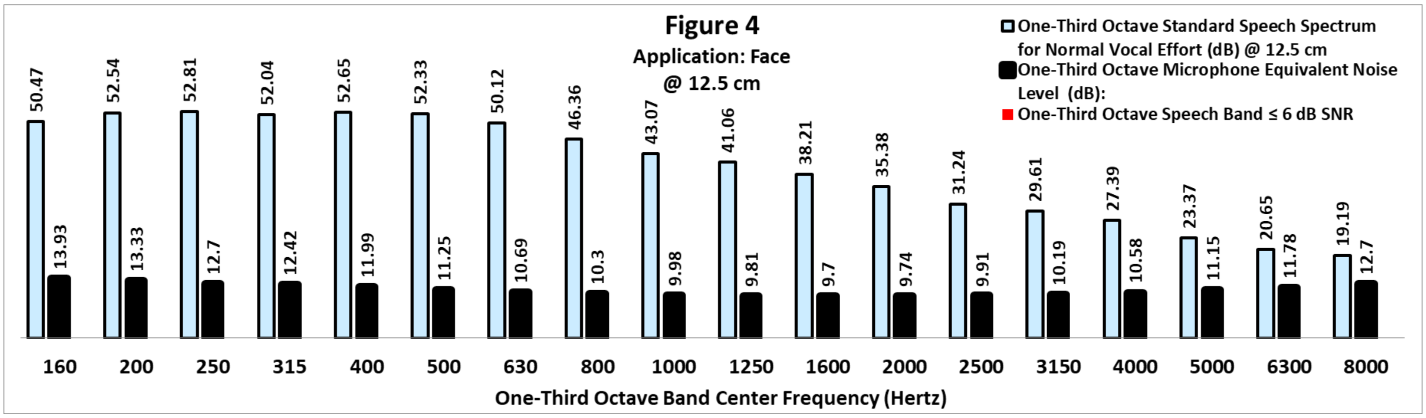


Figure 4
Application: Face
@ 12.5 cm

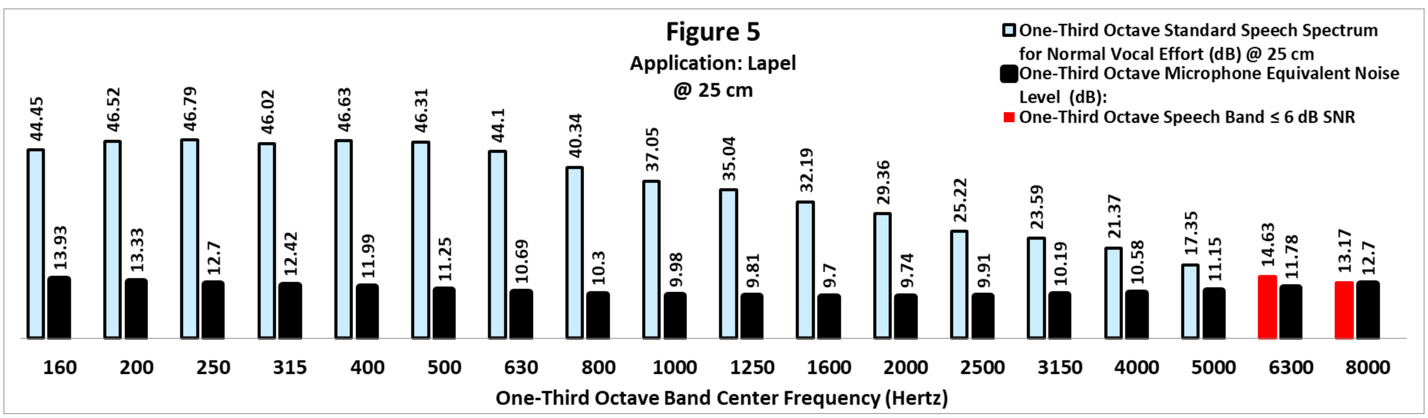


Figure 5
Application: Lapel
@ 25 cm

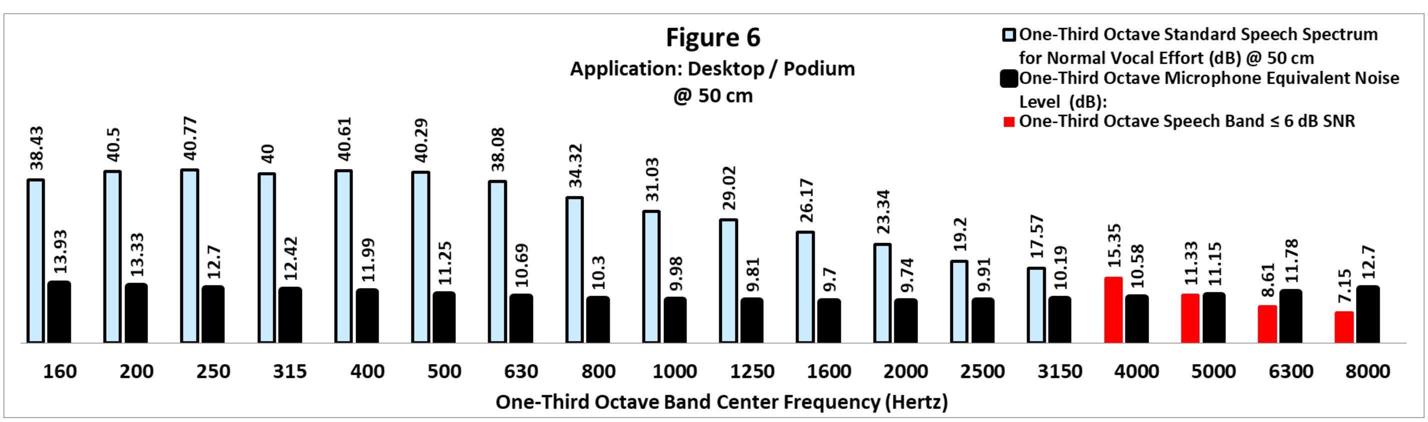


Figure 6
Application: Desktop / Podium
@ 50 cm

Speech vs. Noise at Varying Distances

In Figures 4 through 9, we compare one-third octave normal vocal effort speech levels at different lips-to-microphone distances *with* one-third octave microphone equivalent noise levels for the Figure 2 microphone as might be used in different applications.

SNR

Figures 4 through 9 visually compare the signal-to-noise ratios (SNR):

$$SNR = Signal_{(dB\ SPL)} - Noise_{(dB\ SPL)}$$

for each one-third octave speech band. We highlight when the SNR is at or below + 6 dB by changing the color of the normal vocal effort band from blue to red.

