

You all know the story of Al and Tom. If I remember correctly, it all happened back on June 2, 1875. Al Bell, known for his work with the deaf and the inventor of the Ear Phonograph in 1874, was working in his lab with his buddy Tom Watson on a new device that used tuned reeds. When the reed at the receiver station appeared stuck, Tom plucked it. Al, located in the transmission room, heard an electrically transmitted pitch and overtones emitted from the reed at his station. Within a few months, the basic specifications for the telephone had been written. This was the beginning of the link between hearing instruments and telephones.

In the early 1900s, the first electrically powered hearing aid was introduced, using a carbon granule microphone and a carbon amplifier—basically a telephone system in a box. As hearing aids advanced, the need to use hearing aids with telephones became obvious, and we have Sam Lybarger to thank for introducing the first vacuum tube hearing aid with a magnetic microphone and an inductive telephone pickup in 1947. Over the years, the telecoil power has been boosted, the sensitivity has been increased, and the size has been reduced, making it a popular option for most styles of hearing aids.

All seemed to be going along fairly well until about 6 years ago when we started hearing stories of problems from hearing aid users in Europe who were using the new digital cell phones. In 1996, digital cell phones were introduced in the U.S., and the problem became very apparent. Since that time, a lot of people in the hearing aid industry have worked hard to improve the compatibility between digital phones and hearing aids.

One of the most noted is this month's Page Ten guest author.

Mead C.

Killion, PhD, is the president of Etymotic Research, Inc., and adjunct professor at Northwestern University. Dr. Killion is a man of many talents.

His older friends know him as a TV repairman, his cronies in Uptown know him as a musician, and a farmer outside of Duluth believes he's a marathon runner. Most of us know him for his many patents, innovative products, publications, informative and entertaining instructional seminars, and of course, the K-AMP.

In addition to all his other activities, Mead has devoted countless hours of work to the hearing aid/digital cell phone problem over the past several years. And, as he will tell you in this excellent summary article, through the efforts of many, the problem is nearly solved. Al and Tom would be pleased.



Digital cell phones and hearing aids: The problem is mostly solved

By Mead C. Killion

1 What is the problem?

When held up against a hearing aid, digital cellular telephones—which we will call digital cell phones—create a buzz. With many hearing aids—especially older ones—the buzz can be so loud that it makes speech coming over the telephone impossible to understand. In extreme cases, the speech can't even be heard.

2 I thought everything digital was wonderful. Why does a digital cell phone cause so much trouble?

The digital phone appears to a hearing aid the way a road with corrugations in the pavement appears to a car: Digital cell phones turn their rf (radio frequency) transmitter on and off 50 or 220 times a second, creating the electrical equivalent of a washboard road.

3 Does this problem occur with analog cell phones?

No. The analog cell phone transmitter goes on once at the beginning of the call and stays on until you finish the conversation. It is like driving over a single bump in the road; you may not even notice it.

4 Does the buzz occur when the hearing aid is in the microphone mode or the telecoil mode?

Both, although the telecoil is usually worse because the digital pulses cause both rf and magnetic interference. As we'll see later, the hearing aid designer can solve the rf interference. The magnetic interference comes in just like a signal. To my knowledge, the cell phone manufacturers have not been able to eliminate their strong magnetic buzz.

5 Does the cell phone antenna design affect the interference problem?

Yes, antennae that stick out away from the head seem to cause a little less interference, but the reduction appears to be only about 5 dB in the level of the buzz. After all, the primary purpose of the cell phone transmitter is to send a powerful enough signal to reach several miles to the nearest cell. It is almost impossible to make a dramatic reduction in the effect of the rf striking the hearing aid without weakening the signal being transmitted through space. (Actually, Etymotic Research has a patent on a method for achieving this result. As far as is known, the method is not being used.)

6 When did the problem first appear?

It appeared when cell phone manufacturers introduced the digital GSM system in Europe.¹ (In case you're curious, GSM is an abbreviation for Global System for Mobile communication.)

I discovered for myself how powerful the buzz could be in 1994 when I bought a European GSM digital cell phone and tried to use it in my hotel room. When I started the call, a loud buzz suddenly came from across the room where a television had been playing quietly. The buzz grew even louder as I approached the TV. I had to turn the TV off to hear the cell phone. No wonder holding such a powerful rf buzz source tightly against a hearing aid causes problems!

7 Didn't the European cell phone manufacturers know that such a powerful buzz source would cause a problem with hearing aids?

Of course; several studies showed that it would be impossible to use the new GSM cell phones with most existing hearing aids. European cell phone manufacturers took the position that hearing aid wearers shouldn't buy cell phones!

8 What happened in the U.S.?

Up until 1996, hearing aid wearers could use cell phones because U.S. cell phones were all analog (the type that doesn't interfere with the operation of hearing aids). In 1996, however, Sprint introduced digital phones into the Washington, DC, area. Some members of the consumer organization SHHH (Selp Help for Hard of Hearing People) purchased the new digital cell phones and reported that they couldn't use their hearing aids with them. In some cases, even standing near someone else using a digital cell phone caused a loud buzz in their hearing aid.

