# NUMBER OF TESTS

**Phone / Phone Mode Combinations**

**Maximum = 1 MIRS + (4 modes x 4 TDMA) = 17**

**Realistic = 1 MIRS + (2 modes x ~2 TDMA) = ~5**

**Maximum Number of Test Points**

**= 30 pacers x 177,600 pts x 17 phone modes**

**= 90,576,000 points**

**Estimated Number of Test Points**

**= 130 MIRS + (335 x 30/25 TDMA) x ~150 pts.**

**= ~79,500 points from ~530 test runs**

# PRELIMINARY RESULTS

- 81 of 464 runs had some interaction (17%)
- 32 of 335 TDMA runs had some interaction (10%)
- 4 of 25 pacemaker's - TDMA interaction (16%)
- 15 of 201 TDMA Ringing - interaction (7%)
- 17 of 134 TDMA Talkback - interaction (13%)
- 15 of 17 AAT, 9 of 27 VVT, 8 of 12 DDD mode
- No instance of pacemaker re-programming
- No instance of permanent inhibition

# PLANS

- Continue TDMA Testing
- Begin Testing PCS 1900 MHz and CDMA phones
- Add defibrillators in next test phase
- Will include increased distance between phone and pacemaker

# NSF Industry University Cooperative Research Center
# Wireless Electromagnetic Compatibility
# Project Summary

**Project Name:** Interference Between Cellular Telephones and Hearing Aids (HA)

**Project Investigators:** A. Ravindran, Robert Schlegel, Hank Grant (OU) and Ken Dormer (Hough Ear Institute)

**Description:**

The objective of the project is to (1) determine the extent of interference to hearing aids from cellular phones, in particular, from North American Digital Cellular Phone technologies and (2) evaluate the effectiveness of both short term and long term solutions to "Passer-by" interaction problems and "Hearing Aid User" interaction problems. Both instrument-based and human subject EMI testing will be done to determine overall immunity levels for hearing aids.

**Experimental Plan:**

1. Formation of HA Design Group involving HA companies, cellular phone companies and regulatory agencies to develop test protocols for both subjective and objective EMI tests.
2. Test human subjects to determine extent of interference.
3. Identify and test both short-term and long-term solutions to interference problems.

**Related Work Elsewhere:**

None in the U.S. Some studies have been conducted in Europe and Australia.

**How Ours is Different:**

Most European and Australian studies have tested GSM phones (not used in the U.S.). Our project will study current and new cellular phones based on North American Digital Cellular technologies.

**Related Work in the Center**

Interactions between pacemakers and cellular phones

**Milestones:**

12 months project

**Deliverables:**

1. Acceptable testing protocol.
2. Test results of potential interference of digital phones and hearing aids.
3. Results from tests of potential solutions.
4. User guides for HA users.

**Budget:**

$150,000

**Potential Benefits to Member Companies:**

The cellular phone industry will be able to use the new digital technology without potential interference to hearing aid users. The hearing aid manufacturers will receive recommendations to eliminate interference problems with cellular phones.

September 28, 1995

# The University of Oklahoma

CENTER FOR THE STUDY OF WIRELESS ELECTROMAGNETIC COMPATIBILITY
SCHOOL OF INDUSTRIAL ENGINEERING

# HEARING AID - WIRELESS DEVICES INTERACTION STUDY

## SCOPE

- Survey Existing Literature
- Develop Protocol for Test
- Execute Test Plan
- Recommend Solutions

## PHASE I OBJECTIVES

1. Define the test protocol for physical measurement of the interference generated in hearing aids by cellular phone signals of varying types. The resulting protocol shall produce repeatable results and include parameters such as field strength, threshold distance of interference, and, intensity and frequency of the resulting audio interference output;

2. Define a standard methodology for measuring the immunity of hearing aids, including standards for acceptable "noise floors"; and

3. Define the test protocol for subjective measurement of the extent of the interference generated in hearing aids by cellular phone signals of varying types. The protocol shall include the use of both hearing-impaired and unimpaired individuals.

