HeLPS
SENSIMETRICS

User Guide

Warranty

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Technical Support

One year of free technical support for HeLPS is provided from the date of purchase. If you need technical support, please visit the HeLPS website www.sens.com/HeLPS and click on the Support link for help with known problems and for answers to Frequently Asked Questions (FAQs). If your problem is not addressed there, send a description of it by email to tech-support@sens.com, or by mail to:

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Acknowledgements

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INTRODUCTION

HeLPS – the Hearing Loss and Prosthesis Simulator – simulates the auditory communication difficulties associated with hearing loss along with the benefits provided by hearing aids and cochlear implants. HeLPS allows flexible demonstrations during hearing aid fitting; when counseling families of hearing-impaired and deaf persons; in hearing-conservation and public education programs; and in training audiologists and educators of the deaf.

HeLPS provides a graphic interface on your computer for controlling the simulation and a set of Sennheiser HD 201 circumaural headphones for listening to the simulator's output. To allow the listener to use speechreading, HeLPS provides audio/visual stimuli with the audio component processed by the simulator. Hearing and prosthesis characteristics are specified separately for the left and right sides, with convenient controls for selecting loss and prosthesis settings, talkers, background noises, and reverberation.

After Installation and Setup, described in the next section, you can proceed to the Quick Start section to become familiar with the operation of HeLPS. Subsequent sections of this *User Guide* explain in detail the simulation algorithms and advanced use of the control interface.

SOFTWARE INSTALLATION AND AUDIO SETUP

Software Installation

Insert the HeLPS CD-ROM into your computer's CD-ROM drive and the HeLPS Install Menu should automatically appear. If it does not appear, navigate to the top-level folder of the CD-ROM and double-click the file 'Setup.exe' to launch it. Then follow the on-screen installation instructions.

After installation is complete, you can run HeLPS by going to the Windows Start Menu, then to All Programs, and selecting HeLPS.

Sound Level Calibration

Before using HeLPS for the first time, a calibration step must be performed. The stimuli and the simulation system have already been calibrated for use with the Sennheiser HD 201 headphones provided with HeLPS. This calibration corrects for the shape of the frequency response of the headphones. The calibration also assumes that the audio playback system in your computer and any additional amplifiers that you are using have a reasonably flat frequency response. However, that calibration is not sufficient because the output sound levels from individual PCs and amplifiers are unknown, even when driven by the same stored digital signal. It is therefore necessary for you to perform a calibration of the output level stage, as described in the following steps.

1) Connect the headphones to your computer's headphone output jack.

2) Start HeLPS and go to the SIM SETTINGS window. The Normal Hearing and No Aid entries in the table will be in boldface, indicating that they are the active hearing and prosthesis simulations. If you have gotten to the SIM SETTINGS window some other way and these two entries are not bold-face, single-click them to make them active.

3) This third step can be done in either of two ways, depending on whether you have acoustic measurement equipment.

3-a) If you have measurement equipment**,** such as a probe microphone for making sound level measurements under the headphone, or a sound level meter with a flat-plate coupler, then you can do the calibration acoustically using a steady noise stimulus. To deliver this stimulus, select HeLPS A/V Clips with No Talker as the Selection. Then choose Speech-Shaped Noise, Front, 65 dB SPL, Continuous, and set Reverberation to Anechoic. Then click Play and a steady noise stimulus (with brief occasional pauses) will be presented whose overall level should be easy to measure with your equipment. Go to Step 4.

3-b) If you do not have measurement equipment you must use your own ears to perform a 'biological' calibration that relies on your familiarity with conversational speech levels. To deliver the speech stimulus, select HeLPS A/V Clips with All Talkers. Set the Target Level to 65 dB SPL, set Noise to None, and Reverberation to Anechoic. This will result in a sequence of sentences spoken by ten randomly-selected talkers. The loudness of this

speech heard over the headphones should be equivalent to that of a face-to-face conversation at a distance of 1 meter.
4) Go to the Advanced menu and select Output Calibration. Use the slider in that window to adjust the stimulus to achieve the criterion of 65 dB SPL if you are measuring noise, or normal conversational loudness if you are listening to speech.

5) The value of Maximum Output Level shown to the right of the slider tells you the maximum level of speech that the system will be capable of producing. The Minimum Output Level is the lowest signal level that can be represented in 16 bits given the need to represent speech at the Maximum RMS level (plus a 15 dB peak factor). The Minimum Output Level is simply 75 dB lower than the Maximum Output Level. For most applications, the most important consideration will be to have sufficient Maximum Output Level range ("headroom") available for delivering hearing-aid amplified stimuli. If the Maximum Output Level is less than 85 dB, the combination of input level and hearing aid gain that you can use will be insufficient. Limited headroom results when there is too little gain following the computer's audio output. The first place to look to adjust output gain is Windows' internal volume control. This control is accessed by right-clicking the small loudspeaker icon located in the taskbar at the bottom-right of the screen, and then selecting Open Volume Control. An array of sliders will appear for controlling the several audio sources on your computer. The Volume Control and Wave sliders both control audio output level. Adjust these two sliders to increase volume and then go back to Step 3 and repeat the calibration.

In most typical PC-audio configurations, with the Sennheiser HD 201 headphones plugged into the PC's headphone jack and the Windows Volume Control and Wave sliders at their highest settings, HeLPS with proper output calibration will be capable of delivering speech at a maximum output level of at least 90 dB SPL.

If you cannot achieve the output levels you need by maximizing the Windows volume controls, then the only other solution is to amplify the PC audio output. Consumer-grade amplifiers will suffice. Remember that if you insert an amplifier between the PC audio output and the headphones, you must repeat the calibration *after* the amplifier gain has been fixed.

WARNING!

> **HeLPS is capable of delivering very high sound levels. Be careful when conducting demonstrations, especially with simulated hearing aids, that the sounds are not uncomfortably loud for the listener.**

It is critical that, once the sound level calibration is done, the volume controls (both within Windows and any subsequent amplifier) be adjusted to the same settings when using HeLPS subsequently. It is smart to note what these settings are so that they can be replicated. If the controls change and you don't know how to reproduce them, then the calibration should be repeated.

Fortunately, the accuracy of the HeLPS simulation is not sensitive to the precision of this output level calibration, making the biological calibration adequate. The more important calibration is at the input to the simulation because it is the level of the input signals relative to the elevated detection thresholds that primarily determines the audibility of signals and the intelligibility of speech. Small errors in output level may affect loudness, which is important when estimating the annoyance of amplified sounds, but less important when estimating intelligibility.

If you are delivering the audio via loudspeakers (which is appropriate for some types of demonstrations), the same type of calibration must be performed and maintained. For more information on using loudspeakers with HeLPS, see “Presenting Simulations to Multiple Listeners” in the section titled “Controlling the Simulation” in this *User Guide.*

QUICK START

Use of HeLPS can be learned easily by hearing professionals. This Quick Start tutorial will make the program's basic features clear in about fifteen minutes.

The block diagram in Figure 1 shows the signal flow of the complete simulation along with annotations identifying the available controls. The basic function of HeLPS is to deliver a continual sequence of target stimuli, possibly with added noise, with the audio processed by a specific prosthesis simulation and a specific hearing loss simulation. The target stimuli are specified by playlists. One playlist available with HeLPS is a large collection of audio/video recordings of people speaking sentences. You can also supply your own playlist of signals (containing audio only) for use as targets.

Target signals can be combined with either of two types of noise – speech-spectrum (random) noise and party noise. Target and noise signals are processed to simulate sound propagation and head-diffraction in either an anechoic or a reverberant environment. The combined target-plus-noise signal reaching the microphone of each simulated prosthesis (hearing aid or cochlear implant) is subjected to the specified prosthesis simulation, or is simply passed through the system if there is no prosthesis. The left and right ear signals are then processed through simulations of the left and right hearing losses, respectively, and then finally played from the computer for listening through Sennheiser HD 201 headphones.

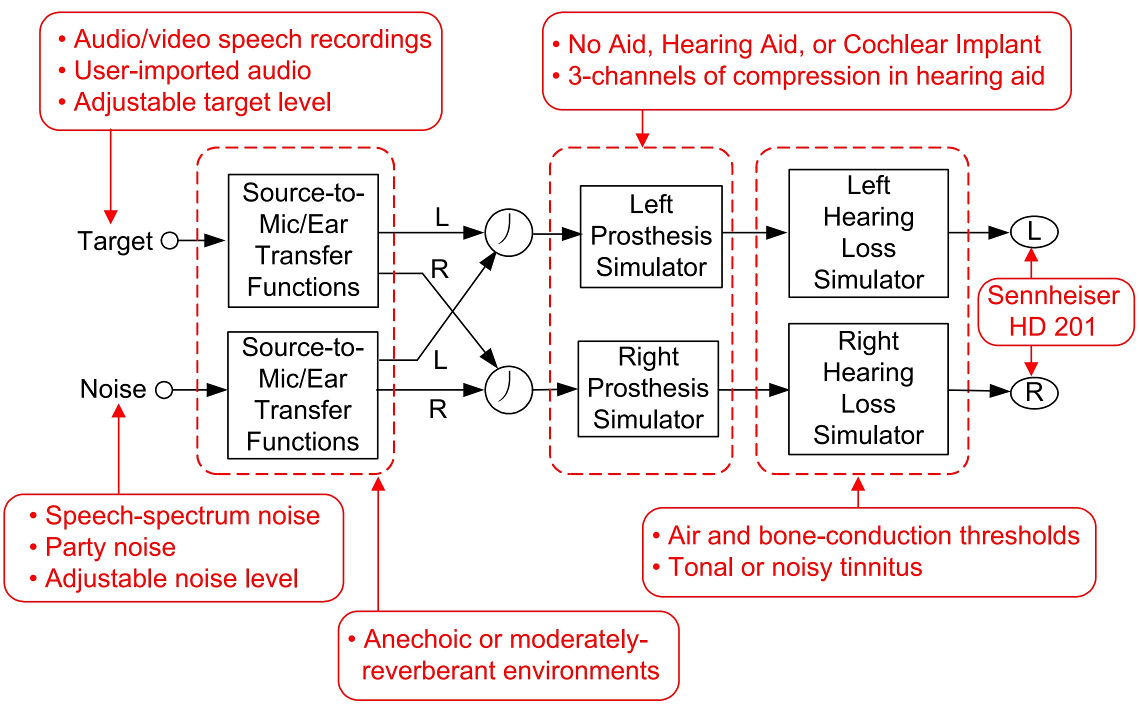


Figure 1. Block diagram showing the main signal and signal-processing components of the HeLPS simulation.

