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Hearing Aids and Cellular Phone Interference

Introduction

During the last decade, a lot of new potential hearing aid interference sources have been introduced onto the market. Cellular phones, burglar alarms, room surveillance systems and PC's are among the most common reasons for problems among hearing aid users.

However, without comparison digital cellular phones such as GSM (Global System for Mobile communication) are the topmost source of the problems. They produce an intermittent buzzing in the hearing aid, which can be anything from a faint background noise to a sand storm making conversations absolutely impossible.

Several factors influence the interference level, making it difficult for Hearing Healthcare Professionals to advise their clients unequivocally. Most explanations are unclear ending up in an "if it works, it works" type of conclusion.

In this issue of WIDEXPress we will explain in some detail how the cellular telephone systems work, why they produce the interference and what is being done about it. Apart from our own research, this survey also relies on research made at National Acoustical Laboratories (NAL) in Australia, by the European Hearing Instrument Manufacturers' Association (EHIMA) in Europe, and at the University of Oklahoma Center for the Study of Wireless Electromagnetic Compatibility in the USA.

Cellular telephone systems

Analogue cellular telephones (NMT450, NMT900, ÖBL-C, ETACS, AMPS) do not significantly disturb hearing aid use as they use FM (frequency modulated) radio waves. In FM systems, the signal is coded as a modulation of the carrier frequency. This means that the amplitude of the radio signal is constant.

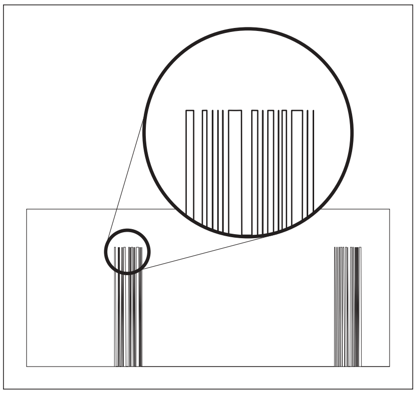

Fig. 1.: Radio signal from GSM cellular phone. 217 times a second a short burst of bits is transmitted.

Radio waves from digital cellular telephones bear much resemblance to AM signals. Time is divided into several intervals allowing several conversations to take place in one frequency band at the same time. While the base stations will normally occupy several of these intervals, the cellular phone often occupies only one. It compresses the signal into short pulses of bits, and sends one such pulse in each interval assigned to this particular conversation. The result of this transmission technique is a radio wave that varies a lot in amplitude with a repetition rate in the audible frequency range.

Digital cellular telephone systems are becoming more and more widespread while the analogue systems are not being further developed. This is due to the better performance of the digital systems. Several systems are available now as can be seen in the list, and more are likely to come.

In Europe, the most used system today is GSM. The system allows portable phones with peak ratings of 5 Watts and car-mounted phones with peak ratings of 20 Watts. In practical applications the ratings are limited to 2 Watts and 8 Watts respectively. The system itself will continuously adjust the cellular phone's transmitter power to the desired level that will ensure a smooth connection. The desired level depends on factors like: air humidity, distance to nearest base station and environment conditions (rural area, mountain area, etc.).

Many of the other digital phone systems are close derivatives of

Phone system:	Carrier Frequency:	Modulation frequency:	Used in:
GSM	900 MHz	217 Hz	Europe, Asia, Australia
DECT	1800 MHz	100 Hz	Europe
PCS-1800	1800 MHz	217 Hz	Europe, Asia, Australia
DCS-1900	1900 MHz	217 Hz	USA
TDMA (DAMPS)	800 & 1900 MHz	50 Hz	USA
CDMA	800 & 1900 MHz	Variable	USA

GSM but in some cases converted to 1800 or 1900 MHz.

DECT (Digital European Cordless Telephone system) is a new cordless local area phone system that uses digital modulation. Carriers with 250 mW peak power in the 1800 MHz range are used. This system does not utilise power control as in GSM. DECT is intended for distances up to 250 m (from the portable handset to the base station). Coverage of large areas (such as hotels and shopping centres) is possible using multiple base stations. The first DECT systems were available in 1996.

Since the output power of DECT phones is often lower than that from a GSM phone, interference will probably occur when a hearing aid user uses a DECT phone himself. However, approximately 1/3 of all business phones in the year 2004 are expected to be DECT terminals!