## PHASE II OBJECTIVES

1. Determination of overall immunity levels for hearing aids and user guides for buying hearing aids with high immunity.

2. Identification of appropriate measures to eliminate interference
   a. For phone technology (e.g. use of small cells, using dynamic power control, use of discontinuous transmission).
   b. For hearing aids (e.g. reducing size, shielding the equipment, filtering, etc.).

## PHONES TO BE TESTED

- ANALOG @ 800 MHZ
- TDMA (D-AMPS) @ 800 MHZ AND 1900 MHZ
- MIRS
- CDMA @ 800 MHZ AND 1900 MHZ
- PCS @ 1900 MHZ
- GSM @ 900 MHZ (not used in US, but included for benchmarking against European studies)

## HEARING AIDS TO BE INCLUDED

Hearing Aid Types:

- Behind the Ear (BTE)
- In the Ear (ITE)
- In the Canal (ITC)
- Completely in the Canal (CIC)

(ITE, ITC, and CIC comprise 80% of the market)

## CURRENT STATUS

- Literature review completed.
- Protocol Design Group involving wireless phone manufacturers, hearing aid companies, hearing aid user groups, researchers and government agencies has been formed.
- Held meetings with the design group and version 3.0 of the test protocol has been developed.

## FOR ADDITIONAL INFORMATION

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DRAFT

Version 2.0
11-12-95

Hearing Aid - Cellular Phone Interaction Study

## I. Research Plan

The EMC Center's plan for developing solutions to the Hearing Aid (HA) interaction issue consists of the following three pronged approach that includes both subject-based and instrument-based testing.

1. The top priority is identifying immediate cost effective solutions based on input from hearing aid manufacturers and users. These solutions will be evaluated utilizing a quantitative, subject-based test protocol involving both hearing-impaired and normal-hearing individuals. Testing of human subjects will begin shortly, with initial results reported by January 1996. This research is in collaboration with the Hough Ear Institute in Oklahoma City and other appropriate research groups. These solutions range from handling present HA designs to providing guidance to newer HA designs under develoment.

2. Work with cellular phone manufacturers to identify any practical/cost effective modifications in design or usage to minimize EMI effects in present HA designs.

3. Additional human subject testing to clearly determine the extent of the interaction of hearing aids with the variety of digital wireless communication technologies, and to identify and evaluate other solutions.

4. Instrument-based EMI testing with an emphasis on identifying the mechanism of the interaction and leading to the development and evaluation of longer-term solutions.

## II. Differences with respect to European and Australian Studies

The OU Center plans to use much of the testing protocol and results available from the European and Australian studies as well as the IEC 118-xxx Standards for hearing Aid EMC tests. However, there are some important differences:

1. Most European and Australian studies are for GSM @ 900 MHZ phones with 2W hand-portable and 8W mobile phones. Our studies would involve all the NADC (North American Digital Cellular) technologies (TDMA, MIRS, CDMA, and PCS). GSM @ 900 MHZ will also be included for bench marking with prior European and Australian studies.

2. We would be using actual wireless phones instead of employing various simulated RF signals. This provides greatest realism in terms of actual signal structure including the format for control and voice traffic (e.g. paging, power control, channel changes).

3. Use of subjective (psycho-acoustic) measurements of interference in our tests. This is important since detectability and annoyance depend on the individual hearing acuity of each user

## III. Accomplishments To Date

- Hosted a planning meeting for the study in Dallas, Texas, in May 1995. This was attended by representatives from the phone and HA industries. Topics discussed included research study objectives, phone & HA technology reviews and testing studies completed to date.

- Completed a literature review of studies performed to date on HA interaction and internationally conducted test protocols used.

- Met with the main researchers (Ken Joyner of Telecom Australia, Jacek Wojcik of Aprel Labs, Ross Roeser of Callier Center for communication Disorders, Ken Dormer of Hough Ear Institute, etc.) to solicit their input and include them in the testing process.

- Formation of the HA Test Design Group to develop the test protocol to be used in the study (membership list attached).

- Held two meetings with the Test Design Group to formulate the Research Protocol. Draft version 3.0 was discussed at the Second Dallas Forum in October 1995. Inputs from the FCC , FDA and HA user groups were obtained for inclusion in Version 4.0.

- Requested meeting with the FAA Chairman to present progress to-date

- Audiologic protocol for Human Subjects testing has been developed with Hough Ear Institution (Version 1.0)

This completes Phase I of the Hearing Aid Study.

