By Brad Ingrao

Hearing aids and cochlear implants generally work very well in quiet settings when the sound source is relatively close (within five or six feet). But when the things we listen to are farther away or the acoustics of the room are less than ideal, we hear and understand less, and must exert much more effort.

This article looks at a group of technologies designed to overcome the limitations of ear-level devices in less than ideal settings. Before we jump into the tech talk, let's briefly review the reasons why these settings are more difficult to hear in.

21st Century Connectivity in Hearing Devices

Acoustics: The Physics of Sound

Our brain is able to analyze very complex sounds quickly and accurately, assuming it gets good information from the ears. The fact that you are reading this magazine probably means that even under the best circumstances, what your ears send to your brain is less than perfect, which makes these acoustic considerations even more important.

Sound has several attributes that are measured and become perceptions in the brain.

***Intensity*—**This measures how much energy a sound has. In a laboratory, we measure this in decibels sound pressure level (dB SPL), but our brain perceives it as loudness. People with sensorineural hearing loss need more intensity to just barely hear some sounds, but also have a distorted perception of loudness changes called recruitment. Hearing aids address both of these.

***Frequency*—**This measures the number of times the sound vibrates per second. We measure it as Hertz (Hz) or cycles per second (cps) and perceive it as pitch. Sensorineural hearing loss also distorts our ability to accurately determine pitch. While hearing aids can't fix this, they can help to a limited degree.

***Temporal Pattern*—**This describes how the intensity changes over time. We perceive this as the rhythm of the sound. Hearing aids and cochlear implants use this information to try to decide which sounds are speech and which sounds are noise.

***Signal-to-Noise Ratio (SNR)*—**This is a measure of the intensity of the desired signal compared to the intensity of all other sounds in the environment. We report this in decibels in either a positive or negative direction (e.g., +10 dB SNR means the speech is 10 dB more intense than the noise). We perceive this as listening effort.

***Reverberation*—**This is a measure of how much "echo" a room has. It is affected by the size and shape of the room as well as the surfaces in it. A small room with carpet, low ceiling and drapes will be much less reverberant than a large room with oak floors, high ceilings and large picture windows. We measure how long it takes a calibrated sound to fade away a certain amount. It is reported as "RT60" and typically has values between 0.3 and 2.0 seconds. The higher the RT60, the more difficult it is to hear and understand speech.

***Critical Distance*—**This is distance from a microphone where background noise mixes with desired signal to a degree that the SNR drops to a level where listening effort increases. It is affected by SNR and RT60.

If everything we needed to hear and understand arrived at our hearing device microphones with a +24 dB SNR in a room with a very low RT60, we'd be all set. The reality is that this almost never happens. This means we need some additional technology to help level the playing field.

We've known for years that people with sensorineural hearing loss are negatively affected by distance, poor SNR and reverberation to a much greater degree than are people with normal hearing. We also know that even the best ear-level hearing devices are at the mercy of these acoustical phenomena.

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Capture, Carry, Couple: The Foundation of Connectivity

Capture

If we reduce the distance between the sounds we want to hear and our hearing device microphones, we dramatically improve SNR and reduce the negative effects of reverberation. The ideal distance is three to six inches. That's a great ideal, but quite difficult to implement.

Just imagine watching TV with your ear three inches from the speaker or asking your boss if you can sit on their lap during your annual review. Kidding aside, let's look at some practical ways to achieve an optimal sound capture.

External Microphones

Depending on the design of your hearing aid or cochlear implant speech processor, you might be able to plug a microphone directly into it and hold it close to the sound source, much like a news reporter. With the increasing trend to make all hearing devices smaller, this is, unfortunately less and less common. Even if you don't have this capability, don't fret, these microphones can be used with other devices that we'll discuss next.

Direct Audio Input Connection

When the sound source of interest is a TV, MP3 player, or other electronic sound system, we can connect a wire between this source and a device that transmits the signal to our hearing devices or a receiver as described in the next section.

Both of these techniques capture the desired signal at an optimal SNR and defeat the negative effects of both distance and reverberation.

Carry

Once the signal of interest has been captured at an ideal SNR, it needs to be delivered to your hearing devices without losing quality. There are several ways to achieve this.