Interference in Hearing Aids

All semiconductors (transistors, diodes, and the like) in an electronic circuit are affected by electromagnetic fields (any radio frequency transmission carrier, AM or FM). The wires and component leads in the circuit act as antennas guiding the interfering signal to the semiconductors. Especially open telecoils are sure sources of interference, but microphone leads and other conductors are as well. Through rectification, the semiconductors will demodulate the signal, thus creating a new signal analogue to the envelope of the carrier.

FM waves in *analogue cellular phones* (NMT- 450, NMT- 900, ÖBL-C, ETACS, AMPS, etc.) which have no amplitude variations, have constant envelopes. Thus the demodulated signal is some kind of dc voltage changing the offset of the circuit only. This may be perceptible (by the hearing aid user) at the beginning and end of the phone use as “clicks”. For some non-linear hearing aids, this DC-offset may reduce gain on the hearing aid, too. However, in most cases interference from analogue cellular phones is not perceptible at all.

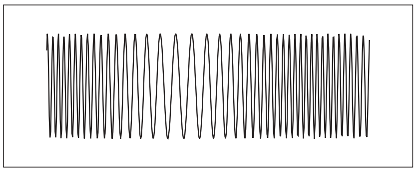

Fig. 2.: FM modulation in analogue cellular phones. The frequency of the carrier is varied according to the proper signal. The amplitude remains constant.

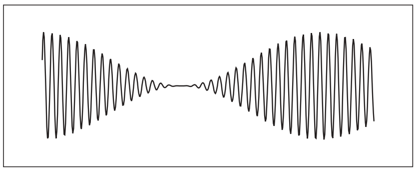

Fig. 3.: AM modulation. The carrier (fast oscillations) has its amplitude modulated with the proper signal.

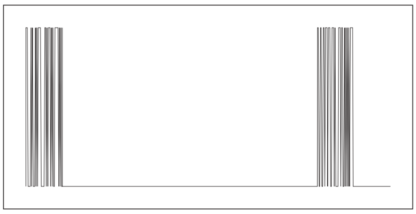

Fig. 4.: AM-like modulation from a GSM phone. Amplitude variations to the high frequency carrier.

The pulsed output from *Digital cellular phones*, like other AM radio waves, has strongly fluctuating envelopes. Demodulation in the semiconductors results in a pulse train which is audible as a “buzzing” at the output of the hearing aid. The buzzing can be heard whenever the phone is transmitting and sometimes even in the standby mode. As an example, GSM digital phones operate at a carrier frequency of 900 MHz and the pulse modulation is done at a rate of 217 Hz. Figure 5 shows the output spectrum of a conventional analogue BTE hearing aid when a GSM phone is placed next to it (field strength 70 V/m). Note the dominant output at 217 Hz and the harmonics of the pulse frequency.

Other AM signals are picked up by the hearing aid, too. As long as they are analogue, like radio waves coming from CB (Citizen Band) or short wave radio, the interference will be analogue to the actual sound signal. In this case, the hearing aid acts as a simple receiver.

How can we measure interference?

IEC has proposed (IEC 118-13) a measurement called IRIL - Input Related Interference Level. It is a relativly simple method that nevertheless allows us to measure which hearing aids are more sensitive to interference than others. If the IRIL is high, the interference is loud. If the IRIL is low, the interference is soft. Hearing aids with low IRIL specifications should be preferred by users of digital cellular phones.

An IRIL of 55 dB SPL is acceptable, according to IEC 118-13. This means that under the prescribed measurement conditions, if the buzzing sounds no louder