All HeLPS simulation controls are accessed via three main interface windows: 1) Hearing for specifying the characteristics of hearing losses to be simulated; 2) Prosthesis for specifying the characteristics of simulated hearing aids or cochlear implants; and 3) SIM SETTINGS*,* for selecting targets, noises, and acoustic environments, and for convenient switching among hearing and prosthesis specifications.

If you have not already done so, start HeLPS now. Then let's look at the SIM SETTINGS window, which automatically appears when the program is started.

The SIM SETTINGS Window

When you are in the SIM SETTINGS window, go to the Help menu and select Display Annotation. This will bring up an example SIM SETTINGS window with key parts annotated. This annotated Help window will change along with the main window as we work through this tutorial (or whenever you bring it up). The Help window can be closed by clicking 'X' in the upper right corner.

Most of the controls for stimulus selection and playback are self-explanatory. You can begin to manipulate any of these controls, but first click Play to start the presentation of target stimuli.

The use of the table in this window, called the *Program Table*, requires some explanation. The Program Table is the place where different hearing and prosthesis specifications can be loaded. The first entries are exceptions, reserved for the commonly used Normal Hearing and No Aid, and cannot be changed. This table allows you to switch quickly among a small set of hearing and prosthesis specifications.

At any time, one hearing specification and one prosthesis specification in this table are the active ones being used in the running simulation. The active specifications are indicated by boldface labels. You can activate any hearing and any prosthesis entry in the table by single-clicking it.

When the program is first started, all of the specifications in the Program Table are Normal Hearing and No Aid. To aid in learning to use HeLPS, the Program Table illustrated in the annotated Help window is provided. To load it from the SIM SETTINGS window, go to the File Menu and select Open. Then navigate to the folder C:\...\HeLPS\work\examples and Open the file Assorted.prog. This will load an assortment of hearing and prosthesis specifications. You can then select any combination of hearing and prosthesis specifications by single-clicking on them. Make sure that stimuli are playing; press the Play button if they are not.

Hearing and prosthesis specifications in the Program Table are identified with short labels. To get a detailed description of a specification, double-click its label. This will 1) make the selected specification the active one; 2) bring up either the HEARING window or the PROSTHESIS window, depending on which type of specification was selected; and 3) "link" the Hearing or Prosthesis specification window to the simulation. In this linked state, any changes you make in the specification window will be made immediately in the ongoing simulation, giving you direct active control. This linked state is indicated in the HEARING or PROSTHESIS window by an asterisk to the left of the label box; in the SIM SETTINGS window it is indicated by an asterisk next to the specification that was double-clicked.

The Hearing Window

Continuing with the same example, if you go to SIM SETTINGS and double-click the hearing specification labeled Sloping 55 at 1k in the Program Table, a HEARING window will appear showing that hearing specification. This particular hearing specification describes a moderate bilaterally-symmetric hearing loss that slopes downward at 10 dB/oct, with HL = 55 dB at 1 kHz, with equal Bone-Conduction (BC) and Air-Conduction (AC) thresholds. There is no tinnitus accompanying this loss. (Tinnitus controls can be viewed or hidden via the View menu). Note that losses that are not bilaterally-symmetric are specified separately for each ear, selected with the buttons above the audiogram.

Now adjust the thresholds by clicking in the audiogram at the desired frequency. By clicking (depressing) either or both of the two buttons to the right of the audiogram you can adjust either the BC threshold alone, the AC threshold alone, or both AC and BC thresholds together (making them equal). Note that the interface automatically enforces the constraint that BC thresholds cannot be larger than AC thresholds.

When stimuli are playing, you can hear the effects of changes you make in the hearing specification. This linkage is in effect because you double-clicked the hearing specification in the Program Table. Linkage is indicated by the asterisk to the left of the specification label. If you came to the HEARING window without having first linked by double-clicking a hearing entry in the Program Table, the specification would not be linked and changes would not be directly implemented in the active simulation. The changes would, however, be made to the specification and would be saved if you choose to save them.

The Prosthesis Window

Return to the SIM SETTINGS window (by clicking its tab), and double-click on the prosthesis specification labeled NAL_RP for Sloping 55. The PROSTHESIS window will appear showing that specification. The PROSTHESIS window for hearing aids presents parameters and controls that are familiar to those who work with hearing aids. The main controls are the channel gains for 1, 2, or 3 channels, which are adjusted by clicking and dragging the graphic handles in the spectral plots. These plots show the third-octave spectra in a listener’s ear canals when presented with speech-spectrum noise at input levels of 55, 70, and 85 dB SPL. If you now go to the Import Loss menu and select From Hearing Window, the hearing loss currently in the HEARING window, which should now be “Sloping 55 at 1k,” will be plotted in terms of dB SPL on the spectral plot. With a hearing loss imported, you can now select a prescription method by going to the Prescribe menu. The target output levels prescribed by the selected fitting prescription will be plotted. You could then adjust channel gains to match the targets if you wished.

If you have followed along with this tutorial and double-clicked in the Program Table, then the prosthesis specification you are controlling in the PROSTHESIS window is linked to the active simulation (indicated by the asterisk to the left of the specification label). Feel free to adjust the hearing aid's parameters and listen to the resulting effect on the output audio.

Clicking on the other two prosthesis options shows that: with *None* there are no controls or parameters to adjust, and with *Cochlear Implant* the only available controls are the Number of Channels (1-20) and the Carrier (noise or tone). If the prosthesis specification is still linked to the active simulation, you should hear the appropriate differences when you select these prosthesis options.

This Quick Start tutorial has illustrated the most important and frequently-used features of HeLPS. The next two sections of this *User Guide* describe the algorithms used to simulate hearing losses and prostheses. Later sections describe in detail how to use the interface to achieve desired simulations.

HEARING LOSS SIMULATION

The HeLPS algorithm for simulating hearing loss is designed to produce for the listener the absolute detection thresholds (i.e., hearing levels) and the sensation of loudness recruitment that are associated with a specified hearing loss. The source signals that are processed by the simulation are recorded audio signals stored on your computer. These source signals have been calibrated so that they can be presented at known equivalent sound pressure levels and processed accurately for the specified degree of hearing loss. With a given simulated hearing loss, a listener will hear these processed sounds and will experience loudness recruitment in approximately the same way as a person with the specified actual hearing loss.

This section of the *User Guide* describes the HeLPS hearing loss simulation algorithm. A later section, entitled "Specifying Simulated Hearing Losses," will explain how to use the HeLPS interface to specify the characteristics of simulated hearing losses.

The HeLPS Algorithm

The HeLPS simulation algorithm uses a model of hearing loss that allows simulation of two types of loss – conductive and recruiting. Consider conductive hearing loss, which is modeled as a fixed frequency-dependent attenuation of the input signal. The degree of conductive threshold shift in a given frequency band is denoted in the model as H_C.

Figure 2 shows the simulation of an example conductive loss in the form of an input/output (I/O) plot. In this plot the input quantity, plotted on the abscissa, is the sound level in a given frequency band at the listener's eardrum with no simulation or device in place (i.e., open ear). The output, plotted on the ordinate, is the level of the sound at the listener's eardrum contributed by the hearing loss simulation. The dotted line for out=in simulates normal hearing. Note that these I/O plots give sound levels relative to the normal absolute threshold for the band. On average, therefore, sounds that exceed an output level of 0 dB will be heard by a normal-hearing listener and those below 0 dB will not be heard.

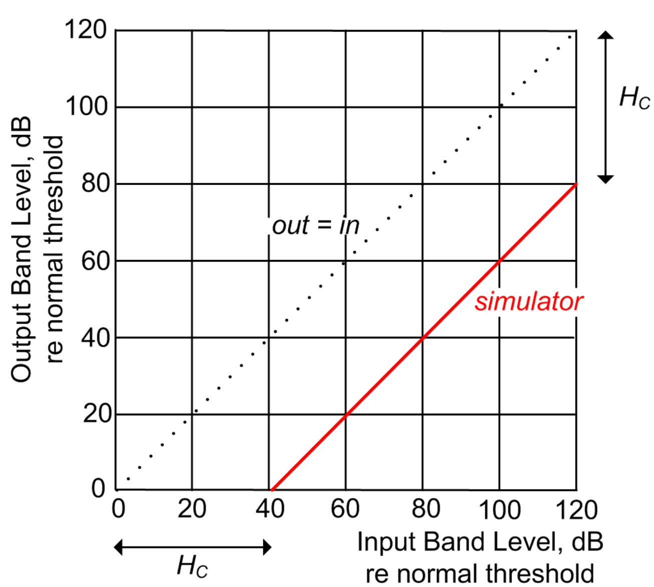


Figure 2. An example I/O plot for one simulator band showing a conductive hearing loss of H_C = 40 dB.

The simulator I/O plot in Figure 2 shows a purely conductive loss of 40 dB. Because a conductive loss is modeled as a fixed attenuation, the simulator output level is simply 40 dB lower than the input level at all input levels. Simulator output sounds begin to be audible (i.e., exceed 0 dB output level) when the input reaches 40 dB, with the output level continuing to increase 1 dB per 1 dB increase in input level above threshold.

Now, consider recruiting hearing loss, which is the second type of hearing loss allowed in the simulation algorithm and which is denoted H_R. A recruiting loss is modeled as a threshold shift with a rapid rise in output level as signal level increases over some *recruitment range r* above threshold, until *full recruitment* is reached. At that point, output level increases 1 dB per 1 dB increase in input level.

