MUSIC AND HEARING AIDS

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Music as an input to a hearing aid poses some interesting problems both for the hearing aid design engineer and for the hearing health care professional. This is as true for the fitting of hearing aids for musicians, as well as for those non-musicians who like to listen to music. In some cases, the question is "which hearing aid manufacturer would be willing to make subtle changes for individual customers", rather than "what is the best set of electro-acoustic parameters." In other cases it comes down to an issue of the number of bits in the front end A/D converter. In order to understand the changes necessary for music as an input to a hearing aid or a cochlear implant, several primary physical differences between speech and music need to be understood. Two factors that have a direct ramification for the setting and/or selection of hearing aids for music are: (i) differing overall intensities, and (ii) crest factors.

DIFFERING OVERALL INTENSITIES

At one meter, speech averages 65 dB SPL (RMS) and has peaks and valleys of about 12 to 15 dB in magnitude. Because speech derives from the human vocal tract, and similar human lungs imparting similar subglottal pressures to drive the vocal chords, the potential intensity range is well defined and also quite restricted – approximately 30 to 35 decibels. In contrast, depending on the music played or listened to, various instruments can generate very soft sounds (20 to 30 dB SPL [e.g. brushes on a jazz drum]) to amplified guitar and even the brass of Wagner's *Ring Cycle* (in excess of 120 dB SPL). The dynamic range of music as an input to a hearing aid is therefore on the order of 100 dB (versus only 30 to 35 dB for speech).

Hearing aids that can handle intense inputs would be better for music than those that cannot. This can be accomplished in several ways- all of which are "hardware" related changes and not "software". The peak input limiting level is not a hearing aid parameter that is typically reported yet it is the most important element in the transduction of intense inputs, such as music, through hearing aids. Once a hearing aid has been overdriven in the "front end" (e.g. A/D) with a high level input, no amount of software manipulation that occurs later on will restore high fidelity. This can be altered by using less sensitive (and non-broadband) microphones, as well as chips that utilize more than 16 bit architecture.

CREST FACTORS

The crest factor is the difference in decibels between the peak of a waveform and its average or root mean square (RMS). For speech the RMS is about 65 dB with peaks extending about 12 dB higher. The crest factor for speech is therefore on the order of about 12 dB. This is well known in the hearing aid industry. Compression circuitry and hearing aid test systems use this information. In contrast, a trumpet has no soft walls or lips. The same can be said of most musical instruments and as such the peaks are less damped and "peakier" relative to the average, than is speech. Crest factors of 18 to 20 dB are not uncommon for many musical instruments. Compression systems and detectors that are based on peak sound pressure levels may have different operating characteristics for music as input to a hearing aid as for speech. That is, music may cause some compression systems to enter its non-linear phase at a lower intensity than what would be appropriate for that individual.

Another aspect of the crest factor for instrumental music is that it has ramifications for specifying both OSPL90 and for gain. Loudness discomfort levels for speech are typically used for setting the OSPL90 for a hearing aid yet music and speech have differing crest factors. The peaks of instrumental music are 6 dB higher than for speech (given the same RMS value) since the crest factor for instrumental music is 6 dB greater than for speech (12 dB versus 18 dB). In order to prevent a tolerance problem for instrumental music, the OSLP90 for a "music program" therefore needs to have a 6 dB less intense OSPL90 than for speech. And, given similar compression characteristics between music and speech, this implies that the gain for a "music program" should be 6 dB less than the gain for a broadband speech channel as well.

CONCLUSIONS: THE "MUSIC PROGRAM"

A "music program" or a set of optimal electro-acoustic parameters for enjoying music would include:

1. A sufficiently high peak input limiting level so more intense components of music are not distorted at the front end of the hearing aid.

2. If playing in an intense environment, even for those with significant sensori-neural hearing loss, a non-occluding BTE *and* a high-frequency emphasis microphone should be used.

3. Either a single channel or a multi-channel system in which all channels are set for similar compression ratios and kneepoints.

4. A compression system (similar to the speech-based compression system) with an RMS detector compression scheme with a kneepoint 5 to 8 dB higher if the hearing aid uses a peak compression detector.

5. OSPL90 and gain, for the instrumental music that is 6 dB less intense than for broadband speech.

6. A disabled feedback reduction system, or a feedback reducution system that uses gain reduction or a more sophisticated form of phase feedback cancellation (either one with short and long attack times or one that only operates on a resticted range of frequencies such as over 2000 Hz).
7. A disabled noise reduction circuit, although because of a long attack time and a short release time, this circuitry may rarely be activated for many forms of music.
