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August 3, 1995

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OFFICE OF SECRETARY

Building The Wireless Future™

CTIA

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Mr. William F. Caton
Secretary
Federal Communications Commission
1919 M Street, NW, Room 222
Washington, DC 20554

Re: *Ex Parte* Presentation
RM-8658

Dear Mr. Caton:

On Tuesday, August 2, 1995, the Cellular Telecommunications Industry Association ("CTIA") provided the attached documents to Mr. Jay Markley, Telecommunications Policy Analyst, Office of the Bureau Chief, Wireless Telecommunications Bureau. The documents are related to issues concerning the Petition for Rule Making to amend Section 68.4 of the Commission's Rules: Hearing Aid Compatible Telephones.

Pursuant to Section 1.1206 of the Commission's Rules, an original and one copy of this letter and the attachments are being filed with your office. If you have any questions concerning this submission, please contact the undersigned.

Sincerely,

Andrea D. Williams

Andrea D. Williams
Staff Counsel

Attachments

No. of Copies rec'd 0+1
List A B C D E

Technology Selection -- PCS Operators
(as of 8/1/95)

Operator	Technology	Base Station Provider(s)	*Estimated* Contract Amount	*Projected* Date: System On-line	Other
American Personal Communications	PCS-1900	Ericsson & Northern Telecom	$60 mil.	Late 1995	330 Base Stations
American Portable Telecommunications					
Ameritech Wireless Communications					
AT&T Wireless	TDMA (IS-136)			1997	
BellSouth Personal Communications	PCS-1900	Northern Telecom	$100+ mil.	Mid 1996	
Centennial Cellular	CDMA	AT&T	$50 mil.	Mid 1996	Note 1
Communications International Corp					
Cox Cable Communications	CDMA				
DCR Communications	PCS-1900	Ericsson	$1.0 bil.		
GCI Communications Corp.					
GO Communications	PCS-1900	Nokia	$200 mil.		Note 2
GTE Macro Communications					
North American Wireless	CDMA				
Omnipoint Corporation	Omnipoint (PCS-1900)	Northern Telecom	$100 mil.	Late 1996	
Pacific Bell Mobile Services	PCS-1900	Ericsson	$300 mil.	Early 1997	
PCS PrimeCo	CDMA				
PhillieCo					
Poka Lambro Telephone Cooperative					
Powertel PCS Partners					
South Seas Satellite Communications Corp.					

Operator	Technology	Base Station Provider(s)	*Estimated* Contract Amount	*Projected* Date: System On-line	Other
Southwestern Bell Mobile Systems					
Sprint Telecommunications Venture (WirelessCo)	CDMA			Early 1996	
U.S. AirWaves	NAMPS -- CDMA Hybrid	Motorola			
Western PCS Corporation (Western Wireless)	PCS-1900	Northern Telecom	$200 mil.		

Note 1: Centennial Cellular's contract with AT&T applies to MTA #25 -- Puerto Rico/U.S. Virgin Islands. It includes an AT&T 5ESS Switch, PCS Access Manager, and up to 100 PCS minicells.

Note 2: Go Communications also has a 10 year agreement with Northern Telecom. Additionally, GO estimates it will require 500,000 handsets.

Hearing Aid - Wireless Telephone Compatibility

A Summary of Studies

prepared by
Dr Jack J. Wojcik, P.Eng, President of Spectrum Sciences Institute
and Science & Engineering Advisor to APREL Laboratories
Ottawa, Canada

This report has been commissioned by the CTIA.

Author's Introductory Remark

Explosion-like technological progress in computing and communications has led to the fast development and rapid increase in use of personal devices. Portable Personal devices such as wireless telephones are opening new, convenient alternatives to communications, and changing our lifestyles. Availability and affordability of personal communications devices makes it possible to shift our work place from traditional offices to "distributed offices" like homes or even cars. Generally, this technological evolution (or maybe revolution) is perceived to have a positive impact on our life. However, there are potential problems that, if not correctly addressed, may have negative effects. As in the case of any new technology, potential future problems (by definition) are not known. Anticipation of future problems is sometimes possible via proactive research that applies existing knowledge and develops new knowledge for the purpose of resolving problems. With this respect, wireless personal communications are not different from any other new technology. Problems will surface. Inherent problems, related to the basic characteristic of wireless communications devices that is radiation of radio frequency (RF or EM) fields, have been reported in anecdotal descriptions of incidents and in some preliminary studies. Compatibility between hearing aids and wireless telephones, in the sense of coupling of these two devices is not possible for as long as interference problem is not resolved. Essentially all of the studies demonstrate that the problem lies not only with the sources of interference but also with the targets (the hearing aids). Joint effort of all parties concerned is required to correctly identify problems and jointly work on appropriate solutions.

Purpose

The purpose of this report is to identify issues related to compatibility of hearing aids with GSM (Global System for Mobile) phones as reported in studies. The focus of this summary is on assessment of issues and on review of proposed recommendations and solutions.

Scope and General Description of References

The scope of this study is to identify, compile, review and briefly summarize existing recent studies and publications relevant to hearing aids and GSM compatibility. This report highlights pertinent issues as reported in studies listed in Appendix "List." The references are identified by number, e.g., [x] unless an issue is of general nature agreed with in multiple studies. Author opinions are limited to remarks needed for continuity of this report.

The studies on potential interference of GSM phones with other electronic devices focus on phones operating at power levels compatible with currently deployed systems i.e. generally higher than those envisaged for North America. There are 68 GSM networks with more than five million customers in successful commercial operation in Europe, Asia, Australia, Africa and the Middle East. The introduction of GSM system using higher transmitting power (2 W for hand held and 8 W for transportable sets) and TDMA (Time Division Multiple Access) technology triggered studies on possible interference of such systems with various electronic devices. Studies were performed in various European countries as well as in Australia and New Zealand. Intuitive potential EMI problems and some reported complaints put a focus of studies on hearing aid compatibility issue. The studies provide valuable information but lack common denominator and good comparison base. Only some studies include DECT (Digital Electronic Cordless Telephone) telephones for comparison with the GSM. For this reason some Canadian studies on the CT2+ (Cordless Telephone 2+) technology were added to the "list" for analysis. No specific studies were available on EMI with analog system or other digital technologies not yet deployed (e.g., CDMA). Some presentations of associations for hard of hearing are also included.