Figure 3 shows the I/O plot for a recruiting loss of 70 dB ($H_C = 0$, $H_R = 70$). For this type of loss the simulator output level is less than 0 dB for input signal levels below the specified threshold-relative input level of 70 dB. As the input level increases above 70 dB, the simulator output level rises rapidly over the recruitment range of r =20 dB in this example. Because there is no conductive loss, the output level at and above the point of full recruitment is equal to the input level (out=in).

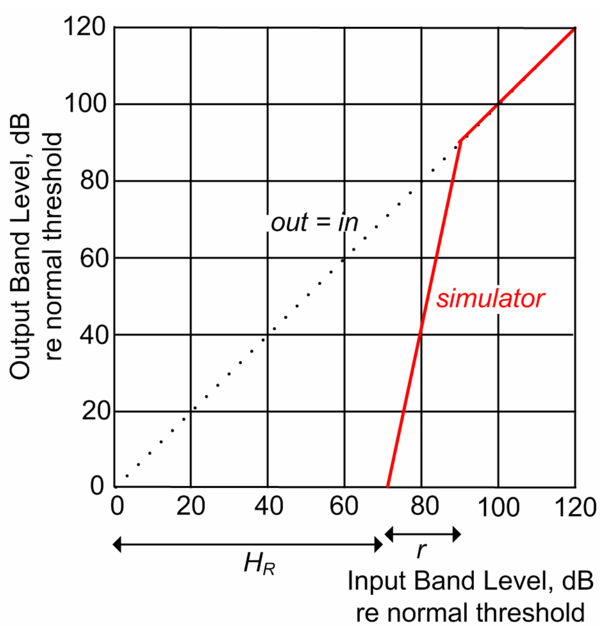
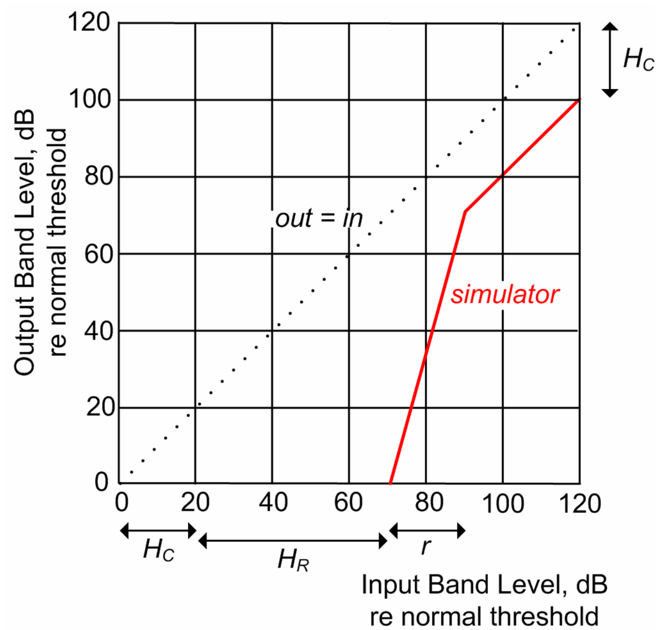


Figure 3. An example I/O plot for one simulator band showing a recruiting hearing loss H_R = 70 dB with a recruitment range r = 20 dB.

What happens with a mixed loss? Figure 4 shows the simulator I/O plot for a hearing loss with a conductive component of 20 dB and a recruiting loss of 50 dB ($H_C = 20$, $H_R = 50$). In this case the simulator output still begins to exceed 0 dB when the input level reaches the total hearing loss (HL= $H_C + H_R$) of 70 dB. The output still has a recruitment range of 20 dB, but now, because of the conductive component, the simulator output in the full-recruitment region remains 20 dB below the input level.

Figure 4. An example I/O plot for one simulator band showing a mixed hearing loss with H_C = 20 dB and H_R = 50 dB, with a recruitment range r = 20 dB.



The signal processing required to achieve the simulator I/O characteristics just described is shown in Figure 5 and is relatively straightforward. The input signal is first filtered into bands. The sound level of each bandpass signal is then estimated over a short time interval, and this estimate is used to control the gain, *g*, of an attenuator through which the filtered signal passes. This automatic gain control (AGC) is varied to achieve the desired I/O characteristic. In terms of the I/O plot, the amount of attenuation needed as a function of input level is given by the vertical distance between the simulator output characteristic and the out=in line. For recruiting hearing losses, this distance is a function of the running estimate of input level; more attenuation is applied to lower sound levels than to higher sound levels. Processing in different frequency bands has the same form, but uses different parameters, in general, for the AGC.

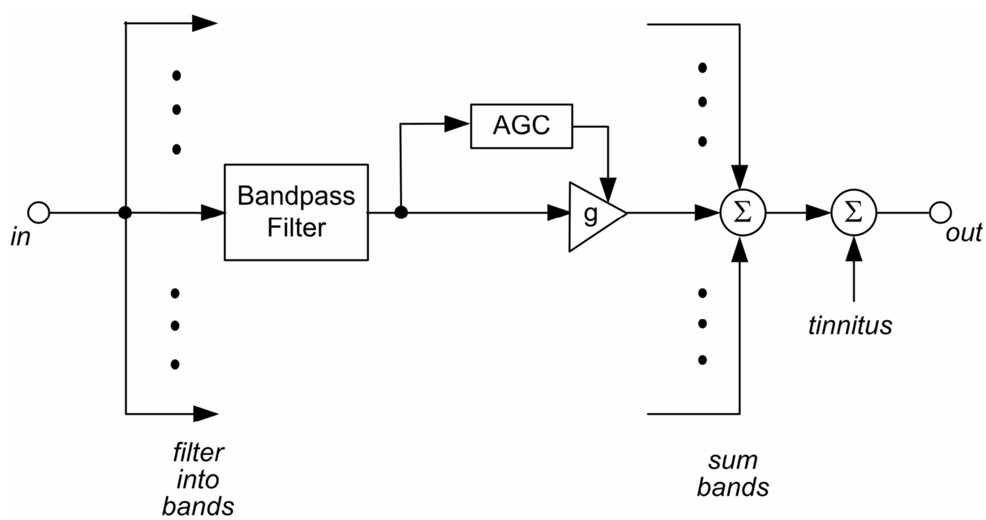


Figure 5. Block diagram showing the signal processing in one band of the hearing loss simulation.

The use of AGC to simulate recruiting hearing loss was first described by Villchur (1977) and later studied by Duchnowski and Zurek (1995) and Lum and Braida (2000). Those studies have shown reasonably good agreement of scores on psychophysical and speech-reception tests between listeners with actual hearing losses and listeners with simulated losses matched to the actual losses. The validity of a hearing loss simulation that incorporates only threshold shift and recruitment is supported by numerous other studies that have used noise-masking simulations of hearing loss (Zurek and Delhorne, 1987; Humes et al., 1987; Dubno and Dirks, 1993).

I/O plots characterize the steady-state response of the simulator. However, because the input level must be estimated over some short time interval, there will be system transient responses to changes in level. In HeLPS, the input level estimate is obtained by forming a running average of the square of the bandpass-filtered input signal, with a time constant of 14 msec. This degree of temporal resolution was chosen as a trade-off that minimizes the effects of audible distortion (with a shorter time constant) and sluggish response (with a longer time constant).

Tinnitus can also be simulated as part of the HeLPS hearing loss simulation. Tinnitus is simulated by the addition of tones or bandpass noise at the desired sound level to the output, as specified by the user.

Although only one side (ear) of the HeLPS hearing loss simulator has been discussed here, the simulation is binaural, with independent operation on the left and right sides.

Simulation Limitations

There are several limitations to the HeLPS simulations that should be understood in order to make valid and effective use of the system.

Ambient Sounds

Because HeLPS uses headphones with little sound attenuation, the listener will be able to hear ambient sounds easily. The audibility of ambient sounds is inconsistent with the demonstration of hearing loss that is the goal of the simulation. To achieve maximal impact, demonstrations should be given in quiet places.

Suprathreshold and/or Central Deficits

The hearing loss simulation implemented by HeLPS is designed to duplicate the threshold shift and loudness recruitment of a specified hearing loss. This type of simulation has been shown to give a good match to the performance of listeners with actual hearing impairments on a variety of psychoacoustic and speech-reception tasks. Some hearing-impaired listeners, however, exhibit performance that is clearly worse than simulated-loss listeners on such tasks. Listeners with auditory neuropathy (Sininger and Starr, 2001), for example, form one group to whom the HeLPS simulation does not apply. Currently, the suprathreshold deficits that underlie such poorer performance are not sufficiently understood to enable them to be simulated.

The HeLPS hearing loss simulation also does not account for cognitive or central deficits that might lead to poorer performance on psychoacoustic or speech-reception tasks. Such deficits, which are most commonly seen in some elderly patients, are not simulated by HeLPS.

PROSTHESIS SIMULATION

HeLPS provides simulations of the two most common types of auditory prostheses – hearing aids and cochlear implants. This section of the *User Guide* describes the main components of these simulations. A later section ("Specifying Simulated Prostheses") will describe how to use the HeLPS interface to control their characteristics.

Hearing Aids

The hearing aids that can be implemented by HeLPS are constructed according to the prototype block diagram in Figure 6. This diagram shows the prototype for one side only; the prototype for the other side is identical. If bilateral aids are used in HeLPS, they operate independently. In addition, fixed correction filters on the input and output are not shown.