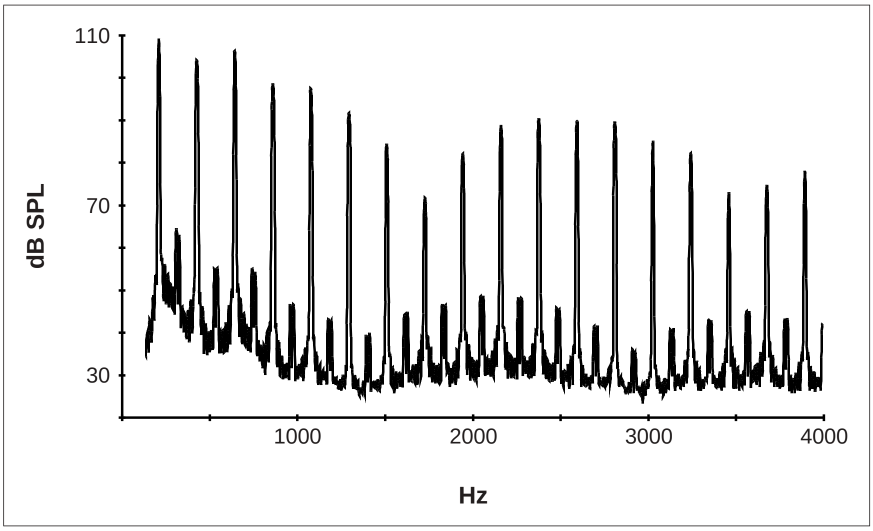

Fig. 5.: Output spectrum from a conventional analogue hearing aid without GSM protection means when a GSM phone is placed next to it. Note the dominant output at 217 Hz. The "spikes" are the harmonics of the modulation frequency.

than any sound at 55 dB SPL, then the annoyance is bearable.

This does not mean that a hearing aid is guaranteed to give lower levels of interference under all circumstances. The IRIL measurements are carried out at specific electromagnetic field strengths. If submitted to stronger interfering fields, the interference level experienced by the hearing aid user will naturally be louder. Under worst conditions, the buzzing is likely to be much louder than indicated by the IRIL figure.

The measurement requires a radio-treated measurement space just as audio measurements require sound-treated rooms or boxes.

Factors in the hearing aid affecting the amount of interference

The amount of interference varies greatly in different hearing aids. This has to do with different technologies and different electronic designs. Some of the significant factors have been identified in the NAL (1995) study:

- length and number of wires and component leads in the hearing aid
- application of electro-magnetic shielding
- shunt capacitors which attenuate the captured signal
- particular circuit techniques which reduce interference compared to the microphone signal

Shielding the hearing aid (with metal-covers or the like) and use of electronic filters at the microphone are both ways to improve the immunity. However, no method is 100% effective.

Using telecoil together with a cellular phone is a bad idea. Many hearing aid users are used to using the telecoil for phoning with their usual telephones. But the telecoil is an excellent antenna, receiving the interfering radio waves from a cellular telephone very efficiently. At the same time, the telecoil is of little use with cellular phones. The receivers in cellular phones normally have electro-magnetic emission levels that are far too weak for the telecoil in a hearing aid. Consequently, the user should much rather use their cellular telephones directly over the hearing aid microphone.

Users of ITE, ITC and CIC hearing aids seem to experience less interference than users of BTEs. Even if the BTE has the same IRIL as the ITE, it will produce a larger amount of interference. The explanation is that the user's head (including brain, skin, fluids, etc.) absorbs some of the electromagnetic energy otherwise transmitted to the hearing aid. If the hearing aid is placed deep in the ear, it gets into deeper radio-shadow.

Digital circuits will inevitably be less susceptible to interference than analogue circuits. While in digital form, the signal will only be disturbed if the interference is strong enough to confuse the bit values. Due to the binary repre-

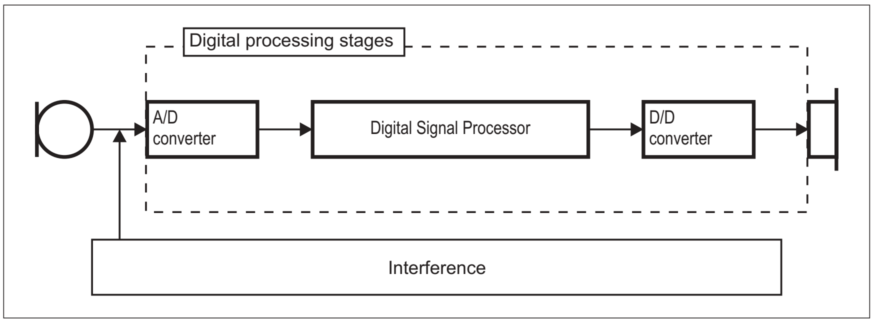

Fig.6.: Block diagram for a digital hearing aid to illustrate the source of interference.

