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I want to thank Dr. Mark Ross for his tireless efforts over the past 18 years writing about research and technology developments in technology for *Hearing Loss Magazine*. His words have been ones to live by professionally and personally since before I completed my bachelor's degree in communication disorders. I have been extremely fortunate to have him as a friend and mentor since we met at the HLAA Convention in Phoenix in 1997. I am honored and humbled to have been asked by HLAA and the RERC on Hearing Enhancement to write on research and technology following Mark's very well-deserved retirement.
—Brad Ingraio, Au.D.

What Exactly is a Hearing Aid Anyway?

The first hearing aids, like those described in Mark Ross' article "From a Body Hearing Aid to Cochlear Implant" (*Hearing Loss Magazine*, July/August 2011) were little more than miniature public address systems. The amplifiers were fairly simple and had a limited frequency (pitch) range. They contained basic tone controls, but often over- or under-amplified areas of hearing loss. In order to hear well, people with hearing loss needed to manually adjust the volume control to try to match the sounds environment. They made life markedly better for people with hearing loss, but were far from ideal.

Modern digital hearing aids are built around tiny computer chips called DSPs (Digital Sound Processors). These, in combination with improved microphones and speakers (sometimes called receivers) allow hearing aids to amplify a wider range of pitches with far less distortion than their predecessors. Using computer software, they can be very finely tuned to the individual's hearing loss and even include memories, analyzers and sub-miniature radio stations. They automatically measure the surroundings and adjust volume and, in some cases, microphone behavior, many

Decibels and Dollars

By Brad Ingrao

A Look at Hearing Aid Features Across Price Points

times per second. All of this technology comes at a price, and anyone who has researched hearing aids knows that the range of prices is large and the choices numerous.

Why an Article on Hearing Aid Features and Price?

In the July/August 2011 issue of *Hearing Loss Magazine*, HLAA Executive Director Brenda Battat described an HLAA initiative to make hearing aids more affordable. An important part of the transparency she calls for in her editorial is a better understanding of the features available in hearing aids at different price points. When we spoke at the recent HLAA Convention in June, she asked me to address this, so here goes. By the way, the second part of Brenda's transparency concern is addressed in the Stephanie Sjoblad, Au.D. and Barbara Winslow Warren, Au.D. article "Unbundling: A Way to Make Hearing Aids More Affordable?" on page 18 of this issue of *Hearing Loss Magazine*.

This article will define the basic functions in hearing aids that address these common needs as well as providing a few of the more common brand names for these features. Following that, we will look at the current offerings by the top six manufacturers and give you an idea of what features you should expect in several price categories.

Channels

The human inner ear, or cochlea, contains tens of thousands of tiny sensory hair cells that convert sound waves into nerve impulses that our brains perceive as sound. These are organized like a piano keyboard with each "key" being a critical band of hair cells. When we develop hearing

loss, some of the keys become less effective and sound softer and less distinct in pitch. Hearing aids attempt to compensate for this by adding more volume. If the added volume is provided by pressing hard on the weak keys with trained and skilled fingers, the correction will be precise and the overall sounds will be mostly satisfactory. If, however, the volume is added by pounding on the keys with an open hand, the result is imprecise, noisy and generally unpleasant.

In hearing aids, the DSP's amplifier is divided into several specific areas of pitch (frequency), each of which can be adjusted independently. One would think that the more the better, which is true to a certain extent. More channels do assist with some automatic features like feedback reduction (see below for more on that), but clinical research doesn't really bear out the need for more than five or six channels. The location of these channels relative to your hearing loss is more important than the absolute number.

Compression

Since the mid-1980s, hearing aids have attempted to correct the distortion of loudness perception inherent in sensorineural hearing loss (recruitment) by adding more amplification (gain) for soft sounds and less for loud sounds. The most effective form of this is called Wide Dynamic Range Compression (WDRC). Nearly all hearing aids today have at least two WDRC compressors in each channel for speech level sounds and one to control the maximum loudness of the hearing aid. Depending on your hearing loss, having more of these compression controls might

allow you to hear more sounds more comfortably and accurately. As with channels, some hearing aids use these compression circuits to assist with noise and feedback reduction.

Multiple Memories

Most of us don't live only in one sound environment. As "smart" as current hearing aids are, they can't predict everything. In addition, certain special situations, such as listening in a hearing loop, on the phone or with an FM system, require very specific hearing aid settings. Most hearing aids allow the audiologist or hearing aid provider to assign these settings to memories that can be accessed with ear level or remote controls.

"Wireless Connectivity"

The newest trend in hearing aids is to use a very short range wireless radio called Near Field Magnetic Induction (NFMI). This is not the same as the traditional magnetic inductance used by the telecoil. Hearing aids use NFMI to share information between hearing aids, or to send and receive information with a gateway device. The ear-to-ear NFMI can be used to make volume and program changes happen in both ears with a single sided adjustment or to assist with directional microphone or noise reduction settings. NFMI to and from gateway devices allow the hearing aids to interface with Bluetooth and 900 MHz telephone and audio devices.