Areas of Concern

Three prime areas of concern are identified in the papers and studies reviewed:

1) Potential electromagnetic interference to hearing aids which may be caused by wireless phones used in their proximity;

2) Potential electromagnetic incompatibility between hearing aids and wireless phones used by hearing aid wearer even when phone is used on an unaided ear;

3) Lack of standardized magnetic, acoustic or other defined coupling mechanism (similar to HAC magnetic flux standard for wireline phones)

Studies on GSM phones and hearing aids deal with the first concern above in some depth. The second issue, the use of GSM at the short distance from hearing aid, needs to be studied further. Numerous assumptions are made for simulations of real life scenarios. They may not accurately represent real phenomena, such as near field radiation, distributed source characteristics or absorbing effects of various parts of human head. The third issue, standardized mechanisms for coupling of GSM phones with hearing aids, is not strongly explored by any but Canadian and US references.

Most of the studies do flag that hearing aids need to be more immune to the electromagnetic environment.

Results of Studies and Proposed Solutions

The key points resulting from studies may be summarized as follows:

a. ***Hearing aid immunity today is insufficient***
There is a consensus that hearing aid immunity is not sufficient, although some immune hearing aids exist on the market [a4], [a15], [b20], [b28], [b30]. The degree of immunity is not known and cannot be predicted without testing. Some attempts are made to identify the elements of hearing aid responsible for susceptibility to EMF. (Often immunity is interpreted incorrectly, as representing only shielding). Discussions on hearing aid improvements [a5], [a9], [a14], [b30] show need for joint efforts of experts from hearing aid industry, specialist EMI laboratories and telecom industry.

b. ***Power of the transmitter is the dominant factor causing interference***
It was demonstrated in all studies that an RF power increase above immunity threshold causes increase of manifestation of the interference. All detectable symptoms (regardless of modulation) disappeared with decrease of radiated RF power below the immunity threshold, by decrease of source power or by increase of distance.

c. ***Peak power and not average power is responsible for EMI***
This observation is consistent with general knowledge of EMI phenomena. It is important to note that the peak power of digital system and FM modulated system is fundamentally independent of transmitted information content or type. All studies show relationship between interference and the magnitude of peak power radiated. Most studies show data which allows to relate interference with immunity of hearing aid. Study by National Audiology Centre in New Zealand concludes that the level of immunity of 7 V/m will result in almost no interference (one case in 29 for 8 W transmitter and one case in 29 for 2 W transmitter), and that no interference is expected for hearing aids with immunity of 10 V/m and better. This finding is consistent with results presented by National Telecom Agency in Denmark by "Working Group on GSM and DECT telephone and hearing aids". However, they also found that 82% of hearing aids studied (included in study 50 models) were not affected by an interfering field of 10V/m, while 18% did not meet this requirement. The peak power of an analog amplitude modulated system will depend on the transmission content and will increase above "rated power" with increased amplitude of content.

d. ***Near field interaction with hearing aids cannot be predicted with far field simulations***
Studies of free field phenomena at elevated field strength level do not yield the same results as subjective studies. Knowledge of near field phenomena needs to be improved before conclusions can be drawn [a3], [b28], [b30]. Studies using standard acoustic head and torso simulators such as KEMAR in [a22] do not simulate RF behaviour of human head. Also, at close distance, coupling via electric field and via magnetic field must be studied separately [a22], [b30].

e. ***Digital modulation is a cause of obvious symptoms of EMI problems (rather than cause of EMI)***

It was stated in the report on studies performed in Denmark [a3] " It can be shown that the audio response to a sinusoidal 80% amplitude modulation (which is a well established standard modulation form in RF immunity testing) within a fraction of and B is identical to the audio response obtained with a GSM-like modulation, provided that the RF test level is adjusted such that the peak amplitude of the modulated field is the same".

f. ***Different types of modulation will create different audible effects***

Studies for GSM, DECT and CT2+ may be compared. A systematic comparison between various frequency repetitions and various duty cycle conditions of digital transmission will produce different spectral content of audio disturbance. It may be extrapolated from Annex A to [a9] and Annex A to [b3] that random repetition of digital pulses with random repetition frequency will result in random noise added to the transmitted signal. It is shown [a21] that RF interfering signal with less identifiable modulation is more difficult to detect and, in some cases, may manifest itself as an increase of background noise.

g. ***Coupling of hearing aids with wireless phones (including "HAC")***

None of the reviewed studies outside of US and Canada properly address the issue of hearing aid compatibility in the sense of coupling of hearing aid and wireless telephone set or use of a wireless set as an assistive device on its own merits. Canadian Working Party concluded that the discussion on HAC (magnetic or other type of coupling) may be addressed only after the EMI to hearing aids from wireless telephone problem is resolved [a18], [a19].

Several potential solutions to the above key issues are discussed:

a. ***Improvements to hearing aid immunity***

There are three types of discussion on this issue. First, discussed in most of studies is the lack of adequate standards and test methods. The second is the need for demonstration of adherence to standards. The third is on improvements to hearing aid design. Greater consideration to standards and their enforcement is required.

The current IEC (International Electrotechnical Commission) requirement for electromagnetic immunity (EMC) is 3 V/m. It is believed that this figure will be increased to 10 V/m for general immunity and be higher for special applications [a9]. Specific limits for hearing aids designated for usage with wireless phones may have to be developed. Some values, given in context of Australian GSM are proposed in the recent joint study by National Acoustic Laboratory, Telecom Australia and AUSTEL [b30].