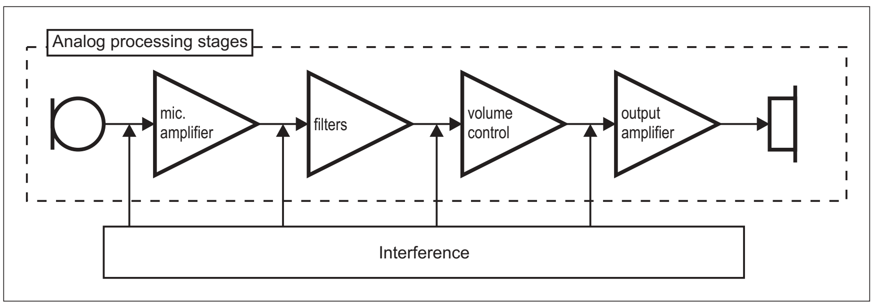

Fig.7.: Block diagram for an analogue hearing aid to illustrate the source of interference.

sentation of the bits, interfering signals must be in the same order of magnitude as the battery voltage to change the signal (that is from "1" to "0" or vice versa). In practical applications, only the microphone and the input of the A/D converter, where the signal of a digital hearing aid is still analogue, can pick up the interference.

In an analogue hearing aid, all the amplifying stages are susceptible to interference. They all process an analogue image to the signal, so any distortion or noise contribution will be present in the signal at the output. This opens more opportunities for noise to enter the hearing aid.

Factors in the telephone affecting the amount of interference

Different digital cellular phone systems cause different degrees of interference. Each of them has its own characteristics with regard to maximum power level, carrier and modulation frequencies. Often some hearing aids are more susceptible to interference from one system than from another, while the opposite may be the case with other hearing aids.

Cellular phones with "built-in" and short antennas seem to cause more interference than those with long antennas. Moving the telephone antenna away from the hearing aid decreases the interference experienced by the user. As the strength of the electromagnetic field at the hearing aid's position determines the level of interference, one way to reduce it is by moving the antenna as far away from the hearing aid as possible. Mounting the cellular telephone in a car with an antenna on the roof will eliminate interference for most hearing aid types.

More interference is experienced when a cellular phone is operating far from a base station, because more power is required from the transmitter in the cellular phone. This suggests that freedom from interference at one location does not guarantee freedom from interference at other locations. We expect this problem to decrease in the future as better coverage will demand more base stations resulting in smaller average distances between cellular phones and base stations and hence smaller power requirements for the transmission.

Hearing aid wearers may experience interference even from someone else's use of a digital cellular phone if it is close by. The amount of interference decreases as the distance between the hearing aid and the cellular phone increases. Only hearing aids with very poor interference protection are susceptible to this.

Some examples

To give an idea of the hearing aid immunity that can be accomplished, we will show how two modern hearing aid designs perform.

Figure 8 shows the output spectrum from an analogue BTE (Widex LOGO L8) which is a modern electronic design implementing several of the actions suggested by NAL. The figure can be directly compared to figure 5 as the conditions are exactly the same except for the hearing aid. Note that the interference level (at 217 Hz) has dropped from almost 110 dB SPL with the traditional BTE to about 55 dB SPL with LOGO L8.

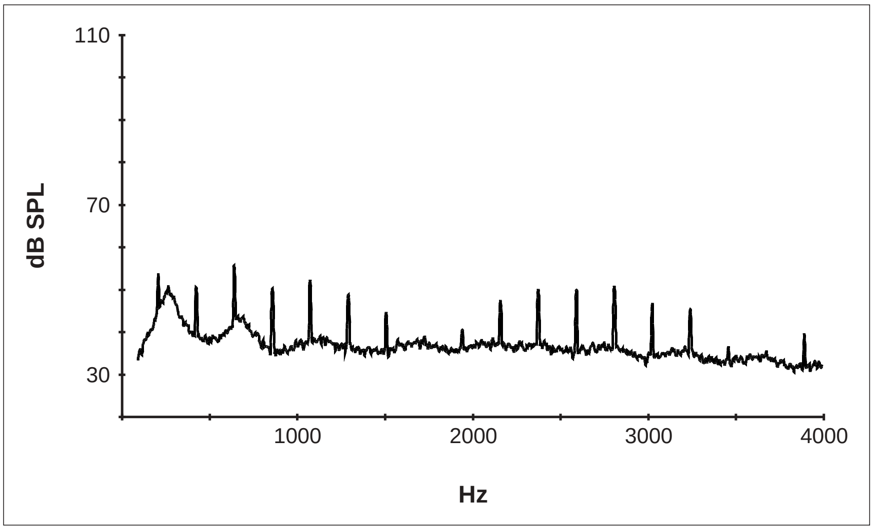

Fig. 8.: Output spectrum of the Widex LOGO hearing aid (model L8, with 2nd generation means to protect against GSM) in the same test condition as Figure 5. Note the significant decrease in output.