Addressing Feedback

At their very basic core, hearing aids are miniature public address systems. Just like the PA at a county fair, if the microphone and speakers get

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too close, the amplified sound loops through the system again and again until you hear a high pitched squeal. In hearing aids, this occurs when the sounds delivered into the ear escape, usually through a vent, and then re-enter the microphone.

In the old days, we fixed feedback by reducing the size of the vent, reducing the output of the hearing aid or by adding acoustic filters to the sound pathway (earmold, speaker tube, etc.) until the feedback stopped. Today, most manufacturers include a feedback test in their hearing aid fitting software to “search and destroy” feedback.

Currently, hearing aids with automatic feedback management use one of two approaches to manage feedback:

Notch filtering systems measure the specific pitch where feedback occurs, then the DSP reduces the amplification at that frequency only. This leaves the overall amplification intact and just removes the very narrow “notch” in pitch that is causing the feedback.

The other is a *phase reversal system*. Much like noise cancelling headphones seen on airplanes, phase reversal systems detect feedback and then tell the hearing aid to produce a sound exactly opposite in phase, which cancels the feedback out. This takes a second or two, so there will still be some feedback, but they do a good job. The more channels in a hearing aid, the more precise these automatic feedback systems can be.

Hearing Better in Noise

In 20 years of practicing audiology, I have almost never encountered a person whose hearing aids were unable to help them hear well in a small, quiet room with carpet, drapes or no air conditioning. On the other hand, almost all of my hearing aid patients complain that no matter how much they spent on their hearing aids, they still struggle in noisy and reverberant

rooms. People with hearing loss need speech to be much louder than other sounds in order to understand well. A high signal-to-noise ratio is the best way to deliver improved speech understanding in less than ideal settings.

While nearly all hearing aids have some kind of noise reduction the best evidence available shows that directional microphones provide the best signal-to-noise ratio for ear level devices. The ideal solution in noise is a remote microphone connected to the hearing aid (Hearing Assistive Technology), but that is a topic for another time.

Nearly all current behind-the-ear hearing aids and larger in-the-ear hearing aids include or can be made to include directional microphones. The most notable difference across different price points is how different hearing aids control the microphones in an attempt to deliver optimal signal-to-noise ratio, and therefore, better understanding in noise and reverberation.

Control vs. Convenience

One of the buzz words in hearing aids today is “automatic.” Some people can do very well with a fully automatic hearing aid assuming they spend most of their time listening to one or two kinds of sound in the same setting. The more common reality is that people with hearing loss, especially well informed, proactive people like HLAA members, are out and about listening and living in many complex environments. They need to be able to tell their hearing aids how to behave rather than the other way around.

Let's Go Shopping!

Hearing aid pricing is a bit tricky to discuss in a national magazine since prices are somewhat indexed to the local cost of living. A recent review of available products from GN ReSound, Oticon, Phonak, Siemens, Starkey and Widex found at least one product in the following price points with these features:

Entry Level (Under \$1,000 per hearing aid)

- Wide Dynamic Range Compression in at least four channels and two loudness levels
- Directional Microphone with basic automatic operation
- At least two memories (programs)
- Telecoil (Behind-the-Ear and larger In-The-Ear models)
- Notch filtering feedback management

Mid Range (\$1,000 to \$2,500 per hearing aid)

- Wide Dynamic Range Compression in at least four channels and two loudness levels
- Directional Microphone with basic automatic operation
- At least four memories (programs)
- Telecoil (Behind-the-Ear models)
- NFMI connectivity for volume, program control and Bluetooth gateway
- Dynamic feedback management
- Noise reduction

Advanced (\$2,500 to \$3,000 per hearing aid)

- Wide Dynamic Range Compression in at least six channels and two loudness levels
- Directional Microphone with two or three modes of operation
- At least four memories (programs)
- Telecoil (Behind-the-Ear models) with selectable orientation
- NFMI connectivity for volume, program control and Bluetooth gateway
- NFMI for directional microphone adjustment
- Dynamic feedback management
- Noise reduction

Premium (over \$3,000 per hearing aid)

- Wide Dynamic Range Compression in at least eight channels and three loudness levels
- Directional Microphone with two or three modes of operation
- At least four memories (programs)
- Telecoil (Behind-the-Ear models) with selectable orientation

- NFMI connectivity for volume, program control and Bluetooth gateway
- NFMI for directional microphone adjustment and noise reduction
- Dynamic feedback management

So, What's the Best Hearing Aid?

As Mark Ross has written many times, finding your ideal hearing aid solution isn't about the product, but rather the process. The hearing aid and its features are only as good as they are appropriate for your needs.

Further, the person fitting them must have the skill to make the hearing aid work for you, and have a personality that is compatible with you and your needs. Being an informed and critical consumer allows you to always get the best bang for your buck. ■■■

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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 and 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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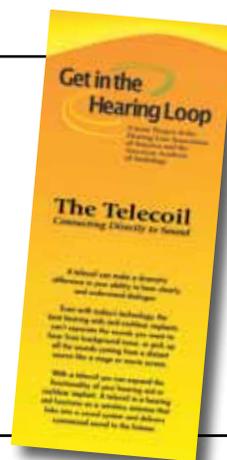
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