Practical approaches for maximising signal-to-noise ratio for music and other applications

Before I developed serious hearing problems, I was very active as a composer, classical record producer, and a recording engineer. I participated in literally thousands of recording sessions, from enormous orchestra dates to small solo gigs. Today, while I no longer hear well enough to produce and engineer, I can still compose without compromise and enjoy a very active life [1]. In order to help me hear, I have adapted many of the specific audio techniques I learned in the recording studio.

I consider the problem of effective hearing assistance first and foremost an audio problem. With modern hearing aid technology, frequency loss and overall loss of volume can be compensated for with relative ease. However, among the most intractable audio problems remaining is a hearing aid’s inability in many environments to provide a signal-to-noise ratio (SNR) high enough for people with hearing loss to extract meaning, both for speech and music.

To try to improve SNR, modern hearing aids, of course, use sophisticated directional microphones. However, directional mics only provide an increase of some 4dB to 5dB compared to omnidirectional microphones, hardly an adequate improvement for many situations in the real world where the desired sound signal is embedded deeply in noise, speech babble and reverberation – often all three combined [2,3]. Even microphone arrays provide, at best, only a small increase in SNR.

To help boost SNR even further, hearing aids employ digital signal processing (DSP) – essentially, algorithm-driven filters, multi-band compressors and limiters – in an attempt to reduce background noise. However, while the DSP in hearing aids is extremely sophisticated and can be helpful in some situations, the real world results are, for many users, including myself, often disappointing. Despite all the sound manipulation, it doesn’t get that much easier in many situations to extract meaningful sound from noise when seated in the middle of a concert hall or in a crowded restaurant.

Why does the combination of directional mic arrays plus advanced DSP often fail to provide adequate SNR improvement in so many situations? To an audio producer and recording engineer, one answer is obvious. In many cases, the microphones in hearing aids – typically located in or near the ear – are simply too far away from the desired sound source; they cannot pick up a clean enough signal for effective listening. Furthermore, no DSP I am aware of will create large improvements in SNR if the environment is very noisy and if the mic is too far away from the desired sound.

My solution is simple. In order to hear, I always start by maximising the signal-to-noise ratio. Once I have as good an SNR as practical, I can then process the signal quite effectively for my specific hearing loss. Fortunately, technology exists today that enables me to maximise SNR – to go directly or place a mic close to a desired sound source – in ways that are relatively convenient and unobtrusive.

I maximize SNR in one of two ways:

1. I go direct whenever possible
2. When going direct isn’t feasible, I place a microphone or microphones as close as I can to the desired sound source.

Naturally, every hearing loss is different; however, I believe that for many people with hearing loss, maximising the SNR whenever possible has the potential to dramatically improve both the enjoyment of music and the comprehension of speech.

Direct audio

Because live sound is often so confounding, I avoid sound transmitted through the air and listen direct whenever I can. For example, before my hearing loss, I very much enjoyed composing at my computer, with the audio output hooked up to a pair of high quality studio monitors. Because of my hearing loss, however, the ambient sound in my studio muddies the sound of the speakers so much that I can’t hear the individual music lines. In addition, my hearing aids have both an audible amount of harmonic distortion and very poor bass response. In short, hearing aids simply are not suitable for serious music listening, an opinion widely shared amongst the musicians I know.

Therefore, I purchased the highest quality in-ear monitor I could find (Figure 1), typically used by normal-hearing pop musicians for listening to stage mixes when performing live. As I only have unilateral hearing now,
the monitor combines both left and right channels into a mono signal. The monitor also has a custom-moulded ear tip which is extremely comfortable – I can wear it for hours on end. The sound quality is absolutely fantastic; I can hear what I’m composing quite clearly and continue to work at a professional level. A recent piece I completed has been played several times at the Metropolitan Museum of Art, for example.

I take a similar approach for enjoying recorded music. Again, I take my hearing aid out and use a very high quality in-ear earphone which seals the ear canal (Figure 2). This is plugged into a good-quality stereo amplifier, computer, or smartphone.

Even at live rehearsals, it is sometimes possible to go direct. For example, in February of 2012, the London Symphony and conductor Marin Alsop performed my oratorio with chorus, orchestra and silent film, Voices of Light, at the Barbican in London. Like most concert halls, the Barbican is equipped with numerous stage mics and an advanced audio mixing system which is used both for live sound reinforcement and archival / broadcast recording. The output of this system is also fed to an induction loop assistive listening system available throughout the hall. During rehearsals, I asked the sound engineer to turn on the loop system and switched my hearing aid to tele-coil. The convenience of hearing via a loop system trumped the sound quality issues in my hearing aid; I could participate fully in the rehearsal process.

Close miking via a smartphone
In many situations where I need to hear well – both musical and social – it is not possible to go direct. Furthermore, because of excessive noise or reverberation, my hearing aids often do not deliver clear enough sound. Frequency Modulation (FM) assistive listening systems are expensive and often very complex. The low-end personal sound amplifiers have poor-quality sound and the absence of output limiting can be dangerous to my hearing.

After a good deal of trial and error, I put together an excellent portable assistive listening system based around an iPhone (Figure 3). I use an inexpensive hearing aid app called SoundAmpR, which has controls for amplification as well as user-adjustable filters and compressors. The app can even record (Figure 4). I attach a high-quality stereo cardioid mic to the power port of the iPhone, which bypasses the lower-quality analog mic input circuitry (Figure 5). Finally, I remove my hearing aid and use the same high quality in-ear earphone I use for music listening. At rehearsals – and also at concerts, dramas and films – I sit as close as possible to the performers or screen and point the microphone at the desired sound source. The sound quality is excellent and I can participate fully in the music-making. This iPhone rig also works quite well in restaurants, typically providing me with far better speech comprehension than my hearing aids are able to deliver. It takes some time to adjust to the occlusion...
effect and requires experimentation with mic placement, but once learned, it is an extremely effective assistive listening device.

**Conclusion**

Obviously, I am highly motivated to hear well despite my hearing loss, and I am comfortable enough with audio technology to create solutions when my hearing aids aren’t effective. But for many people with hearing loss, assistive listening devices are not as easy or safe to use as they could be. Furthermore, many people with hearing problems are, at present, reluctant to use any kind of visible assistive listening technology.

However, audio equipment can be streamlined and attitudes can change. What cannot change is a basic acoustical fact: If the signal-to-noise ratio is low enough – as it is in many common situations in the real world – it will often be impossible to extract meaningful sound information no matter how sophisticated the DSP. Approaches to hearing assistance that use technologies which enable direct audio input or closer miking than hearing aids allow can maximise SNR in many environments and can do so relatively unobtrusively and effectively. As the equipment becomes easier to use and more powerful, the current notion – that effective hearing assistance can be achieved merely by placing microphones near the ear and applying extensive signal processing in an attempt to clean up a very noisy signal – will seem quaint.

If an integrated approach is taken that utilises good audio equipment and seeks to maximise signal-to-noise ratio, millions of people with some degree of hearing loss will be able to better hear music and also participate more fully in social events that are, at present, difficult if not impossible for them to enjoy.

(My solution is simple. In order to hear, I always start by maximising the signal-to-noise ratio)

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References