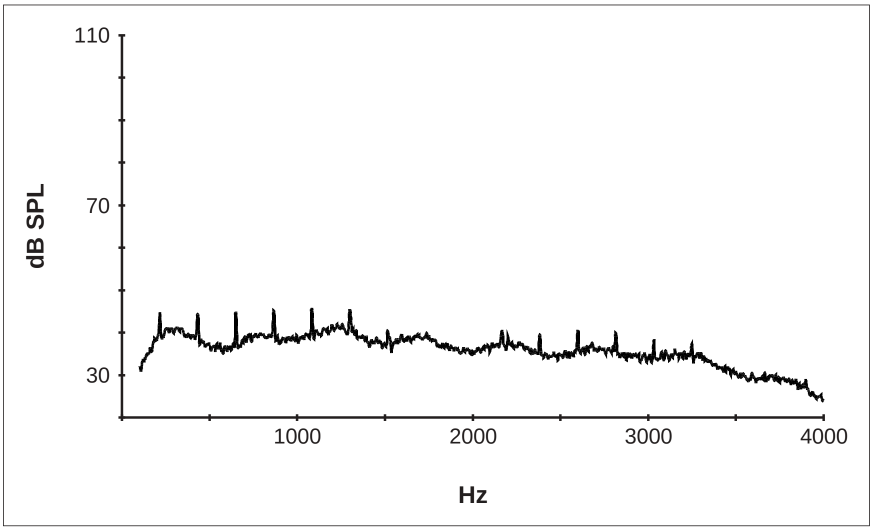

Fig. 9.: Output spectrum of the Widex SENSO hearing aid (model C8, with advanced 3rd generation GSM protection means) in the same test condition as Figure 5. Note that the output has decreased even more.

	"GSM" (800-1000 MHz)	"DECT" (1400-2000 MHz)
C8	< 25 dB SPL typical 15 dB SPL	< 32 dB SPL typical 25 dB SPL
CX	< 25 dB SPL typical 15 dB SPL	< 50 dB SPL typical 25 dB SPL

Figure 9 shows the output spectrum of the Widex SENSO digital hearing aid exposed to the same GSM phone used in Figures 5 and 8. Note that the interference signal has decreased further down to about 43 dB SPL at 217 Hz.

SENSO has the shortest possible leads between the microphone and the amplifier. The interference picked up by the microphone and the leads to it are minimised by use of special built-in filters inside the microphone and advanced filters in the A/D converter itself. If a small amount of interference signal is picked up in the digital circuits, it will have no effect on the desired signal, since the interference energy is much too small to change a "1" to a "0" or vice versa. Thus the digital circuits in SENSO have inherently high immunity against interference from cellular phones. Also the SENSO CROS/BiCROS system has built-in electromagnetic interference protection circuits.

To verify the extremely low sensitivity of SENSO, Widex employed DELTA, a Danish accredited laboratory for electromagnetic measurements, to determine IRIL performance. As can be seen in the table, the results are extremely positive.

This means that digital cellular phones can be used with SENSO hearing aids on the same ear as the hearing aid in most situations and on the opposite ear in all situations. No other hearing aid that we know of has the same high level of immunity as the SENSO. The user will sometimes experience a weak "buzz" sound during the phone call, but in most cases they will find that the level of the buzz is acceptable.

In case of interference

If a client experiences interference between a cellular telephone and their hearing aid, what is there to do?

1. Check that the telecoil is not used for cellular telephone conversations.

2. Assure that the hearing aid is a modern type with GSM protection.

3. If possible, have the client use a mounting kit in their car with the antenna on the car roof.

4. Have the client try out different types of cellular telephones to find the type with the least interference.

A fifth possibility exists in combining a portable hands-free set for the telephone with the direct audio input of the hearing aid. We have tried to obtain data from a number of manufacturers of cellular telephones to assess the viability of such a solution. So far without any luck. In case that we get any information, we'll share it with all our representatives, so that they can help and counsel their clients in the best of ways.

What about the future?

Electromagnetic interference from digital cellular phones is a major source of frustration for hearing impaired people who rely on their hearing aids while communicating through their cellular phones. With the advances in technology, it is foreseeable that more hearing impaired people will use hearing aids and digital cellular phones, if both are compatible. It is in the interest of all parties to develop meaningful solutions for people with hearing impairment. This is the reason Widex is committed to improving the immunity of our new products on a continuous basis. Also, the telecommunication industry has become aware of the problems, and they have promised to work towards solutions.

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