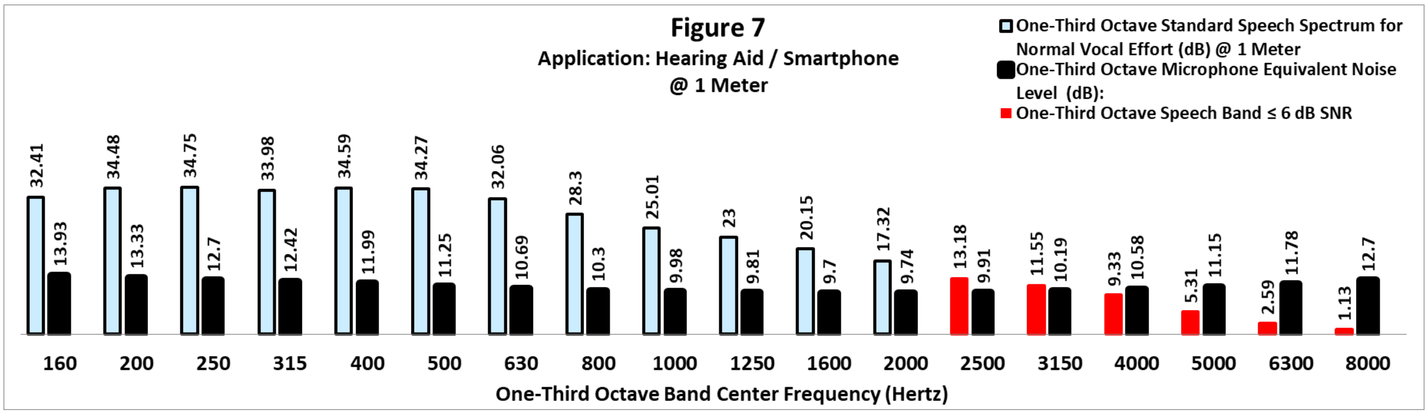


Figure 7
Application: Hearing Aid / Smartphone @ 1 Meter

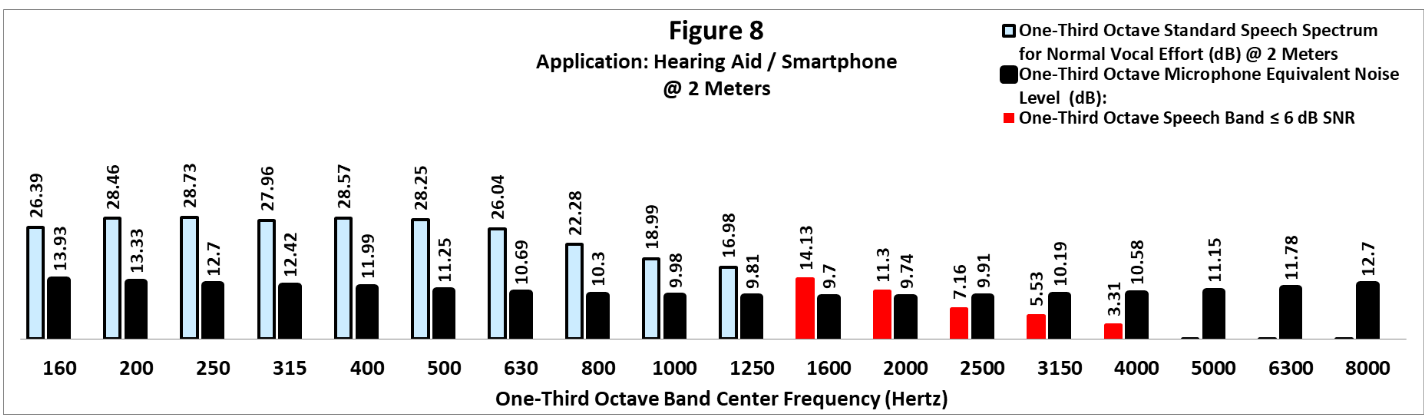