Led by Donna Sorkin, then executive director of SHHH and now executive director of the Alexander Graham Bell Association for the Deaf and Hard of Hearing, and Brenda Battat, now acting executive director of SHHH, members of SHHH and A.G. Bell mounted a campaign to get things changed. (The SHHH website, www.shhh.org/NewWeb/Advocacy/request.html, provides more information on this and other advocacy issues.)

9 Why didn't the cell phone manufacturers simply say "buzz off," as they did in Europe?

Because in the U.S., the Americans with Disabilities Act requires that disabled people have equal access to services. Under the intense pressure mounted by the consumer groups, the members of Congress who passed the act put pressure on the Federal Communications Commission (FCC) to fix the problem it had caused by allowing digital cell phones—well known to be incompatible with existing hearing aids—into the United States.

Since all the cell phone ads claimed that digital cell phones were the best (which actually isn't true for sound quality),

Donna Sorkin and others argued, that according to the law, digital cell phones must be made compatible with hearing aids.

10 What happened?

Well, first you should know that FCC obtains some \$10 billion each time it auctions off a band of cell phone frequencies. It was thus most encouraging when, in 1996, FCC chairman Reed Hundt promptly called a summit meeting in Washington, DC, where he said "solve it" to the several hundred representatives of cell phone companies and hearing aid companies who attended. At that meeting, I played a videotape (made with the help of the Chicago area Ameritech telephone engineers) demonstrating just how thoroughly the buzz could mask conversation.

11 Why did you make that videotape?

Donna Sorkin had asked me to be a "consumer's representative" at the joint cell phone/hearing aid industries meetings. Most of the representatives and lawyers from the cell phone companies had never heard the buzz themselves, so it seemed like a good idea to provide a demonstration.

12 What happened then?

Beginning in 1996, several meetings ensued, with over 100 engineers and lawyers in attendance at the initial meetings. Groups of 30 to 50 engineers, lawyers, and consumer advocates discussed possible solutions to the various aspects of the problem: One of those groups specifically addressed the telecoil problem, for example.

We started out assuming that cell phones would meet hearing aids halfway, each solving half the problem. It didn't happen. Most cell phones don't produce much less of an rf buzz than they did in 1996.

13 After all this work, has the problem been solved?

Yes, at least for operation of the hearing aid in microphone mode. Our heroes, the hearing aid engineers, solved the problem for those using the hearing aid in microphone mode by designing hearing aids that were highly resistant to rf interfer-

ence. The problem was simplified when Knowles Electronics and Microtronics introduced microphones that were themselves almost completely immune. Some hearing aid circuits (such as, dare I mention it, the K-AMP circuit) were already immune; others were later designed to be immune.

The combination of the microphones and circuits and careful wiring produced hearing aids that can be worn against a digital cell phone with little or no interference.

14 I'm sure our readers would like you to explain the engineering details.

Gladly. In the case of the microphone, a filter at the microphone terminals keeps the rf out of the microphone pre-amplifier, where it is otherwise converted into a strong buzz. In the case of the circuit, a variety of design tricks can be used. A well-balanced input circuit, for example, can reject the buzz by opposite-phase cancellation.

The toughest problem in custom hearing aids is to wire all these components together without effectively creating an antenna that can deliver more rf to the microphone or amplifier circuit than even well-designed components can handle.

15 If digital cell phones cause buzz problems, how about digital hearing aids?

Digital hearing aids can be designed to have just as excellent immunity in the microphone mode as analog aids. However, neither will have good immunity in the telecoil setting until a digital cell phone is designed with drastically reduced magnetic buzz output. That may not be practical, because of the large current pulses required by the rf output stage.

On the other hand, anyone willing to use a headset—leaving the rf pulses down on the belt with the cell phone—can have excellent telecoil compatibility. Suitable devices are becoming available now, and many non-hearing-impaired young executives use them to look cool in airports and the like.

16 Is buzz immunity better with BTE, ITE, ITC, or CIC hearing aids?

All of them can be designed to be immune. The BTE is a real challenge because the wires are longer and the circuit compo-

nents larger, creating the potential for more rf pickup. As mentioned above, custom ITEs create difficulties because each has a different wiring.

When digital cell phones were introduced, most existing BTE and ITE aids showed a large interference problem. (After all, no one told the hearing aid designers they would soon be facing a strong rf buzz source 1/4 inch away!) Some CIC aids, however, were relatively buzz-free. The CIC instrument is the easiest to immunize because all components are small and the wires are short.

17 Is there some standard immunity rating that will guarantee that hearing aids will work with any digital cell phone?

Yes, there now is. Although most of the 100 cell phone and hearing aid engineers and lawyers who attended the first meetings drifted away after the first few meetings, a few hardy souls have been meeting regularly over the last 4 years to produce a standard method of testing hearing aids and cell phones. The resulting ANSI C63.19 standard will make it possible for hearing aid companies whose designs are usable with digital cell phones to make that claim.²

18 Which heroes worked on that standard?

Chief among them were Tom Victorian of Starkey Laboratories and Steve Berger of the Siemens U.S. cell phone operation, who were co-chairmen of the C63 draft standards committee. They spent an enormous amount of their own time trying to pull all the data together and write an acceptable standard in a very complicated area.