In reference [a4] the following statement is found: "It was agreed that, for the use of clinics and institutions in their advisory capacity, that manufacturers and suppliers will, before 15 August 1994, inform them of the immunity category in which the measured equipment may be classified in relation to GSM and DECT. Alternatively, this information will after that date be available from National Telecom Agency or from Technical-Audiological Laboratory." Also, CE Mark will be needed for hearing aids after 1st of January 1996. Reference [a26] predicts " ..."dumping" of hearing aids with poor immunity on the Canadian market, which could occur if ETSI standard re. EMI in electronic devices is deemed to apply to hearing aids". The same scenario may apply to the US market. The general methods for testing hearing aids, such as IEC series 118, will be most likely used as basis for developing immunity criteria in Europe [a4].

Improvements of the design of hearing aid are reported in two forms. Actual modifications of several hearing aids were made [a9] and results showed improvements of immunity in the order of 10 dB. In other studies [a15], [b30] possible improvements are discussed in general terms. Some of the proposed solutions are effective *in labo* and are yet to be proven through engineering applications supported with sophisticated knowledge of EM hardening. It is clear from the reports that the multidisciplinary character of such tasks must be more carefully addressed [b28], [b30].

The probability of achieving a high degree of immunity, needed for simultaneous and contra-lateral use of hearing aids with wireless phones is already proven by manufacturers. References [a4], [a20] and others give examples showing that hearing aids which can work in the close proximity of wireless phones.

b.& c. ***Control of radiated power***

Radiated RF field for a given power of a transmitter is dependent on the distance from the transmitter. The RF power, and therefore field strength, decreases with an increase of the distance. The relationship is inversely proportional. This relationship is valid for far field, i.e. a distance exceeding 35 cm or 14" for a handheld phone operating at 800-900 MHZ. The probability of interference will also decrease with the increase of distance. This approximation of free field propagation allows determination of minimum distance at which interference should not be expected. Most studies propose, as a rule of thumb, a distance of 1m from 2 W hand held phone and 2 m from 8 W transportable phones [a8], [a9] or the more conservative value of 2m and 6 m respectively [a10], [a14]. However, the same source as [a14], in the new studies [b30] suggest that a distance of 1 metre will be interference-free for hearing aids meeting Criterion 1 (same as IEC immunity level). More complex modelling is proposed by Jon Short [a10]. This work includes probability considerations and some detailed assumptions. Similar modelling study could be conducted for North American systems, with some updates to assumptions based on latest studies [b30] or resulting from new studies currently being undertaken.

d. **Improved understanding of Near Field phenomena for enhanced interaction with hearing aids**

Currently available studies show that some hearing aids may work with wireless telephones. This results were demonstrated in subjective experiments for GSM, DECT and CT2+ [a4], [b28], [b20], [b30]. No objective studies are available which will describe radiation in the close proximity of hearing aid in position and in the environment corresponding to real use. Some incorrect assumptions are made when the hearing aid is mounted on a manikin designed for acoustic research and not for RF propagation study [b22]. None of the existing studies addresses the separation of electric field and magnetic field interaction of hearing aids and telephones. In one study by Unitron [a23] and by National Acoustical Laboratory [b30] it was shown that low frequency and low impedance (magnetic) sources generate interfering signals from the telephone e.g., battery circuit. Further studies of near field behaviour may result in new recommendations for hardware design and for better criteria for EMC than those found in [b30].

e. & f. **Understanding of impact of modulation techniques on transmission quality**

Current studies show that electromagnetic interference is a function of peak power. However, the hearing sensations are related to average power and to modulation characteristics [a9], [a21]. Criteria for detection of AM and pulse modulation are better known because of their extensive use in military and commercial standards. The interference will always be proportional to peak power of the "intruding" field.

The interference may change hearing aid characteristics with or without obvious manifestation of such change. When interference is accompanied by demodulation of audible frequencies, it may create resulting signals in form of noise, intermodulation distortion products or masking (annoying) tones. Interfering RF carrier modulated with a digital signal with specific pulse

repetition will manifests itself as a "buzzing", easily recognizable sound at the output of hearing aid.

The effect of "buzzing sound" may vary from a decrease of sound quality to a strong discomfort. However, it alerts the user of the hearing aid that interference is occurring. Conversely, if an unmodulated carrier or carrier modulated with randomly varying signals interferes, or when demodulation product has similar spectral characteristics to speech, the subjective recognition of interference may be impossible. The resulting change in characteristics of hearing aid may not be identified or may be attributed to noise conditions (background or connection) or sidetone/crosstalk. The resulting decrease in ability to understand conversing party may then be attributed by the user to poor network/carrier connection.

The criteria for recognizing electromagnetic interference separately from real modulation effects are used in several studies using simulated RF signal with 80% AM modulation. Other criteria than audible output may be developed to correlate transmission quality and EMI. Full understanding of interference mechanism may provide more inside information for future quality improvements in wireless telephones.

g. Improved wireless telephones for hearing impaired and hearing aid compatibility

The studies reviewed do not address the possibility of using a wireless telephone (personal device) as an assistive device for hard of hearing in lieu of hearing aid. The telephone set may presently amplify speech by 20 dB or more. With modifications, or using an add-on device, an amplification of 40 dB or more is possible. In addition, such a personal adaptor could easily integrate frequency filtering similar to that achieved with a hearing aid.

Wireless telephones may have magnetic output corresponding to currently required HAC. However, this will not be of any help if the electromagnetic interference is present. Ways of decreasing this interference for far field will address only a part of the issue. In the near field improvements may have to be made to decrease interference caused by magnetic field coupling.

Summary of pertinent conclusions and recommendations

- Wireless telephones may cause electromagnetic interference with some electronic devices, and hearing aids in particular, in some cases. Furthermore, a wireless telephone will cause interference if the electronic device is not designed with appropriate consideration to electromagnetic immunity and it is brought in very close proximity to such device.