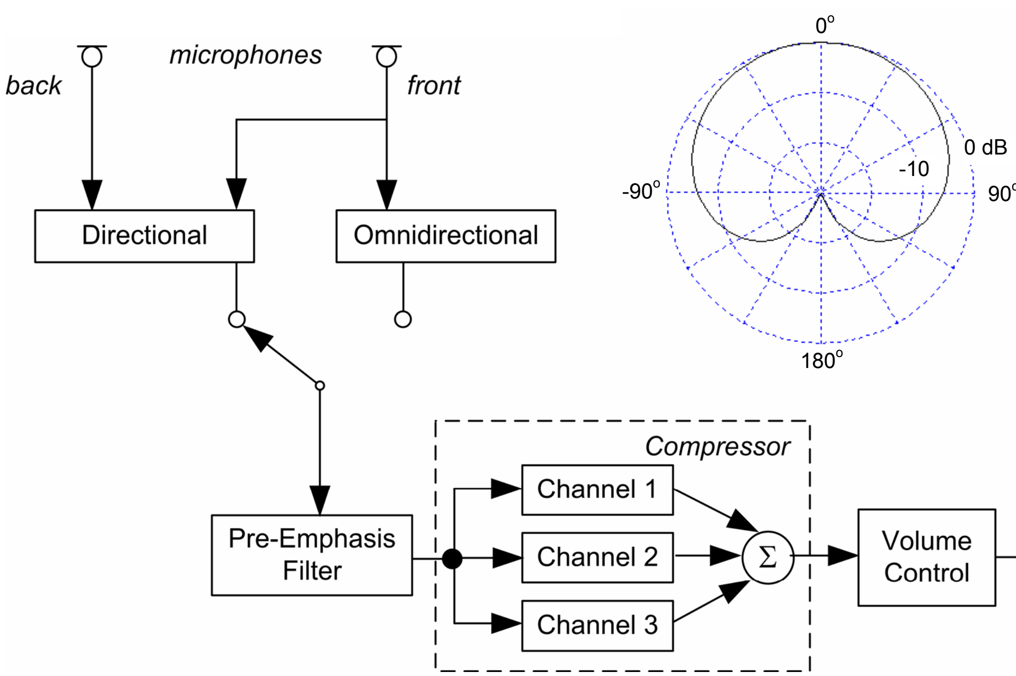


Figure 6. Block diagram of the prototype hearing aid implemented by HeLPS.

Microphone Directionality

The microphones on a HeLPS hearing aid can be either omnidirectional or directional. Either type of microphone is simulated as sensing points on a rigid-sphere model of the head. The directional microphone response in free space has the cardioid polar response pattern shown in the inset in Figure 6. Directional microphone processing includes compensation to make the on-axis (0^o) frequency response the same for omnidirectional and directional microphones. Other compensations can be implemented with the pre-emphasis filter described below.

Pre-Emphasis Filter
An adjustable linear filter is provided to allow for spectral shaping prior to compression. The magnitude response of this filter can be controlled via adjustment of a center frequency and variable-slope skirts above and below that center frequency.

Compressor
The compressor provides independent automatic gain control in up to three frequency channels. The crossover frequencies between channels are adjustable, as are the input/output characteristics and time constants within each channel. Note that all HeLPS hearing aids are, strictly speaking, compression hearing aids, because the compressor is always active. Linear hearing aids are achieved by specifying gain that is fixed, independent of input level.

Volume Range and Control
The range of gain on the hearing aid's volume control can be specified. Note that the placement of the volume control following the compressor results in the type of compression known as "input compression" (Dillon, 2001).

Simulation Limitations
An important difference between real hearing aids and HeLPS hearing aids is that there is no feedback in HeLPS aids. Consequently, there is no limit to the maximum gain that can be provided by a simulated aid. With actual hearing aids a point of instability will be reached when excessive gain is used.

Cochlear Implants
The HeLPS cochlear implant simulation is shown in Figure 7. The pre-processing is the same as for hearing aids: selection of an omnidirectional or a directional microphone and pre-emphasis filtering. The number of channels, N, in the simulation is an important parameter. Specifying N results in the audio band from 0.1 – 9 kHz being separated into N channels of equal width in octaves. Varying the number of channels can be used to adjust the quality of the signal representation and the resulting psychoacoustic performance, with a larger number of channels leading to better performance.

It is important to note that the number of channels in the CI simulation is not simply related to the number of channels or electrodes in an actual implant. The number of simulation channels only provides a means of controlling spectral resolution and, thereby, psychoacoustic performance, and should not be taken as a literal equivalent to the number of channels in an actual implant.

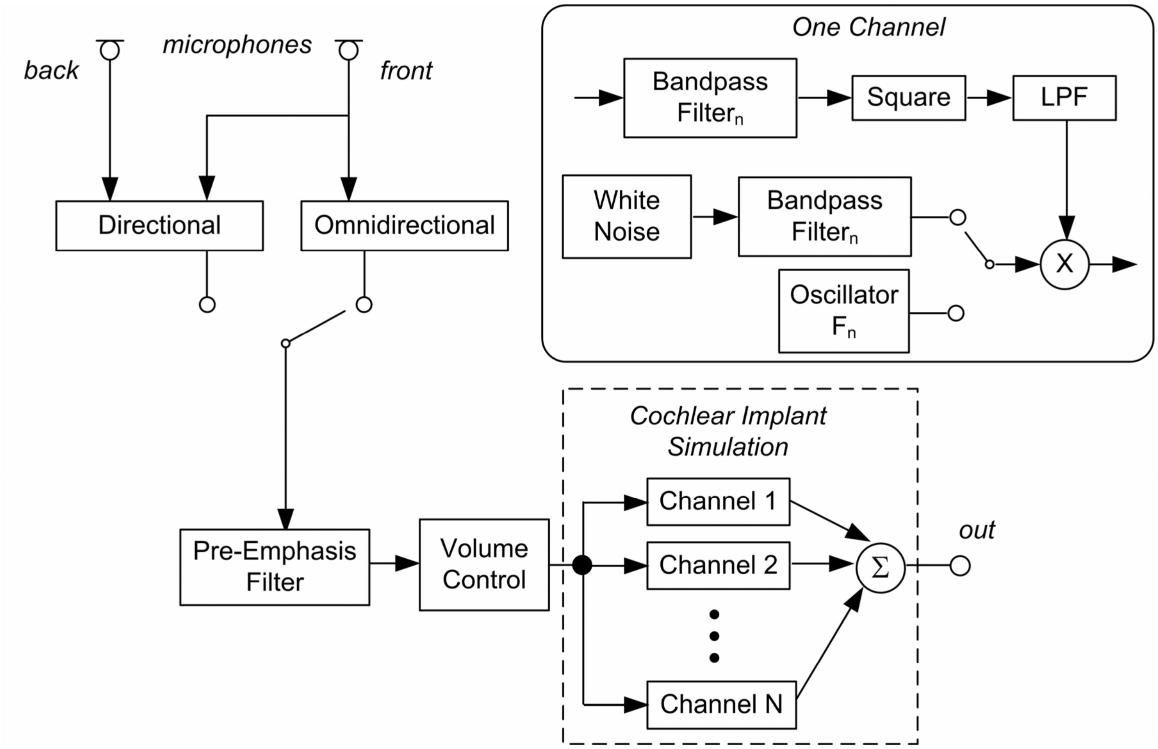


Figure 7. Block diagram of the prototype cochlear implant simulation. The processing performed within any one channel of the implant simulation is shown in the inset.

The processing performed within any channel of the cochlear implant simulation is shown in the inset of Figure 7. This simulation processing is similar to that described in the literature (e.g., Friesen et al., 2001; Qin and Oxenham, 2003) in which the envelopes of bandpass filtered signals modulate either noise band or tone carriers. Some researchers have found no difference in speech reception between these two carrier types (Dorman, Loizou, and Rainey, 1997) while others have observed slightly better speech performance with tone carriers (Whitmal, et al., 2004). But even if one carrier does give better scores than the other, that alone is not a reason for supposing that it provides a better CI simulation. At this point it is not clear which carrier type should be used. The main point to be made with demonstrations to family members is that a range of performance with CIs can be expected, and this range can be demonstrated by varying channel number using either carrier.

Simulation Limitations

Simulating cochlear implant stimulation for a normal-hearing person is more complicated than simulating acoustic stimulation with hearing aids. A person who uses a cochlear implant typically has a hearing loss that is severe-to-profound or profound. Yet this very large hearing loss, which is most often due to hair cell damage or loss, is circumvented with direct electrical stimulation of the auditory nerve. The loss of information along the pathway from acoustic signal, through the implant, to representation in the central auditory system is still poorly understood. The unexplained variability in performance of implantees on psychoacoustic and speech-recognition tasks (e.g., Munson, et al., 2003), and the difficulty in predicting implanted performance from pre-implantation measures, reflect this basic ignorance.

The accuracy of current state-of-the-art cochlear implant simulations is correspondingly limited. Performance of listeners using the simulation is controlled only by varying the number of channels. Unlike the case of acoustic hearing, where threshold shifts provide a fairly accurate basis for simulating performance on speech-recognition and psychoacoustic tasks, there are no such clinical measurements that can be used to customize the simulation to a specific cochlear implant user.

The complexity of cochlear implants also requires an accommodation to the HeLPS simulation. Because cochlear implant users receive electrical stimulation that by-passes the acoustic path, it is impossible to simulate simultaneously their threshold shifts and the loudness of the stimulation they receive. If implantees' very large losses were simulated accurately, the audible stimulation that could be delivered acoustically would be very loud. Actual implantees, however, receive their electrical stimulation at levels that go down to their absolute detection thresholds, and so can be very soft.

The accommodation that has to be made for HeLPS simulation of cochlear implants is to simulate normal hearing in the ear with the implant. Even though it seems wrong to simulate normal hearing for a person with a profound hearing loss, it is necessary to achieve the simulation. The simulator's CI output levels have been chosen so that they are clearly audible and comfortable to the listener when no hearing loss is simulated.

SPECIFYING SIMULATED HEARING LOSSES

When the HEARING tab of the HeLPS interface is clicked, a window will appear in which you can specify simulated hearing loss and tinnitus for the two ears. Symmetrical and asymmetrical losses can be generated by using the buttons located at the top of the audiogram to specify the losses for the right ear, the left ear, or both ears simultaneously.