Hearing aid engineers Marco Condiago, Mike Sasha, Mario Augustyniak, Harry Teder, Elmer Carlson, Tom Scheller, and Horst Arndt made substantial contributions. Similarly, cell phone engineers Paul Moller and Querno Balzano of Motorola provided a great deal of help with cell phone rf measurements, test methods, and general understanding of the problem, along with Ed Bronaugh, Skip Bryan, Mohamed El-Rayes, Ron Johnsen, Steve Hausworth, and Scott Kelly. Marlene Skopec of the Food and Drug Administration and Dave Means of the FCC provided excellent counsel and criticism as we went along.

There was also research at the university level. Harry Levitt at the City University of New York Graduate School and Judy Harkins of Gallaudet made extensive measurements of the signal-to-buzz ratio required for acceptable conversations. King Chung and I independently reached very similar conclusions in experiments at Northwestern University.³

A group at the University of Oklahoma was contracted to put it all together, taking our cell phone and hearing aid measurements made in accordance with the draft standard, and trying out the combinations on real people. The results were less satisfying than we all hoped because of the combined error of the large number of measurements required, but they clearly confirmed the basic conclusion: A hearing aid that should be acceptable based on the standard measurement can be reasonably expected to be buzz-free.

19 So when I fit my next pair of hearing aids, how will I know if they will work with digital cell phones?

The simplest check is to try the hearing aid with a digital cell phone! Even better is to have the patient bring his or her own cell phone to your clinic on the day the hearing aids are fitted.⁴

20 What do we have for all that standards effort?

The new standard will finally permit hearing aid manufacturers to legitimately claim that a hearing aid passing the limits will work fine with nearly any digital cell phone, and especially a cell phone that also passes the cell phone limits in the standard.

Those same hearing aids will almost certainly be immune to future rf interference from things like Blue Tooth, the highly touted method of eliminating all external wires in computer systems (except for the 110-volt plugs), providing hands-free cell phone operation, controlling the temperature in your home, and making wireless earphones possible. Since more rather than less rf interference can be expected in the future, it is probably good that we faced the problem when we did.⁵

NOTES

1. There are different types of modulation technology used with digital cell phones. The original is European GSM (PCS in the U.S.), which allows eight talkers on a

channel and has a nasty 220-Hz buzz (217 Hz, to be exact). For a while, the most popular modulation scheme in the U.S. was TDMA (Time Division Multiple Access), which uses a slightly more civilized 50-Hz buzz, but allows only three talkers on a channel. The most sophisticated modulation scheme is CDMA (Code Division Multiple Access), a spread-spectrum scheme that takes the "equivalent of 136 Intel 386 processors between two talkers to keep it alive," according to one telephone engineer.

2. This standard is now finished. It took 4 years because the problem is so complicated. Also, those of us in the U.S. preferred a "dipole" method for testing, whereas the Europeans preferred the "GTEM" method. The latter takes about \$20,000 of equipment and doesn't test the hearing aid with a close-up rf source. Fortunately, a series of experiments carried out by Delta Acoustics in Denmark (and paid for by U.S. and European hearing aid companies) produced results suggesting that either type of test would pass hearing aids that would work well with digital cell phones. The final U.S. standard allows either type of measurement.

3. The answer was that 20 dB SNR was required for the 50-Hz buzz and 25 dB for the 220-Hz buzz in order for 90% of hearing-impaired subjects to judge the buzz acceptable. Note, however, that nearly half of the subjects accepted 10 dB SNR or 15 dB SNR.

4. For a complete test, you need to drive around a bit while carrying on a conversation. When you drive between "cells" (those 50-to-100-foot-tall poles with metal candles around the top), the cell system tells your digital cell phone to operate at nearly 600 mW (full power), which produces the most buzz.

5. As mentioned above,² there are two measurement methods given in the U.S. standard: a "dipole method," where an antenna driven by an rf source is positioned almost against the hearing aid (a "near field" measurement), and a "GTEM" method, where the hearing aid is located a foot or two down the length of a GTEM cell (a more or less "far field" measurement). The dipole version has four immunity categories:

- U1 30-35 dBV/m
- U2 35-40 dBV/m
- U3 40-45 dBV/m
- U4 >45 dBV/m

The GTEM version will have the same categories and limits. Any company can choose which measurement method to use.

Note: Combined with cell phone ratings, a sum of ratings of 5 or better should allow normal hearing aid use with that cell phone. (In practice, most cell phones fall in the U2 category producing <41 dBV/m.)

If a company chooses the GTEM method, then the test results should be

applicable in Europe, where it appears the IEC will approve two limits:

37.5 dBV/m (75 V/m)

for general use with digital cell phones
20 dBV/m (10 V/m)

for immunity to "bystander" problems.