Figure 8
Application: Hearing Aid / Smartphone @ 2 Meters

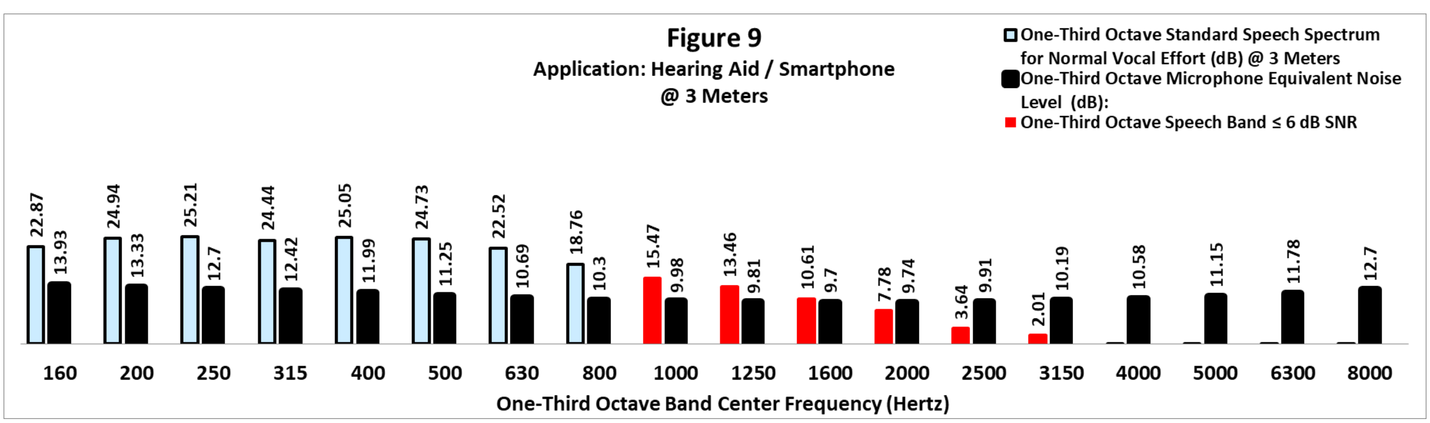
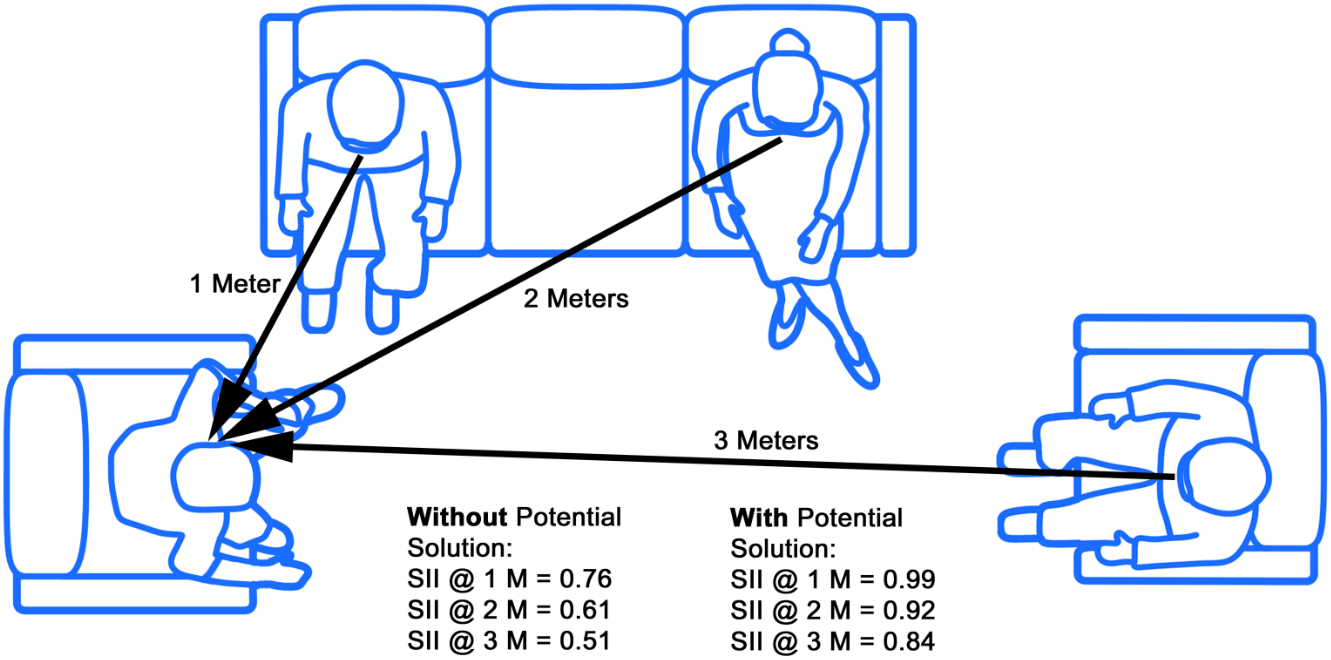