Hearing Loss

Hearing loss for a particular ear (or for both ears simultaneously) is specified by entering air-conduction (AC) and bone-conduction (BC) thresholds into the audiogram. The buttons to the right of the audiogram labeled AC and BC determine which type of threshold will be entered. Equal AC and BC thresholds may be specified by depressing both the AC and BC buttons at the same time. If AC and BC thresholds are entered separately, HeLPS will automatically enforce the restriction that the BC threshold must not exceed the AC threshold.

AC and BC thresholds are accepted at ten frequencies: the six octave frequencies from 0.25 to 8 kHz plus the four inter-octave frequencies of 0.75, 1.5, 3 and 6 kHz. Entries at 0.25, 1, and 4 kHz are required and cannot be deleted. Threshold entries at the other seven frequencies can be added or deleted as desired. Threshold entries (AC or BC or both, depending upon the setting of the AC and BC buttons) may be added or adjusted by clicking on the audiogram at the desired frequency and the desired HL, which is indicated in the telltale (the small yellow box that pops up to display numerical values), and then clicking. Thresholds at any of the seven non-required frequencies can be deleted by right-clicking on one of the thresholds at that frequency and selecting Delete Frequency.

The gray swath in the audiogram gives the average speech spectrum range. At each frequency it extends vertically between X+12 to X-18 dB where X is the average third-octave band level of normal conversational speech measured in a free field, 1 m in front of a talker (ANSI S3.5, 1997), expressed in terms of hearing level (ANSI S3.6, 1996).

The AC and BC thresholds that are entered in a hearing specification determine the conductive and recruiting components, H_C and H_R, respectively, of the total hearing loss, HL, as described above (in “Hearing Loss Simulation”). In the HeLPS simulation, these hearing loss components are related to the audiometric measurements by

$$H_R = BC,$$
$$H_C = AC – BC \text{ (aka ‘air-bone gap’),}$$

and

$$HL = H_C + H_R = AC.$$

Simulation Limits

As mentioned above, during threshold entry, the graphical interface imposes the constraint that the BC threshold cannot be larger than the AC threshold. If you enter a BC threshold that is larger than the current AC threshold at that frequency, the interface will automatically change the AC threshold to be equal to the new BC threshold.

Tinnitus

You can specify the characteristics of either tonal or noisy tinnitus. To display the Tinnitus Controls, enable them from the View menu. For tonal tinnitus, the frequency and level of up to three continuous sine wave signals can be specified (with level specified in dB SPL). Noisy tinnitus is simulated by a continuous band of noise, and is specified by its lower and upper band limits and its overall level.

Simulation Limits

The following limits apply to the tinnitus simulation:

1) Tonal tinnitus frequencies must be below 11025 Hz. The highest cutoff for noise tinnitus must be less than 11003.
2) Both tone and noise tinnitus levels are limited to be less than 85 dB SPL.
3) If tonal tinnitus is specified for both ears at the same frequency, those tones will be presented in-phase. Noise tinnitus is uncorrelated between sides, even if their spectra overlap.

Copying, Saving, Importing, Linking and Printing

The entire collection of data that describes a given simulated hearing impairment (AC and BC thresholds and tinnitus characteristics for the two ears) is called a *hearing specification.* A hearing specification must have an identifying label in the box at the top of the window. The interface will not allow the label box to be empty and will insert a label such as "Untitled Hearing 1" if necessary.

Two forms of copying are available while in the HEARING window. First, you may copy the specification for one ear to the other ear through the use of the COPY button, which is located to the right of the audiogram when either the *Right* ear or *Left* ear audiogram display option is active. This is useful when designing similar right and left specifications.

Second, you may copy a hearing specification to a "clipboard" for use in other windows of the HeLPS interface. For example, if you want to use the current hearing specification for a demonstration, you can copy it to the clipboard (by going to the Edit menu and selecting Copy or by typing Ctrl-c) and then insert it into the Program Table by switching to the SIM SETTINGS window, single-clicking on a hearing entry in the Program Table, and pasting it (by going to the Edit menu and selecting Paste or by typing Ctrl-v). [Use of the Program Table is described in more detail later in "Controlling the Simulation"].

A hearing specification can be saved to a hearing file, which will be given the extension ".hrg". To save a specification to a file, go to the File menu, select Save As, and then specify a folder and file name in the usual way. The file name will then be displayed in the title bar at the top edge of the window. Before a specification is saved to a file a temporary name such as Untitled_Hearing_3 is displayed there. Changes made in a specification window are not made to the associated file (if there is one) until a Save command is given.

Note that there is no connection between a file name and a label. Moreover, you need not save a specification to a file. Once a specification has been imported into the SIM

SETTINGS Program Table, it will continue to reside within the table and will be retrievable for as long as HeLPS is running. Care must be taken, however, since any specification contained within the Program Table might be overwritten at some later time, leaving no record of the original. If you think you will want a record of a specification in the future, you should save it to a file.

You can import a previously-saved specification into the HEARING window. To do so, go to the File menu, select Open, and navigate to the .hrg file you wish to open. Before the new specification is imported, a prompt will ask you to save the current specification.

You can also import a hearing specification into the HEARING window from the SIM SETTINGS Program Table. This is done in either of two ways: (1) single-click on the desired specification in the Program Table, select Copy from the Edit menu (or press Ctrl-c), click on the HEARING window tab, and then select Paste from the Edit menu (or press CTRL-v) or (2) link the specification to the HEARING window as described in the following paragraph. Note that method 1 does *not* link the HEARING window to the simulation.

The process of *linking* allows you to have the changes you make in the HEARING window be implemented immediately in the active simulation. In order to be linked, a hearing specification must be loaded into the SIM SETTINGS Program Table. Link the hearing specification to the HEARING window by double-clicking on its label in the Program Table. This will cause three things to happen: 1) it will make that specification the active one; 2) it will bring up the HEARING window; and 3) it will link the HEARING window to the simulation. In this linked state, the changes you make in the HEARING window will be made immediately to the ongoing simulation, giving you direct active control. This linked state is indicated in the HEARING window by an asterisk to the left of the label box; in the SIM SETTINGS window it is indicated by an asterisk next to the specification that was double-clicked.

The hearing specification displayed in the HEARING window can be printed. go to the File menu and select Print and proceed as usual when printing. A copy of the hearing window will be sent to your default printer.

Some example .hrg files are provided in the folder C:\...\HeLPS\work\examples . You can Open any of these and use it, or modify and save it, as desired.

SPECIFYING SIMULATED PROSTHESES

When the PROSTHESIS tab of the HeLPS interface is clicked, a window appears that allows you to specify a prosthesis (if any) for each ear. The buttons above the main plot can be used to select the left or right ear, or both ears if the prosthesis is to be the same on the two sides. There are three prosthesis options: 1) None (no prosthesis); 2) Hearing Aid; or 3) Cochlear Implant. When starting with a New prosthesis specification (by selecting New from the File menu), the prosthesis is set to None and the display shows the output spectra for three levels (55, 70, and 85 dB SPL) of free-field speech spectra modified by the free-field-to-eardrum transfer function (ANSI S3.5, 1997).

No Prosthesis

If *None* is selected, no modifications may be made to the displayed output spectra. Hearing-specification thresholds can be added to the plots to enable comparisons of speech levels to audibility thresholds. The SPL thresholds are derived from the audiograms of a hearing specification and can be imported by issuing either of two commands in the Import Loss menu: 1) From HEARING Window will load the audiograms from the current HEARING window; or 2) From File will load audiograms from a selected .hrg file. Thresholds from the current HEARING window may also be imported by copying the hearing specification to the clipboard (as described above) and choosing Paste (from the Edit Menu) while in the PROSTHESIS window. This latter method will produce a warning that the hearing specification in the clipboard will also be imported into the HEARING window. The hearing-threshold display can be de-activated by selecting None from the Import Loss menu.

Hearing Aid

If *Hearing Aid* is selected, the display of output spectra changes slightly and some additional controls appear at the bottom of the window. These graphical and numerical controls are used in specifying the characteristics of the hearing aid. To help with the specification of the hearing aid, the output band-level plots are continuously updated to reflect current settings.

When the *Hearing Aid* display of a new prosthesis is first entered the default specification is identical to *None*. This “transparent aid” uses an omnidirectional microphone, and has fixed linear gain of 0 dB.

While *Hearing Aid* is selected, two displays are possible, as selected from the View Menu: Real Ear Output and Pre-Emphasis.

Real Ear Output

The Real Ear Output plot shows the hearing aid output third-octave spectra at the listener’s eardrum in response to speech-spectrum noise (straight-ahead of the listener) at 55, 70, and 85 dB SPL. These displayed spectra will reflect changes in the gain-frequency response resulting from the pre-emphasis filter and the compression amplifier hearing aid components described in Figure 6.

Note that because these plots apply only to a straight-ahead source, and because there is a built-in compensation for the frequency response of a directional microphone, there will be no change in the output spectra when you switch between an omnidirectional and a directional microphone. Of course, there could be large differences between the output spectra from these two microphones if the source were not straight-ahead.

Pre-Emphasis

The Pre-Emphasis plot shows the shape of the pre-emphasis filter from Figure 6. This is an adjustable linear filter that is provided to allow for spectral shaping prior to compression. The plot that appears shows the idealized magnitude response of the pre-emphasis filter. This filter is controlled by changing the cutoff frequency f_c (by clicking and dragging the green vertical line) and the slopes of lines above and below f_c (by clicking and dragging the square handles). The filter gain at f_c is fixed at 0 dB and the lines have fixed slopes in dB per octave. The gain of the pre-emphasis filter is limited as shown to the range from -60 to +20 dB. Gain may be limited below +20 dB if the resulting output level from any channel (with 85 dB speech spectrum noise) exceeds the maximum channel output level. Likewise, filter gain may be limited above -60 dB if the resulting output level from a channel would go below the compression knee value with 55 dB SPL speech spectrum noise. Such limits on gain are indicated in the telltale.

Microphone

Either *Omnidirectional* or *Directional* microphones must be selected. Recall that directional microphone processing includes compensation to make the on-axis (0^o) frequency response the same for omnidirectional and directional microphones. As a result, switching from one to the other causes no change in the displayed output spectra.