- North American wireless telephones e.g., PCS (0.6W) are less likely to become a source of electromagnetic interference than GSM system using stronger (2W plus) telephones since power is the major determinant of interference.

- In order to reduce probability of interference to susceptible devices, a reasonable minimum operational separation between such devices and wireless telephones ("restricted distance e.g., 0.5 or 1 metre) should be specified. The definition of such distance shall be based on immunity criteria defined jointly by appropriate multidisciplinary working groups.

- Special EMC design considerations are required for hearing aids (or other devices) which have to be used at closer distance than the "restricted distance".

- Criteria for classification of hearing aids and values of immunity for such classification must be established.

- 80% amplitude modulation (AM) with sine wave or other suitable but identifiable signals (e.g., defined pulse) should continue to be used as simulation to determine immunity of audio or other devices to interference from wireless telephones regardless the actual modulation used by the telephone.

- Subjective studies should continue for the purpose of correlating with objective measurements to determine immunity criteria.

- Identification of immunity levels of hearing aids shall be available to users (e.g., voluntary certification program).

- Explanation on restrictions (distance, coupling to other devices, etc.) should be provided in user manuals for wireless telephones.

- Near field electric and magnetic fields i.e. fields directly in the proximity of wireless telephones are less known and should be studied to determine ability of telephones and hearing aids to work together

- Hearing aid industry, wireless industry, acoustics and EMC experts as well as audiologists should work together to implement and verify proposed and new solutions.

- Opportunities to benefit the hearing impaired, represented by wireless personal telephones working as assistive devices should be further explored.

The personal wireless telephone - an assistive device for hard of hearing

It has been demonstrated in studies carried out by APREL Laboratories [1] that hard of hearing persons, in most of their auditory environments, may use a wireline telephone without use of hearing aid, provided that the set is equiped with appropriate acoustic amplification. Such gain control is not universally available. The wireline phones are "tied" to places, not people. The wireless telephone, as a personal device, may afford the opportunity to ensure a match between the user's need and *his/her* telephone. Some notes:

- Face to face conversation results in acoustic pressure in a listener ear of 65 dB SPL;
- Telephone nominal acoustic output at the PLL (preferred listening level) is 85 dB SPL in the concha cavity of the ear;
- most currently available portable cellular telephones have volume controls allowing additional amplification of at least 6 dB;
- some cellular telephones have volume control gain greater than 10 dB (may be as high as 18 dB);

The "insertion" gain of the cellular telephone subscriber set is:

NOMINAL GAIN (dB) = (85 dB - 65 dB) = **20 dB**
MINIMUM VC GAIN (dB) = (85 dB - 65 dB) + 6 dB = **26 dB**
OPTIMUM VC GAIN (dB) = (85 dB - 65 dB) + 10 dB = **30 dB**

Acoustic improvement of a wireless phone for use by hard of hearing

A wireless telephone is a personal device and therefore may be adapted to needs of the owner.

Special passive devices may be designed to be added or integrated with handset to decrease acoustic source impedance by adaptation to auditory characteristics of an external ear (concha and ear canal). In addition to already available "insertion" gain, such device will raise sound pressure output of a telephone by up to 10 dB.

NOMINAL GAIN with "auditory adaptation" (dB) = (85 dB - 65 dB) + 10 dB = **30 dB**
MINIMUM VC GAIN with "auditory adaptation" (dB) = (85 dB - 65 dB) + 6 dB + 10 dB = **36 dB**
OPTIMUM VC GAIN with "auditory adaptation" (dB) = (85 dB - 65 dB) + 10 dB + 10 dB = **40 dB**

An active adaptor with volume control and filters to control frequency response and compression characteristics may be designed to further improve hearing ability

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For more information contact Dr. Jack J. Wojcik at Spectrum Sciences Institute, tel. (613) 723-1658 or fax (613) 723-1657

[1] Wojcik J.J. Report on the Coupling of Telephones and Hearing Aids. Prepared by APREL Industrial Acoustics Ltd. For Department of Communications Canada. November 1983

ELECTROMAGNETIC COMPATIBILITY WIRELESS TELEPHONES & HEARING AIDS IN SEARCH OF PRACTICAL SOLUTIONS

Through the CTIA efforts, the following elements of electromagnetic interference management in relation to the wireless phone - hearing aid compatibility are currently in place or are being put in place:

i. Control of RF power of wireless telephones (current CTIA certification testing of AMPS, NAMPS and TDMA subscriber sets at APREL Laboratories);
ii. Control of radiation patterns of wireless telephones for near field coupling phenomena (current certification testing of vehicular antennas and upcoming certification testing for SAR at APREL Laboratories);
iii. Studies on modelling of wireless telephones and hearing usage (studies at University of Oklahoma);
iv. Development of simulations and characterisation of "test beds" (Spectrum Sciences Institute)
v. Studies on modelling of electromagnetic environment - shielding and absorbing properties of buildings and other elements of environment (studies at Spectrum Sciences Institute)
vi. Monitoring of interference - analysis of incidents (studies at University of Oklahoma);
vii. Engineering analysis of devices involvement in cases of interference (studies at Spectrum Sciences Institute, testing at APREL laboratories and studies at University of Oklahoma);
viii. Control of immunity of hearing aids (upcoming CTIA certification testing at APREL Laboratories and joint EMI design projects with hearing aid industry);
ix. Dissemination of information for use by industry (CTIA, Oklahoma University of Oklahoma, Spectrum Sciences Institute)

CTIA.....