Figure 9
Application: Hearing Aid / Smartphone @ 3 Meters

Figure 10 - Speech Intelligibility Index (SII) for Normal Vocal Effort where Noise = Figure 2 Levels



Effects on the Speech Intelligibility Index

Moore[1] suggested that individuals with normal hearing require a SNR of at least +6 dB for satisfactory communication. In Figures 4 through 9, we increasingly see speech frequency bands sink below +6 dB SNR as the microphone is moved farther away from the speaker's lips. With the loss of each band below +6 dB SNR, there is a corresponding loss of the speech information contained in that band. As we outlined in a previous paper[2], ANSI S3.5 can be used to quantitatively calculate the corresponding Speech Intelligibility Index for the microphone at each of these distances. Thus, we see how the oversimplified comparisons made in Figure 1 distort Speech Intelligibility Index calculations.

The quantitative calculations for the Speech Intelligibility Index at 1, 2, and 3 meters using the Figure 2 microphone are shown on the left side in Figure 10.

A Potential Solution

A passive amplifier can be used to increase the sound pressure level of a speech signal at the MEMS microphone port opening. On the right side in Figure 10, Speech Intelligibility Index benefits are shown when using this potential solution. Read the Pixation paper: *Expanding the Reach of Microphones: Improving Intelligibility* at www.pixation.com for more information about passive amplifiers.

Conclusions

The best microphone for catching speech detail is a face microphone (Figure 4) because of its close proximity to the lips. A recording engineer will move a lapel microphone (Figure 5) as close to the lips as the cinematographer will allow; again, to catch speech detail.

Directional microphones for desktop, podium and other applications use acoustical interference which attenuate even the on-axis speech signal, forcing the performer's face ever closer to the mic. A MEMS microphone *with a passive amplifier* can solve these problems.

Hearing aid engineers may overcome distant listening problems by using a MEMS microphone with a passive amplifier. This solution yields sufficient SNR to frequency shift speech information to any audible bands for the hearing impaired.

Hollywood quality sound recording and acoustic virtual reality also require distant listening solutions.

Understanding microphone equivalent noise and lips-to-microphone performance dependence is essential for many applications.

For more information contact: pixation@pixation.com.

[1]Moore B. An Introduction to the Psychology of Hearing. London: Academic Press, 1989.

[2]Anderson D. Expanding the Reach of Microphones: Improving Intelligibility. www.pixation.com, 2021.