Volume Range and Control

The third-octave spectra of speech-shaped noise shown in the real ear output plots are calculated on the assumption that the volume control is at 0 dB gain. The range of gain allowed in the volume control can be specified, but this range must include 0 dB; i.e., allowed entries in the left box must be less than or equal to 0 and in the right box must be greater than or equal to 0. If no volume control is desired, enter 0 in both boxes.

The main prosthesis volume control is located in the SIM SETTINGS window. When the PROSTHESIS window is linked to the active simulation (as described below), a duplicate volume control is visible to the right of the plot box in the PROSTHESIS window for convenient access The volume control steps are fixed at 1 dB.

Compressor

Advanced compressor controls are accessed by activating them from the View menu. If you simply wish to use default values for the compressor, you can leave these controls hidden.

The compressor provides independent automatic gain control in up to three frequency channels. The crossover frequencies between channels are indicated on the Real Ear Output plots by the green vertical lines and are adjusted by clicking and dragging these lines. If you want to implement a compressor with only one or two channels, move one or both of the vertical lines to the far right of the display.

The input/output characteristic within each compressor channel is composed of line segments that you specify indirectly. The procedure is illustrated in Figure 8. The Input Channel Level variable in this plot is the level of speech-spectrum noise within the channel in a listener's open ear canal. The Output Channel Level variable is the level of speech spectrum noise in the listener's ear canal, within the channel, with HeLPS implementing the specified aid. Both of these variables depend, of course, on the upper and lower frequency limits of the channel.

The input/output curve in Figure 8 is composed of straight lines determined by five points, labeled 1-5. The coordinates of these points are determined according to the following algorithm.

1) The output coordinates of the three middle points (#2-4) are determined by the placement of the three graphic handles, one for each of the three input levels of speech spectrum noise, for that channel in the Real Ear Output plot. Although the handle is placed graphically on the third-octave spectrum curve, the quantities displayed in the telltale are actual channel input and output levels.

2) The output level of point #5, labeled O_{max}, is an advanced compressor control parameter and is set by numerical entry in the 'max' boxes for the three channels. O_{max} specifies the maximum output level for the channel, which is controlled via compression limiting. The input-level coordinate paired with O_{max} is determined by the intersection of the horizontal line at Output = O_{max} and the extension of the line joining points 3 and 4. As a result, the slope of the compression curve is constant between points 3 and 5.

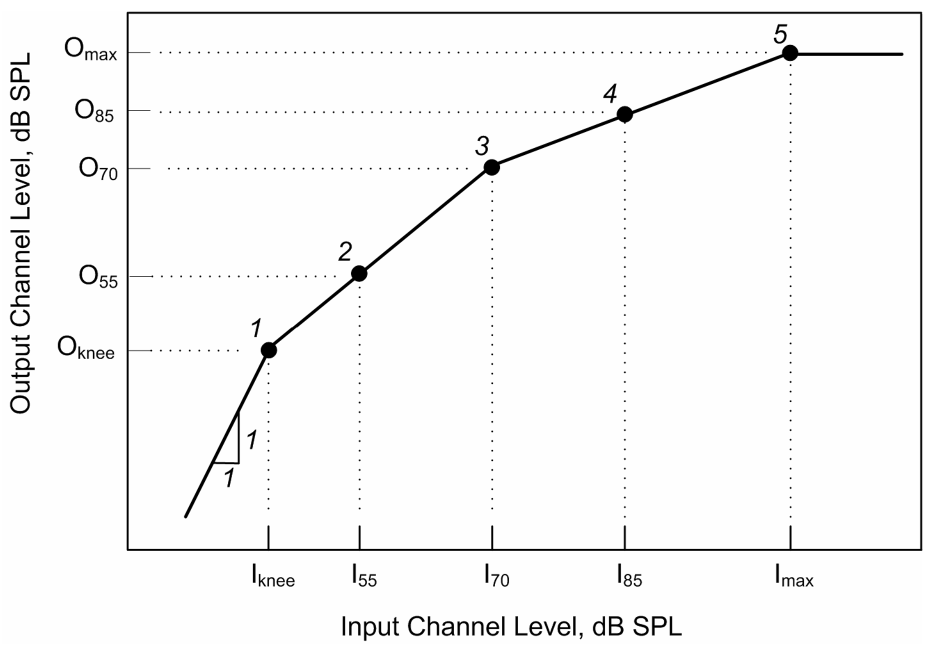


Figure 8. Example I/O characteristic for one channel of a compression hearing aid.

3) The output level of point #1, point labeled O_{knee}, is also an advanced compressor control and is set by numerical entry in the 'knee' box for each channel. O_{knee} specifies the output level for the channel at the lower end of the compression range. At input levels below this point the applied gain is fixed (and hence the slope is 1 dB/dB). The input-level coordinate paired with O_{knee} is determined by the intersection of the horizontal line at Output = O_{knee} and the extension of the line joining points 2 and 3. As a result, the slope of the compression curve is constant between points 1 and 3.

It is important to keep in mind that the max and knee output parameters have precedence over other parameters. All adjustments to the three middle points (#2-4) will be automatically limited by the interface to comply with the max and knee output constraints. Note from Figure 6, however, that because the volume control is placed after the compressor, it will be possible to increase the volume control and exceed the maximum output level specified via the interface.

The temporal parameters for each channel of the compressor are the attack and release times, which are entered numerically.

Prescriptions

The Prescribe menu provides six different threshold-based hearing aid prescriptions. Three of these – POGO-II, NAL_RP, and DSL – are for linear hearing aids. The other three – FIG6, CR2, and NAL_NL1 are for nonlinear (compression) aids. The three linear prescriptions and FIG6 have been implemented in accordance with the descriptions provided by Dillon (2001). NAL_NL1 is a proprietary prescription method for nonlinear aids available from the National Acoustics Laboratories of Australia. CR2 is a custom compression prescription that uses a three-segment compression characteristic in each channel obtained by: 1) calculating the gain prescribed by NAL_RP and assigning that gain to an input level of 65 dB SPL; 2) using a compression ratio of 2 for input levels from 40 to 95 dB SPL; and 3) using a fixed gain below 40 dB and an infinite compression ratio above 95 dB SPL.

In order to generate a hearing aid prescription, a hearing specification must first be imported into the PROSTHESIS window. This process is identical to that described above for the No Prosthesis description. Prescriptions are calculated for the three overall input speech levels of 55, 70, and 85 dB SPL and are shown as dashed lines. A hearing aid prescription is then programmed by adjusting the three Real Ear Output level curves (using both the compression band tags in the Real Ear Output plot and the Pre-Emphasis filter) to match the displayed output curves from the prescription. Note that the hearing aid is not automatically programmed to match a prescription; you must manually adjust the output level curves using the graphic handles. If you wish to remove the prescribed curves from the plot, select None from the Prescribe menu.

Simulation Limits

The maximum output of a HeLPS hearing aid is a parameter that can be adjusted. The largest maximum output allowed by the interface is 110 dB SPL within a channel. These high output levels are made available in order to simulate high-gain hearing aids. If such high levels are not needed, you should set the maximum output level to a lower value, such as 90-100 dB SPL.

Cochlear Implant

If Cochlear Implant is selected, the display of output spectra changes slightly and some additional controls appear at the bottom of the window. These controls are used to specify the characteristics of the implant. To help with the implant specification, the output band-level plots are continuously updated to reflect current settings.

While Cochlear Implant is selected, two displays are possible, as selected from the View Menu: Real Ear Output and Pre-Emphasis.

Real Ear Output

The Real Ear Output plot shows the third-octave spectra produced by the implant simulation at the listener's eardrum in response to speech-spectrum noise (straight-ahead of the listener) at 55, 70, and 85 dB SPL. These displayed spectra will reflect the number of cochlear implant channels used and changes in the gain-frequency response resulting from the Rre-Emphasis filter as described in Figure 7.

Note that because these plots apply only to a straight-ahead source, and because there is a built-in compensation for the frequency response of a directional microphone, there will be no change in these idealized output spectra when you switch between an omni-directional and a directional microphone. Of course, there would be large differences between the output spectra from these two microphones if the source were off-axis.

Pre-Emphasis Filter

The Pre-Emphasis plot shows the shape of the Pre-Emphasis filter from Figure 7. This filter is controlled by changing the central frequency f_c (by clicking and dragging the green vertical line) and the slopes of lines above and below f_c (by clicking and dragging the square handles). The filter gain at f_c is fixed at 0 dB and the lines have fixed slopes in dB per octave. The gain of the pre-emphasis filter is limited as shown to the range from -60 to +20 dB. Gain may be limited below +20 dB if the resulting output level from any channel (with 85 dB speech spectrum noise) exceeds the maximum channel output level. If that limit is reached it will be so indicated by a telltale.

Microphone

Either *Omnidirectional* or *Directional* microphones must be selected. Recall that directional microphone processing includes compensation to make the on-axis (0^o) frequency response the same for omnidirectional and directional microphones. As a result, switching from one to the other causes no change in the displayed output spectra.

Volume Range and Control

The third-octave output spectra shown in the Real Ear Output plots are calculated on the assumption that the volume control is at 0 dB gain. The range of gain allowed in the volume control can be specified, but this range must include 0 dB; i.e., allowed entries in the left box must be less than or equal to 0 and in the right box must be greater than or equal to 0. If no volume control is desired, enter 0 in both boxes.

The main prosthesis volume control is located in the SIM SETTINGS window. When the PROSTHESIS window is linked to the active simulation (as described below), a duplicate volume control is visible the right of the plot box in the PROSTHESIS window for convenient access The volume control steps are fixed at 1 dB.

Number of Channels

The number of *Channels* in the simulation must be between 1 and 20, inclusive.

Carrier

Either a band of noise or a tone at the center frequency of each band can be used as the *Carrier* in the simulation.