APRELLaboratories, established in 1981 is the leading independent North American laboratory, with expertise in communications, acoustics and electromagnetics. Expertise of trained staff is supported by a multimillion dollar facility including acoustic anechoic room, three shielded rooms - one anechoic, fibreglass covered 10 metre Open Area Test Site, environmental labs and more than a thousand pieces of specialized test instrumentation. APREL is the contracted laboratory for CTIA Certification Programs, and performs testing, develops Test Plans and provides consulting in technical matters related to the Certification Programs. APREL staff has experience in testing of hearing aids and have been involved in development of international and national standards on hearing aids and on compatibility of hearing aids and telephones (IEC, CCITT, CSA, H&W). APREL Laboratories are currently being moved to Spectrum Sciences Park - technology hub for communications and measurements.

Spectrum Sciences Institute was designed in 1986 as an independent center for electromagnetic engineering and acoustics. In 1995 the new home for the Institute was established in the 18-acre Spectrum Sciences Park. The synergy with independent engineering, testing and calibration service providers co-located in the Park, as well as Goverment, Acadamic and Industrial resources and partners, gives the Institute access to the best tools for conducting research projects in the telecommunications field.

University of Oklahoma Centre for the Study of Wireless Electromagnetic Compatibility established in 1994.....

This combination of academic research, with engineering applied research and with Product Integrity engineering & testing capabilities gives our industry the powerful tool to resolve EMC issues.

DETECTING ELECTROMAGNETIC IMMUNITY (EMC) POSSIBLE MISUSE OF WIRELESS TELEPHONES AS TEST EQUIPMENT

Any radio frequency (RF) signal may cause change of characteristics of circuits in an electronic device. RF signal may be of frequency ranging from DC to hundreds of gigahertz. Some RF signals (above the immunity threshold) will alter performance of a device in some way. Every RF source may have modulating signals (by design or random) which, if detected by an electronic device, may generate intermodulation products and change performance characteristics of such a device (malfunctioning).

No device or system may be built to be completely immune to all possible electromagnetic fields (not many will withstand a Nuclear Electro-Magnetic Pulse for example). However, every device or system shall, within allowable tolerances, perform in some degree of electromagnetic severity appropriate for its intended use. Designing devices or systems to be immune to some typical levels of RF fields in which they may operate is refere to as "designing for electromagnetic compatibility (EMC") or "designing to meet EMC requirements".

Meeting EMC requirements is still a most expensive "liability" to any electrical or electronic product manufacturer. The costs of design and quality verifications are high. Once the design is made, the expensive design expertise may become redundant for a given product line(s). The costs of electromagnetic environment simulations and knowledge related to proper use of the EM simulations are very high. For cost or expertise availability reason, the "first choice" shortcut used by any manufacturer. However, today, many products simply cannot be put on the market if the EM immunity is not built-in.

Explosion of wireless communications and computing increases wanted and unwanted radio frequency radiation at all frequencies with radiating sources distributed geographically and often brought into proximity of individuals. The need for "cheap and fast" simulators of RF fields to qualify the extent of potential problem is intensified but not new. As an example, when in 1956 a simulation was needed for testing of shielding effectiveness, Military Standard 285 stipulated use the Ford ignition coil (well characterised) to generate high electric fields. This allows generation of thousands of volts per metre with a simple low voltage (12 V) battery.

Portable wireless RF devices are often today used this way as simulators of electromagnetic field. They are inexpensive and readily available. This is why in many studies performed today, personal communication devices, selected without full characterisation, are used as radiators in attempt to detect and qualify electromagnetic immunity problems. The quantification of electromagnetic immunity of a target would be possible only if the specific source (e.g. telephone) was fully characterised for all appropriate parameters. This is difficult and the cost of proper laboratory characterisation may be very high. Defining the source will give investigators more idea what their simulation is doing. In spite of this limitation, the obvious presence of symptoms (e.g., when the radiator is a digital phone and a target is an audio device such as hearing aid) may be an opportunity to find out that device is not as good as it should be. The probability of creating an unrealistic simulation, that is, creating scenario unlikely to be encountered in normal use, exists and is higher in near field (short distances between a source and a target).

People and their personal (and less personal) electronic equipment are exposed today to many different sources of electromagnetic interference with variety of signals being emitted. The convenience of use of wireless telephones as simulators of such field with modulation convenient for detection and subsequent reporting of such experiments may (and often does) lead to an inappropriately exaggerated view of such telephones as major source of electromagnetic interference.

For more information contact Dr. Jack J. Wojcik at Spectrum Sciences Institute, tel. (613) 723-1658 or fax (613) 723-1657

ELECTROMAGNETIC COMPATIBILITY & HEARING AIDS

Every electrical circuit (including a simple piece of wire) located in an electromagnetic field (EMF) is affected by this field. The change caused by electromagnetic field may be detectable or not, depending on characteristics of the circuit or system. Electromagnetic Interference is a term used to describe one of two situations: (1) system performance changes under exposure to the EMF or (2) it is anticipated that system performance may change if exposed to certain fields. Electromagnetic Interference (EMI) is managed by control of sources of radiation and receivers (also called "target" or "victim"), in order to achieve electromagnetic compatibility (EMC) for both system elements. The sources are controlled by a limiting spurious emissions for unintended radiation sources and by spectrum management requirements for intended radiation sources. The receiver's compatibility with such controlled sources is achieved by adequate immunity requirements.

Electronic equipment is generally not fully immune to electromagnetic fields (natural or man-made; controllable or not). The immunity has to be built in by design, according to requirements of the allowed changes of performance in the intended environment. If the immunity is not built into a product, product risks to be inadequate for some intended environments. Ability of a product to operate in its intended electromagnetic environment without changes to product characteristics is called electromagnetic compatibility (EMC).

The need to include EMC as a product integrity parameter was recognized more than 50 years ago for military products and more than 25 years ago for consumer products. The telecom industry adopted voluntary immunity requirements many years ago, and this requirement grew over time from immunity to fields of 1 V/m, to fields of 10 V/m. In special cases, required immunity is much higher. Requirements of 20 V/m and 200 V/m are not uncommon. As for frequency, the voluntary requirements for consumer products started with an upper limit of 150 MHz and has been extended today to well above the 10 GHz regions. Additionally, the FDA requirement of immunity to electromagnetic fields of at least 7 V/m for medical instruments and devices was introduced in 1979.