Magnetic Inductance

If your hearing devices have telecoils, the captured sound information can be fed into an amplifier and then sent into a loop of wire. This wire then creates an electromagnetic field that contains all the sound information. Any telecoil-equipped hearing devices inside the loop receive the signal essentially the same as it was captured. These loops can be worn around your neck, placed in a small pad under your easy chair cushion or even surround an entire room, house or car. Audio loops have been installed in theaters, auditoriums, airports, grocery store checkouts and train station ticket counters.

For more information about loops and how to get more in your area, visit **http://loopamerica.org**.

To learn about "Get in the Hearing Loop," a joint project of the Hearing Loss Association of America and

continued on page 26

Connectivity *cont. from page 25*

the American Academy of Audiology, visit **www.hearingloss.org**.

Infrared

Infrared is an invisible light wave that carries information across relatively long distances as long as the transmitter (also called an emitter) and receiver are within line-of-sight of each other. There are no hearing devices with Infrared receivers in them, so using this technology requires some kind of receiver. Infrared systems are quite common in movie and stage theaters and often come with either headphones or neck loops. Infrared is also used in dedicated TV listening systems that embed the receiver in a pair of earphones.

FM

FM, or Frequency Modulation is exactly the same technology used in your home or car radio. FM systems for people with hearing loss operate on a specific frequency band protected by the FCC (usually 216-217 MHz—megahertz). FM systems have two components. Transmitters often include one or more microphones and a way to make a direct audio input connection (via a "patch cord") to sound sources. The second component of FM systems is the receiver. These can be body-worn (about the size of a deck of playing cards) or connected to your ear-level hearing devices.

Bluetooth

Bluetooth is a relatively new addition to the hearing device-compatible group of carry technologies. Bluetooth is an FM signal operating at 2.4 GHz—gigahertz that works by creating a secure connection between two devices. This "pairing" ensures that a given transmitter will only talk to the receiver it is designed to talk to. Bluetooth is used widely with cell phones allowing people to listen, talk and control their phones from their hands-free headsets. Bluetooth has a range of between 30 and 50 feet in most settings.

Because of size and power requirements, Bluetooth cannot yet be directly installed in ear-level hearing devices. Instead, "Bluetooth compatible" hearing devices require a "gateway device" which is usually worn around the neck or in a shirt pocket. Some of these gateways also allow for direct audio input. At the time of the writing of this article, none of these gateways includes a telecoil, but that may be offered in the future. Hearing aid manufacturers offer proprietary gateways for their devices, but universal gateways are available with a variety of coupling options, usually a neck loop or earphones.

Dedicated Wireless Systems

Two hearing aid manufacturers have decided to include wireless receivers directly in their devices. One uses 900 MHz, the other 2.4 GHz. They sell proprietary "streamers" for use with their devices. While this may seem like a great idea, it precludes the use of more universal solutions. If your hearing care professional suggests one of these systems, be sure to get a model with at least a telecoil so you can take advantage of at least one non-proprietary connectivity option.

Couple

The final piece of the connectivity puzzle is coupling the captured and carried signal to your hearing devices.

Telecoil

As discussed earlier, a telecoil allows for the greatest flexibility in coupling. Using a telecoil you can couple to a room loop or an FM, Infrared or Bluetooth receiver via a neck loop or silhouette inductor (a small, flat "loop" that sits next to your hearing device). You can even plug a neck loop into your MP3 player.

Audio Shoe/Boot

Many Behind-The-Ear (BTE) hearing aids and cochlear implant speech processors allow you to connect a "boot" that can connect to an audio cable or FM receiver. You many need your hearing care professional to set up a special "DAI" (direct audio input) program to optimize the sound quality of this connection.

Near Field Magnetic Inductance (NFMI)

NFMI is the new kid on the coupling block. This wireless technology is a digital signal with a very short range (about 20 inches) that is "locked" between specific devices. NFMI is used to couple Bluetooth signals from proprietary gateway devices to hearing aids as well as to allow some hearing aids to communicate with each other to synchronize volume and program changes, and to assist in noise reduction attempts.

A Few Examples

Now that we have a good handle on all the pieces of the connectivity puzzle, let's look at a few common ways these technologies can help you hear and better understand in challenging settings.