Simulation Limits

As described in "Prosthesis Simulation," an adjustment in the simulation of cochlear implants must be made to accommodate the fact that a cochlear implant provides low- and moderate-level auditory stimulation to a person with very large hearing loss. In order to best simulate these conditions, HeLPS delivers the implant simulator output at a moderate level, and in order for the listener to perceive that output signal *Normal Hearing must be used with the simulated implant.*

Copying, Saving, Importing, Linking, and Printing

The entire collection of data that describes a binaural pair of prostheses (including None) is called a *prosthesis specification*. A prosthesis specification must have an identifying label in the box at the top of the window. The interface will not allow the label box to be empty and will insert a label such as "Untitled Prosthesis 1" if necessary.

Two forms of copying prosthesis specifications are possible. First, if you are specifying a prosthesis for one ear, you can copy that specification to the other ear by clicking the copy button to the right of the plot. These buttons can save you time when specifying a prostheses that are similar between the ears.

Second, you can copy a prosthesis specification to a "clipboard" for use in other windows of the HeLPS interface. For example, if you want to copy the current prosthesis specification to the Program Table in the SIM SETTINGS window, you can first copy it to the clipboard (by going to the Edit menu and selecting Copy or by typing Ctrl-c), then switch to the SIM SETTINGS window, and then paste it into a slot in the table (by going to the Edit menu and selecting Paste or by typing Ctrl-v).

The on-screen prosthesis specification can be saved to a prosthesis file, which will be given the extension ".pros". To save a specification to a file, go to the File menu, select Save As, and then specify a folder and file name in the usual way. The file name will then be displayed in the title bar at the top edge of the window. Before the specification was saved to a file a temporary name such as Untitled_Prosthesis_3 was displayed there.

Changes made in a specification window are not made to the associated file (if there is one) until a Save command is given.

Note that there is no connection between a file name and a label for a specification. Moreover, you need not save a specification to a file. Once a specification has been imported into the SIM SETTINGS Program Table, it will continue to reside within the table and will be retrievable as long as HeLPS is running. Care must be taken, however, since any specification contained within the Program Table might be overwritten at some point, leaving no record of the original. Thus, if you think you will want a record of a specification in the future, you should save it to a file.

You can import a previously-saved specification into the PROSTHESIS window. To do so, go to the File menu, select Open, and then navigate to the .pros file you wish to open. Before the new specification is imported, a prompt will ask you to save the current specification. You may also import a prosthesis specification from the SIM SETTINGS Program Table. This may be done in one of two ways: (1) single-click on the desired specification in the Program Table, select Copy from the Edit menu (or press Ctrl-c), click on the PROSTHESIS window tab, and then select Paste from the Edit menu (or press CTRL-v) or (2) link the specification to the PROSTHESIS window as described in the following paragraph. Note that method 1 does *not* link the PROSTHESIS window to the simulation.

The process of *linking* allows you to have the changes you make in the PROSTHESIS window be implemented immediately in the active simulation. In order to be linked, a prosthesis specification must be loaded into the SIM SETTINGS Program Table. Link the prosthesis specification by double-clicking on its label in the Program Table. This will cause three things to happen: 1) it will make that specification the active one; 2) it will bring up the PROSTHESIS window; and 3) it will link the PROSTHESIS window to the simulation. In this linked state, the changes you make in the PROSTHESIS window will be made immediately to the ongoing simulation, giving you direct active control. This linked state is indicated in the PROSTHESIS window by an asterisk to the left of the label box; in the SIM SETTINGS window it is indicated by an asterisk next to the specification that was double-clicked.

The information contained in the prosthesis specification can be printed. To do so, make sure that the desired specification is loaded into the PROSTHESIS window, go to the File menu and select Print and proceed in the usual way as with other Windows products.

Some example .pros files are provided in the folder C:\...\HeLPS\work\examples. You can Open any of these and use it, or modify and save it, as desired.

CONTROLLING THE SIMULATION

Clicking the SIM SETTINGS tab of the HeLPS interface brings up a window that allows you to:

1) load hearing and prosthesis specifications into the *Program Table*, select them for the current simulation, control prosthesis volume level, and store complete Program Tables as files for future use;
2) select *Target, Noise,* and *Environment* characteristics for the simulation; and,
3) *Play* and *Pause* presentation of target stimuli and select whether audio only, video only, or both components of an audio/video stimulus are presented.

Working with the Program Table

The Program Table has six slots for hearing specifications and six for prosthesis specifications. Hearing specification #1 and prosthesis specification #1 are fixed at *Normal Hearing* and *No Aid*, respectively, and are not programmable. The remaining slots in the table (#2-6) can be filled by five hearing specifications (left column) and five prosthesis specifications (right column). These specifications are identified by the labels given to them in their respective specification windows. Specification labels cannot be changed in the SIM SETTINGS window.

A specification can be loaded into a slot from either of two sources, the specification window or a file.

1) <u>Loading from a specification window.</u> A hearing or prosthesis specification can be copied in its entirety from its specification window and pasted into a slot in the Program Table. This copying can be done in either of three ways:

a) While in the specification window, go to the Edit Menu and select Copy (or, simply type Ctrl-c). Then go to the SIM SETTINGS window, single-click on the slot into which the specification is to be inserted, and select Paste from the Edit menu (or, type Ctrl-v). The label for that specification will be placed in the slot, indicating the specification has been copied.

b) In the SIM SETTINGS window, click the slot in the Program Table into which you wish to load a new specification. Then go to the Import Specification menu and select From Hearing (or Prosthesis) Window. The specification that is loaded will replace the specification that previously occupied that slot. A short-cut to the Import Specification menu is available by right-clicking on a label.

c) If you double-click on a label, then that specification window (either hearing or prosthesis) is brought to the foreground displaying the specification assigned to that label. As described in previous sections, double-clicking on a label establishes an interactive link so that changes made in the specification window (including its label) are made immediately in the Program Table, and consequently, in the currently-active simulation. The existence of a link is indicated by an asterisk to the left of the label.

2) Loading from a file. A hearing or prosthesis specification that was previously stored in a file may also be loaded. First click on the slot in the Program Table into which you wish to load the stored specification. Then select From File in the Import Specification menu. This will bring up a dialog box for specifying the file. Note that the two steps of clicking on the slot and going to the Import Specification menu can be reduced to one click. Just right click on a slot to bring up the Import Specification menu in a pop-up window.

In addition to copying from a specification window and importing specifications, any specification that is already in the Program Table can be copied and pasted into another slot in the Table. This can be useful when creating a specification that differs slightly from an existing one. To do this, highlight the specification's label by single-clicking on it. Then type Ctrl-c to copy it to the clipboard (or go to the Edit Menu and select Copy). Click in the slot into which you wish to insert this specification and then paste it in by typing Ctrl-v (or selecting Paste from the Edit Menu).

It is important to remember that there is no logical connection among labels in the Program Table. It is up to you to avoid giving different specifications the same label. If a label appears more than once in a table, even if for the same initial specification, a change in one of those specifications does not propagate to others with the same label.

In addition to the file operations with individual specifications, it is possible to save the entire Program Table to a program file (with a ".prog" extension). To do so, go to the File Menu and select Save or Save As. When a Program Table is saved all of the specifications contained in it are saved along with it. Program files can be loaded by selecting Open from the File Menu. A Program Table can be printed by selecting Print from the File Menu.

The example program file Assorted.prog, which was used in the *Quick Start* tutorial, is provided in the folder C:\...\HeLPS\work\examples. You can Open this file and use it, or modify and save it, as desired.

Stimulus Selection and Playback Control

HeLPS provides flexible control over the selection of target and noise stimuli that are delivered as inputs to the prosthesis and hearing loss simulators.

Target Settings

Targets are the audio or audio/video stimuli that are presented when the Play button is clicked.

There are two sources of target stimuli. The first, the *HeLPS A/V Clips*, is a collection of about 400 audio/video recordings of everyday sentences spoken by ten talkers -- five females and five males. These talkers exhibit a range of regional accents, voice quality, speaking habits, and speech-readability. Using the pull-down menu, you can select any one of these talkers, or all of them, or all talkers of the same gender, as the subset to sample. Sentences are picked at random (with replacement) from the selected subset.

The second target source, *User-Supplied Stimuli*, allows you to use as a target any audio file, or collection of audio files (in .wav format), that you have stored on your PC. To make files available for access by HeLPS, you must first specify their location. By default, HeLPS looks to the folder labeled UserStimuli within the main HeLPS installation folder. If you wish to use audio files stored elsewhere, you can change the target folder by going to the Advanced menu in the SIM SETTINGS window and choosing Select User Stimuli Folder.

When *User-Supplied Stimuli* is selected, HeLPS automatically populates the source drop-down (or scroll) menu with the contents of the specified User Stimuli Folder. HeLPS interprets these contents in the following way: individual .wav files are regarded as single-stimulus sources while subfolders are regarded as playlists (consisting of the .wav files contained within the subfolder). If you select an individual .wav file it will be repeated until Pause is clicked or HeLPS is exited. If you select a subfolder, all the .wav files in that folder will be played in the alphabetical order of their filenames, with that presentation repeated until stopped. (Subfolders within the selected subfolder are disregarded). Valid .wav files for use with HeLPS must contain a one-channel signal sampled at one of these sample rates: 48, 44.1, 24, 22.05, 16, 12, or 11.025 kHz. If HeLPS detects a stereo signal, it will produce an output using only the left channel. If HeLPS detects a signal with a valid sampling rate (from the list above), it will re-sample it at the default HeLPS sampling rate of to 22.05 kHz for processing and output. Signals with invalid sampling rates will be ignored. User-supplied target stimuli are processed just like HeLPS A/V targets to simulate arrival from straight-ahead, and are further processed to add reverberation if that option is selected.

Sample stimuli are provided in the HeLPS/UserStimuli folder. These samples include tones, noise bands, music, spoken passages, and environmental sounds.

Be aware that because of the intensive processing performed by HeLPS, there is an initial delay in the presentation of User Stimuli. This delay increases with the length of the file. If a single file is repeated, however, the gap between repetitions is very short.

A *Repeat* switch is provided to allow you to repeat one stimulus continually. This capability is convenient for making direct comparisons among hearing losses or prostheses with the same stimulus.