Requirements limiting electromagnetic interference (EMI) define allowable radiation from computing devices and allowable stray signals and power limits for spectrum management requirements. The requirements in the US are published by the FCC and are well known to industry. Canadian requirements, following the same principles, are published by Industry Canada (former DOC). Voluntary industry standards, such as those promulgated by IEC, TIA, EIA, IEEE, etc. also exist.

The increase of RF radiation, associated with increase in computing and communications, causes concerns with respect to possible interference of one device on another. Medical instruments and assistive devices are of special concern. Despite legal definition varying from country to country, users and providers (audiologists, dispensers, etc.) do identify the hearing aid as a medical device.

In absence of specific North American regulatory requirements for hearing aids, it would seem to be appropriate to use, as minimum, the FDA immunity limit of 7 V/m. European requirements for hearing aids were set several years ago at 3 V/m and this minimum limit is now proposed to be increased to 10 V/m. The limits for electromagnetic immunity define to the hearing aid community (manufacturers, providers and users) what is seen by experts to be a typical "intended electromagnetic environment." More stringent immunity (EMC) requirements may apply if a hearing aid is to be used in an environment with stronger fields.

Studies investigating hearing aid immunity, directly or indirectly, demonstrate that some hearing aids exceed all of the above standard requirements. However, it is reported in several studies that there are hearing aids on the market (and in use) which are practically not immune to any electromagnetic fields expected in typical home or office environment (immunity less than 1V/m).

For more information contact Dr. Jack J. Wojcik at Spectrum Sciences Institute, tel. (613) 723-1658 or fax (613) 723-1657

Binder	TITLE	COUNTRY	ORGANISATION	AUTHOR	DATE	Remarks	# of pages
a 1	GSM Phones and Hearing Aids	USA	CTIA	Houghton, M.	N/A	Various releasys	16
a 3	EMC and the new Modulation Technologies	Denmark	Telelaboratoriet TELECOM Denmark	Lauridsen, Ole	10-May-94	Presented at: "Cellular: The Next Generation" London May 10-11, 1994	12
a 4	Interference with hearing aids caused by GSM digital cellular telephones and DECT digital cordless telephones	Denmark	National Telecom Agency		28-Jun-94	Conclusive Report by the Working Group on GSM and DECT telephones and hearing aids	33
a 5	Report to the HIA on RF Interference to Hearing Aids from Digital Cellular Telephone Signals	N/A	N/A	Geddes, Dr. Earl	23-May-94		8
a 6	Effects on TDMA-Modulated Hand-Held Telephones on Pacemakers	Switzerland	Swiss Telecom	Eicher et al.	N/A		9
a 7	GSM Cellular Phone Interference with Implantable Pacemakers: In Vitro and In Vivo Observations	Italy	Instituto Superiore di Sanita	Barbaro et al.	N/A		7
a 8	Mobile Telephones Interfere with Medical Electrical Equipment	Australia	Monash Medical Centre & Telecom Australia	Clifford et al.	N/A	latest reference included is dated 1993	10
a 9	GSM EMC considerations	France	ETSI	ETSI	1 Feb-93	ETSI Technical Report GSM 05.90 Version 4.0.0	9 + A19 + C3 + D4
a 10	A GSM Interference Model	UK	BT Laboratories	Short, Jon	22 Feb-90	Annex B to ref. 9 (ETSI)	17
a 11	Summary Document on GSM-TDMA Interference	UK	RTL	Mellish, F	1-Jul-91	Project 60; Support to R2/MTS2; file KJ201	6
a 12	Guidance as to Restrictions on Exposures to Time Varying Electromagnetic Fields and the 1988 Recommendations of the International Non-Ionizing Radiation Committee	UK	National Radiology Protection Board	NRPB-GS 11	none	Annex G to ETSI SGM 05.90 ver. 4.0.0 Feb. 1993	
a 13	German draft standard DIN VDE 0848 Part 2 Safety in Electromagnetic Fields; Protection of persons in the frequency range from 30 kHz to 300 GHz	Germany	DIN	DIN VDE	1-Oct-91	Annex G to ETSI SGM 05.90 ver. 4.0.0 Feb. 1993	10
a 14	Possible Interference and Health Effects Associated with GSM Mobile Phones	Australia	Telecom Research Laboratory	Joyner, Ken	none	Latest quote March 1993	19

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a 15	Interferance to Hearing Aids by the new Mobile Telephone System, Global System for Mobile (GSM) Communications Standard	*Australia*	National Acoustical Laboratories	*Joyner, Ken et al.*	30-Mar-93		14
a 16	Interference from the TDMA structure in digital mobile communication to PSTN	*Finland ?*	Televerkets Forskningsinstitutt	*Egil Hauger*	6-Oct-92	SMG2 #6, Helsinki	28
a 17	Potential GSM Hazards on Cardiac Pacemakers	*Italy*	CSELT	*ETSI*	21-May-91	Annex G to ETSI SGM 05.90 ver. 4.0.0 Feb. 1993 also presented ETSI/GSM2 Berne, 21-22 May 1991	6
a 18	Working Party- DCT/HAC			*Corey, Bob*	none		
a 19	Wireless Access Equipment and Hearing Aid EMI			*Thorpe, L.*	25-Nov-92		
a 20	Subjective Assessment of CT-2 Interference to Hearing Aids	*Canada*	Department of Communication	*Corey, R.*	21-Jan-93		5
a 21	Susceptibility of Hearing Aid Devices to Radio Frequency Fields	*Canada*	Department of Communication	*Kasper, Brian*	21 Jan-93		[illegible]
a 22	EMI Interaction between the CT2 Digital Handset and Hearing Aids	*Canada*	Unitron	*Arndt, H.*	16 Feb 93	submitted to TAPAC	
a 23	CT2 Digital/Cordless Telephone Study Hearing Aid Compatibility	*Canada*	Unitron	*Arndt, H.*	12-Mar-93	submitted to TAPAC	[illegible]
a 24	Answers to "GSM Questions & Answers"	*Germany*	GSM-MoU Group	*Hillebrand, F.*	3-Apr-95	also "Navigating the Business Minefields of PCS"	11
a 25	GSM - A challange to the hearing industry	*Denmark*	Danavox	*Bisgard, N.*	10-Sep-93	memo to all subsidiaries and industries	2
a 26	Considerations regarding Hearing Aid Compatibility of DCT terminals	*Canada*	NT/BNR	*Thorpe, L.*	16-Feb-93	including draft recommendations	6
a 27	Wireless Access Equipment and Hearing Aid EMI	*Canada*	BNR	*Thorpe, L.*	25-Nov-92	presentation to TAPAC	21
b 3	European digital cellular telecommunications system (Phase 2) GSM Electro Magnetic Compatibility (EMC) considerations (GSM 05.90)	*France*	ETSI	*ETSI*	1-Feb-94	Annexes: A [a10]; B&C [a9]; D [a17]; E [a11]; F [a15]	