Watching Television

TV is an important part of many of our lives. We get news, weather, entertainment and important safety information from a box that is almost always in a non-ideal setting. Most of our living rooms are large rectangles with at least some reflective surfaces. We put the TV at a wall, and put our sofa 10 or more feet away. We now have distance and reverberation working against us. Turning up the volume makes it worse in many cases.

If we attach a loop, or transmitter (FM, Infrared or Bluetooth) to the audio output of the TV, the sound can be delivered to our hearing devices loud, clear and without all the degradation of the room acoustics.

Telephone

If our phone is Bluetooth compatible, we can pair it to a Bluetooth gateway. Then, when a call comes in, the gateway transmits the ring to our hearing aids via NFMI. We answer the call by pressing a button on the gateway, and hear the caller in both ears, which almost always makes it easier to understand. These gateways have a microphone, so we can take a call "hands free." To hang up the call, we simply press the same button on the gateway and disconnect.

Dinner and a Movie

Dinner out at your favorite restaurant can be a challenge to say the least. Attaching a remote microphone to your date's shirt collar (hardwired, Bluetooth or FM) and coupling to your hearing devices via DAI or your telecoil allows their voice to stand tall apart from the background noise (high positive SNR). When the server comes to describe the specials, your date can hand them the mic and you hear "Duck l'Orange" loud and clear.

After a great meal, you and your sweetie head to the theater. Thanks to the efforts of local and HLAA Chapters and HLAA state organizations, they installed an audio loop last year. You take your seats in row "M" and switch your hearing devices to "T+M" allowing you to hear the actors on stage just as well as your date whispering sweet nothings into your ear.

The Whole Ball of Wax (Integrated Systems)

At 7 a.m. your super-loud, strobe-equipped alarm clock wakes you from a restful sleep. After you shower and dress for work, you slip your hearing devices in your ears and your gateway around your neck. While making breakfast, you listen to the morning news streamed from the TV adapter to your gateway, then into your hearing aids via NFMI. The house phone rings, and with a press of a button, the gateway mutes the TV and connects the call. As you disconnect the call, the TV un-mutes and you finish the news.

You hop in the car, switch your hearing aids to T+M and turn on the radio, sending your favorite music through the car loop. You pick up your carpool partner, turn off the radio, and hand them the Bluetooth microphone that connects to your gateway. You hear them without road noise, but still hear the ambulance approaching on your left.

At work, you grab your FM system and head to the training session scheduled for the morning. You hand the mic and transmitter to the person leading the training, plug your receiver into your gateway with a patch cord and settle in to learn about the next widget you'll be selling.

Wrapping Up

We can't change the laws of physics and how they work against those of us with hearing loss. We can, however, fight back using a few fairly simple tools. All these advanced technologies are fantastic, and as a die-hard geek, I love working with them, but writing this article reminds me of a story of good old fashioned human connectivity.

I met the great Dr. Mark Ross at the HLAA Convention 2007 in Phoenix, Arizona. I saw him in a ballroom full of folks all using extension microphones and FM systems to overcome poor acoustics and background noise (a hundred plus people talking and a band). As I approached Dr. Ross, he put up his index finger and said, "Hang on a second." He then led me out of the room, stood in the foyer and listened. He shook his head and we moved a few feet over to a smaller alcove. He listened again, and then said, "That's better. Now we can talk like gentlemen. I'm Mark Ross, nice to meet you."

Even though we have all this technology at our disposal, if you can control the physical surrounding, you will always hear better. It might mean asking for a different table at the restaurant or simply stepping away from the noise, but you and your communication partners deserve the best possible opportunity to make each human connection loud, clear and comfortable.

The fact that you're reading this article could mean that your ears may be somewhat less than accurate.

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Brad Ingrao, Au.D., has been an audiologist for 20 years, but surrounded by hearing loss all of his life. His uncle, son and most of his friends have a hearing loss. He was an early adopter of the Internet, has contributed to several hearing listservs for more than 15 years, as well as lecturing and publishing internationally on hearing loss, hearing aids, earmolds and assistive technology. A long-time supporter of HLAA, he has written for Hearing Loss Magazine, *given webinars and presented at HLAA annual conventions. Dr. Ingrao is currently in private practice in St. Petersburg and Largo, Florida and may be reached via e-mail at* doc@e-audiology.net.

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