Target Level represents the level of the direct sound wave at the listener’s location (equal to overall level in an anechoic environment). In reverberation the target level at the listener’s location is slightly higher than the nominal level due to the added reverberant energy. A typical level for normal conversational speech is 65 dB SPL.

User-Supplied Stimuli are scaled to be presented at the selected Target Level. However, this scaling must be done carefully to avoid problems that would result, for example, if the RMS average were to be calculated over a long-duration audio signal that has only a brief burst of high-amplitude signal. The algorithm that is used in scaling a signal to achieve a given output level is based on taking a running average with a 0.5-sec time constant through the entire file. The scaling is done so that the largest output from this averager is equal to the specified sound level in dB SPL.

An additional option with User-Supplied Stimuli is to have no scaling applied. This No Scale option gives you direct control over the signal level. In order to make use of this to achieve a given sound pressure level, you will need to know that the mapping used for scaling in HeLPS is that an RMS value of 3500 calculated on a digital signal (regarding the 16-bit samples as integers ranging from -32768 to 32767) corresponds to an input sound level (in the free field at the listener's center-head position) of 85 dB SPL.

Noise Settings

There are two types of noise provided with HeLPS – Speech-Shaped Noise and Party Noise. Speech-Shaped Noise is random noise that has been filtered to give it the spectral shape of the long-term speech spectrum. The direction of arrival of this noise can be chosen to be either straight-ahead (0^o) to the listener's left (-90^o), right (90^o), or rear (180^o). Speech-Shaped Noise can also be chosen to be diffuse – arriving from all directions.

Party Noise is composed of individual talkers from many directions. If Party Noise is selected there are no options for selecting direction of arrival.

Noise level can be selected, and it can be presented nearly continuously (with brief interruptions) or only coincident with each target stimulus.

Environment Settings

Two degrees of reverberation can be selected. Anechoic represents a very low degree of reverberation, typical of a room with extensive absorption (e.g., thick carpeting, drapes, upholstery). The moderate degree of reverberation is typical of a very 'live' room with little acoustic absorption, such as a kitchen. Note that these settings describe the reverberation added to the target+noise stimuli. If you supply targets that are already reverberant, they will still be reverberant even if you select Anechoic, and they will have increased reverberation if you select "Reverberant."

Volume Control

The volume control to the right of the Program Table controls prosthesis volume (both together if two prostheses are used).

Playback Control

To enable demonstrations of the value of the visual signal for speechreading (and, the audio signal for listening), controls are available under the video window for turning off either the video or the audio. When audio-only stimuli are being played these controls are de-activated.

Advanced Playback Control

Because the real-time simulations implemented by HeLPS are computationally intensive, some computers may have problems playing audio/video stimuli or even audio-only stimuli with hearing loss and hearing aid simulations in effect. Problems are more likely with older computers, many of which are slower and have less memory than current (mid-2006) PCs. To accommodate such PCs as much as possible, HeLPS provides controls that can be adjusted by the user to optimize performance. These Playback Settings are available under the Advanced menu in the SIM SETTINGS window.

The Current Statistics in the Playback Settings window summarize error rates (over the recent past) for audio and video processing. Ideally, these would both be zero. Realistically, however, there will be occasional errors. If these rates are low enough the errors will not be noticed. If error rates increase beyond about 10%, however, there will be noticeable problems in stimulus delivery.

If you notice problems in the audio output, try adjusting the Processing Buffer size. Increasing this parameter will lead to fewer dropped audio blocks at the cost of slower response to changes. In general, try to set Processing Buffer Size to be the smallest value that yields audio with no stutters. The Gap Noise Growth Rate parameter affects processing required when the Continuous option is selected. Make this parameter as large as possible without producing audio stutters in the noise in the inter-stimulus period.

Video problems will most likely arise from dropped frames, which cause the video image to jump abruptly. If you see such problems, you may have to reduce Image Quality and/or decrease Image Size. The low Image Quality setting produces images that are noticeably pixellated when viewed from a short distance. Decreasing Image Size makes the pixellation less visible, at the cost of a smaller image.

A final piece of advice regarding HeLPS playback problems is to close other applications and accounts that may be open in the background. Demands from other programs can slow the time-critical computation required by HeLPS.

Storing Audio Output

A selection under the Advanced menu allows you to store the processed simulator output to an audio file. If you turn this feature on, a Save Output Signal dialog box will appear following each stimulus presentation, enabling you to give that audio file a name and save it. All changes that you make during the stimulus presentation will be recorded to the output file *except* for changes in tinnitus. For technical reasons, the tinnitus settings that are in effect at the end of the stimulus presentation will be implemented throughout the entire stored stimulus, even if changes to tinnitus settings were made during presentation.

Presenting Simulations to Multiple Listeners

When there is more than one person who is to listen to a demonstration, it would be efficient to deliver the simulator output to all of them in parallel rather than have them listen sequentially with one set of headphones. One way to achieve simultaneous listening is to use multiple sets of headphones connected in parallel. Audio adapters that enable connection of multiple headsets to one audio output jack can be obtained from consumer electronics outlets. Assuming that your audio system is capable of driving the desired number of headsets, and assuming that the headsets are all the recommended Sennheiser HD 201, the only other consideration is that all of the listeners have a good view of the video display, if there is one.

Another solution for multiple listeners is to deliver the output signals from loudspeakers. This approach has several limitations, however, that must be understood. These limitations arise because the left and right simulator outputs are designed to be delivered to left and right calibrated earphones. Delivering them instead to loudspeakers can be done if the loudspeakers are set up and calibrated properly and then used with an understanding of the limitations. Follow these steps if using loudspeakers.

1) Position the two loudspeakers to either side of, and equally displaced from, the PC monitor on which videos (if any) will be viewed. The angle from straight-ahead of the listener to either loudspeaker should be between 30^o and 60^o, and equal for the two loudspeakers. Try to keep the distance from the loudspeakers to the listener's location as short as practically possible (within about one meter) in order to minimize effects of room reverberation.

2) After the loudspeakers are positioned, perform a calibration like that described in the Software Installation and Audio Setup section of this *User Guide*. Deliver stimuli as described there from the loudspeakers and either measure (if using measurement equipment) or adjust the volume to achieve the calibration criterion.

3) When giving demonstrations with loudspeakers, keep in mind that the simulation will be invalid for any condition in which separation of the signals to the two ears is critical. For example, it would make no sense to attempt to simulate a highly-asymmetric hearing loss using loudspeakers because the signal intended for the better ear will be delivered also to the poorer ear, and vice versa. Likewise, a large hearing aid gain on one side will result in that amplified signal reaching both ears when using loudspeakers. As a result of these constraints, the simple rule that governs the use of loudspeakers is:

> *When using loudspeakers, only simulate hearing losses and prostheses that are left-right symmetric.*

With respect to spatial effects of the noise sources, the listener will notice that Speech-Shaped Noise to the left or right will be localized at the left or right loudspeaker, respectively. Diffuse noise and Party Noise will tend to be localized in-between the two loudspeakers instead of all around the listener.

REFERENCES

ANSI S3.5 (1997). “American National Standard Methods for Calculation of the Speech Intelligibility Index,” American National Standards Institute, New York.

ANSI S3.6 (1996). “American National Standard Specification for Audiometers,” American National Standards Institute, New York.

Dillon, H. (2001). *Hearing Aids.* (Thieme, New York).

Dorman, M. F., Loizou, P. C., and Rainey, D. (1997). “Speech intelligibility as a function of the number of channels of stimulation for signal processors using sine-wave and noise-band outputs,” J. Acoust. Soc. Am. 102, 2403–2411.

Dubno, J.R., and Dirks, D.D. (1992). “Factors Affecting Performance of Psychoacoustic and Speech-Recognition Tasks in the Presence of Hearing Loss,” in *Acoustical Factors Affecting Hearing Aid Performance*, *Second Edition,* G.A.. Studebaker and I Hochberg (Eds.), Allyn and Bacon, Boston.

Duchnowski, P. and Zurek, P.M. (1995). “Villchur revisited: Another look at AGC simulation of recruiting hearing loss,” J. Acoust. Soc. Am. 98, 3170-3181.

Friesen, L. M., Shannon, R. V., Baskent, D., and Wang, X. (2001). “Speech recognition in noise as a function of the number of spectral channels: Comparison of acoustic hearing and cochlear implants,” J. Acoust. Soc. Am. 110, 1150–1163.

Humes, L.E., Dirks, D.D., Bell, T.S. and Kincaid, G.E. (1987). “Recognition of nonsense syllables by hearing-impaired listeners and by noise-masked normals,” J. Acoust. Soc. Am., 81, 765-773.

Lum, D.S. and Braida, L.D. (2000). “Perception of speech and non-speech sounds by listeners with real and simulated sensorineural hearing loss,” J. Phonetics 28, 343-366.

Munson, B., Donaldson, G.S., Allen, S.L., Collison, E.A., and Nelson, D.A. (2003). “Patterns of phoneme perception errors by listeners with cochlear implants as a function of overall speech perception ability,” J. Acoust. Soc. Am. 113, 925-935.

Qin, M. K. and Oxenham, A.J. (2003). “Effects of simulated cochlear-implant processing on speech reception in fluctuating maskers,” J. Acoust. Soc. Am. 114, 446-454.

Sininger, Y. and Starr, A. (2001). *Auditory Neuropathy*. (Singular, San Diego CA).

Villchur, E. (1977). “Electronic models to simulate the effects of sensory distortions on speech perception by the deaf,” J. Acoust. Soc. Am. 62, 665-674.

Whitmal, N. A., III, Poissant, S. F., Freyman, R. L., and Helfer, K. S. (2004). “Effect of combining different carriers across bands on speech intelligibility in cochlear implant simulation,” ARO Abstracts 27, 29.

Zurek, P.M. and Delhorne, L.A. (1987). "Consonant reception in noise by listeners with mild and moderate hearing impairment," J. Acoust. Soc. Am., 82, 1548-1559.