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ıder							
	Radio Frequency Immunity Requirements for Equipment Having an Acoustic Output Draft PN-3210 Issue 6	*US*	TIA/EIA	*TIA/EIA*	1 Dec-94		
4	Coupling hearing aids to telephone sets	*UK*	CCITT	*submission to CCITT SG XII*	1-Jul-91		
5	TAPAC Digital Cordless Telephone Service Committee	*Canada*	The Canadian Hearing Society	*Hahn S.B.*	5-Feb-93		
6	Report on the Coupling of Telephones and Hearing Aids	*Canada*	APREL	*Wojcik, J.J.*	1-Nov-83		
7	T 515, Fourth Draft (TIA/EIA -504A Draft PN-3399	*Canada US*	CSA/TIA/EIA	*CSA/TIA*	30-May-95		
8	Parallel Universes	*US*	Audio	*Sweeney, D.*	1-Sep-90		10
20	The Intermodulation Problem in Mobile Communications	*Germany*	Microwave Journal	*Lang, M.*	1 May 95		5
21	Low Power Wireless Radiation Issues	*Canada*	Telecom Canada	*planning & standards group*	1 Aug 91		40
22	Statement of Rep. Gary A. Condit, Chairman Subcommitte on information, justice, transportation and agriculture, house government operations committee.	*USA*				"do cellular and other wireless devices interfere with sensitive medical equipment?	26
23	Congressional Record -Senate	*USA*			14 Jun 95		2
24	Safety Action Bulletin	*Northern Ireland*	Dep. of Health	*N/A*	1-Nov-94	portable, cordless and cellular telephones: interference with medical devices	1
25	Partial Transcript of "Tomorrow's World"	*Canada*			29-Oct-93	broadcast on BBC TV	3
26	HEAR-IT NOW Petition for Rule Making	*USA*	HEAR-IT NOW	*N/A*	28-Jun-94	with attatchaments	24 +
27	Digital Cellphones & Interference with Hearing Aid Users	*New Zeland*	National Audiology Centre	*Greville, A.*	1-Aug-93	also submitted by HEAR-IT NOW	19
b 28							

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b 29	EMC CONSIDERATIONS FOR DIGITAL CELLULAR RADIO AND HEARING AIDS	UK	BT Laboratories	Short, J.	N/A	also submitted by HEAR-IT NOW	

Reference	*[a3]* EMC File at Spectrum Sciences Institute
Country	*Denmark*
Title	EMC and the new Modulation Technologies
Authors	*Ole Lauridsen*
Source	elelaboratoriet - TELECOM Denmark Presented at "CELLULAR: THE NEXT GENERATION" London, May 10-11, 1994

The author predicts problems of electromagnetic interference of cellular transmitters with a variety of electronic devices, both analogue and digital." Interference problems have been observed in several cases. The actual number of registered complaints is still relatively small. Based on available information, we expect that number will increase dramatically in the nearest future." "It is common to all the interference cases except the more exotic ones, that the equipment suffering the disturbances was designed with no consideration of EMI."

The author refers to GSM and DECT as sources of interference. Several anecdotal cases are cited. Distances are given to relate field strength with power radiated by 8 Watt and 2 Watt transmitters assuming plane wave characteristics of EM field. Mention is made that for closer distances (near field) more studies are required. The author suggests that reason for severity of the TDMA is that the system has "pulsing" modulation. However, the studies described use amplitude modulation. The reason given is that: "it can be shown that the audio response to a sinusoidal 80% amplitude modulation . . . is identical to the audio response obtained with a GSM like modulation provided that the RF test level is adjusted such that the peak amplitude of the modulated field is the same." He is further attributing the interference to EM field strength rather than to modulation type in his statement: "Furthermore the rather often claimed EMC-superiority of CDMA-system is basically due to the lower transmitter power . . . " and proposes further "TDMA-systems like GSM and coming similar systems can also implement . . . lower transmitter power levels."

The solution for EMI problems proposed by author is in adherence to recognised immunity levels. He suggests that " . . . the equipment suffering the disturbance was designed with no consideration of EMC." With respect to hearing aids, author proposes that the immunity of hearing aids must be determined in order to establish the extent of the problem and that acceptable levels and test methods need to be found.

Reference	*[a4]* EMC File at Spectrum Sciences Institute
Country	*Denmark*
Title	Interference with Hearing Aids Caused by Gsm Digital Cellular Telephones and Dect Digital Cordless Telephones
Authors	Conclusive Report by the Working Group on GSM and DECT telephones and hearing aids
Source	National Telecom Agency June 28, 1994

Four elements are reported in this "conclusive" *(read Final)* summary:

(1) Experimental study on hearing aids immunity when exposed to a simulated EM plane wave modulated with pulses corresponding to a transmission envelope of GSM and DECT system and set on the levels expected from 2 Watt and 0.25 Watt hand held transmitters respectively. The complex near field phenomena in the proximity of handset are approximated with far field waves having elevated field strength. The worse case interference is recorded in all categories tested. The measurements' results showed (p.5) that 82% of hearing aids are not disturbed by persons other than the aid user using hand portable 2 W GSM telephones. Further, they conclude that user will experience no interference with his hearing aid from DECT telephones used by other person. In spite of uncertainties resulting from simulations used, it is shown that there are hearing aids on the market that can be used with a 2W GSM (16%) and 250 mW DECT (26%) placed on the same ear as hearing aid. The figures given for use of hearing aid on an opposite ear are 22% and 26% respectively. This study shows that interference is directly related to peak power of the transmitted signal almost regardless of modulation (GSM/DECT). The only symptom used to determine malfunctions of hearing aid was a "buzzing" noise.

(2) Status of European standardisation of hearing aids is given. It is expected that 10V/m immunity standard for hearing aids will resolve the interference issue. However, a mechanism is needed to inform users which hearing aids are meeting such standards and in addition which hearing aids have immunity level making them compatible with the GSM or DECT.

(3) A considerable part of the report deals with possibilities of EM hardening of hearing aids. Various ways of hardening are tabled. Retrofit of hearing aids is perceived to be difficult and it may change other characteristics of hearing aid circuits. However, it is concluded that in new constructions of hearing aids it will be possible to ensure a higher degree of immunity.

(4) Recommendations are made for dissemination of information (in Denmark) on various issues related to use of hearing aids with GSM and DECT: "It has been agreed that, for use of clinics and institutions in their advisory capacity, manufacturers and suppliers will, before 15 August 1994, inform them of the immunity category in which the measured equipment may be classified in relation to GSM and DECT. Alternatively, this information will after that date be available from the National Telecom Agency or from the Technical-Audiological Laboratory."

5) General "Conclusion and Summary" section compiles each member of Working Group contribution and assumes correctness of opinions following a principle of a consensus " . . . characterised by absence of sustained opposition to substantial issues . . . " Some elements of this section are summaries of sections 1-4 here. Some other elements exceed the scope. For instance, in the TAL

[a4] cont'd

study the interference is measured by exposing hearing aids to simulated GSM and DECT signals only and detected as audible buzzing sound (no other characteristics of hearing aid were investigated).

The results presented confirm that the RF peak power, and not the difference between two modulations used, determines extent of interference. However, in the conclusions on page 5 (para 3) it states "Interference from both GSM and DECT is caused by the special nature of radio signals due to the principle of time division multiple access (TDMA) used. Interference becomes manifest by, e.g., the occurrence of a very unpleasant snarling tone, the basic frequency of which depends on the repetition frequency of the radio system." This conclusion is incorrectly presented. There is no mention of studies of any other modulation nor any other "manifestation" of change, e.g., change of performance characteristic of hearing aid such as compression saturation, gain change, etc.

(In the reviewer's opinion this paper makes impression of a comprehensive study that it is not; Conclusions to a certain extent contradict each other)

Reference	*[a5]* EMC File at Spectrum Sciences Institute
Country	*USA*
Title	Report to the HIA on RF Interference to Hearing Aids from Digital Cellular Telephone Signals
Authors	*Earl Geddes, Ph.D.*
Source	n/a May 23, 1994

This paper contains selection of information included in reports on GSM interference studies in Europe and Australia. The author discusses the origin of fundamental audio frequency disturbance in North American TDMA and in European GSM. The tables supporting dependance of interference on the peak RF power transmitted are presented. The author adds his own view on possible design solutions to hearing aid immunity problems. This paper is very informative; however, a claim that CDMA is "completely compatible with hearing aids" is not supported in this presentation.

Reference	*[a8]* EMC File at Spectrum Sciences Institute
Country	*Australia*
Title	Mobile Telephones Interfere with Medical Electrical Equipment
Authors	*K.J.Clifford[1], K.H.Joyner[2], B.D.Stroud[1], M.Wood[2], B.Ward[2] and C.I.Fernandez[1]*
Source	1 Clinical Engineering Unit, Monash Medical Centre, Clayton, Victoria 2 Electromagnetic Compatibility Section, Telecom Australia Research Laboratories, Clayton, Victoria date not available

The root of a problem is shown to be the difference in peak RF power increase from 0.6 W for analogue telephones to 0.8 W and 2 W for GSM.

The baseline used by the author is the FDA immunity requirement for medical devices of 7 V/m (US 1979). The IEC requirements published in 1993 call for immunity of 3 V/m.

Measurements were made for three telephones: analogue 0.6 W, GSM 2 W and GSM 8 W. Measurements are reported for both peak and RMS value of electric field strength. It states that peak electric field is primarily responsible for EMI effects. Results show that the field of 7 V/m was measured for analogue phones at approximately 35 cm, for GSM 2W at approximately 1 meter, and for GSM 8 W at 2 meters. In subsequent tests the telephones were placed near various pieces of medical equipment. At the distance of 50 cm, 3 pieces of equipment were affected with AMPS phone and 8 pieces of equipment malfunctioned with the GSM phones. Some units, equipped with audible output, produced 217 Hz audible sound. No interference was observed when phones were more than 2 m from equipment.

The author proposes restrictions of distances from sensitive medical equipment. The author recognises need for more factual reporting followed by engineering studies. The data presented in this paper and the author's conclusion suggest that EMI from mobile phones is unlikely to be a problem with medical equipment at distance dependent on power of a transmitter (e.g., 2 m for 8W). Also suggestion is made that 7 V/m may not be a sufficient immunity requirement for medical devices including hearing aids.