## IV. Resources Available to the Center

1. Industry Advisory Board (AT&T, Bell South, Ericsson, Hewlett Packard, Motorola, Nokia, Northern Telecom and Southwestern Bell Mobile Systems).

2. HA Test Design Group consisting of 45 U.S. and international representatives of wireless manufacturers and service providers, including AT&T (Don Heirman), Motorola, Ericsson (U.S. and U.K.), Qualcomm and Telecom Australia; HA companies (Argosy, Siemens, Starkey); trade associations (CTIA, HIA, HIMA); government agencies (FCC, FDA, Health Canada); and HA user groups (Self-Help for Hard of Hearing).

3. Research Labs and Testing Facilities

   - AT&T EMC Testing Lab in Oklahoma City
   - Aprel Labs in Ontario, Canada
   - Hough Ear Institute in Oklahoma City
   - Callier Center for Communication Disorders in Dallas, Texas
   - FDA in Rockville

Note: OU is considering additional resources with further EMC background

4. Hearing Aid companies that have provided test samples (Argosy Electronics, Oticon, Phonic Ear, Unitron, Starkey Lab and Dahlberg, Inc.). Also, suppliers of critical HA components have been contacted (e.g. Knowles Electronics)

5. ANSI/C63 EMC Committee and AAMI-EMC Committee

6. Phone companies providing test phones

## V. Phase II Research Goals

The next phase of our study will answer the following important questions:

1. What are the short term solutions to ìHA userî interaction problems?

2. What are the short term solutions to ìPasser-byî interaction problems?

3. What is the extent of the interference problems for HA users?

4. What are the long term solutions to the ìHA userî and ìPasser-byî interaction problems?

5. What are the effects of the various phone technologies?

6. What are the effects of the various HA technologies?

The specific objectives, deliverables and time tables for the above questions are given below:

### Q1: Short term solutions to HA user interaction problems

**Objectives:**

- Identify process to develop solutions from the international studies.
- Identify U.S. based solutions from HA manufacturers and cellular phone manufactures, if any.
- Examine the effectiveness of these solutions using HA wearers in clinical tests.

**Deliverables:**

- Extent of the interference problems to HA users.
- Effectiveness of existing or proposed (short term) solutions.
- Protocol for human subjects testing of HA interference.

**Time Table:**

- Initial results by January 1996.
- Preliminary report by March 1996
- Final Report by June 1996.
- Progress reviews bi-monthly (60 days) or sooner as significant results appear.

## Q2: Short term solutions to "Passer-by" interference problems

### Objectives

- Identify process to develop solutions to the ìPasser-byî problems from the international studies.
- Develop U.S. based solutions.
- Determine detection threshold distances for Hearing Aids and phone technologies not considered by the European studies.

### Deliverables

- Overall immunity levels for existing HA on the market
- User guides for buying HA with high immunity.
- Usage guidance, if practical

### Time Table

- Initial results by January 1996.
- Preliminary report by March 1996
- Final Report by June 1996.
- Progress reviews when significant activity concludes.

## Q3: Extent of the interference problem to HA users

### Objectives

- Obtain data from European and Australian studies.
- Obtain interference reports from HA trade organizations, user groups, and others in the U.S.
- Quantify the extent of interference.
- Perform human subjects and laboratory tests and actual usage ("Passer-by") tests.
- All NADC phone technologies, hearing aid types and other assistive devices (implants, FM systems, etc.) will be included. Priorities will be set based market penetration and usage statistics.

### Deliverables

- Quantification of the interference problem to HA users due to cellular phone usage by others.
- Quantification of the interference problem to HA wearers when they use cellular phones.

### Time Table

- Initial results by January 1996.
- Preliminary Report by March 1996.
- Final Report by June 1996.
- Progress reviews when significant activity concludes.

## Q4: Long term solutions to HA users

### Objectives

- Identify technical solutions through cellular system design (e.g., dynamic power control in mobile station; small cell sizes in Urban areas; use of discontinuous transmission)

- Identify technical solutions to HA design to reduce EMI (e.g. reducing HA size, shielding the HA by metallic coating, filtering with shunt capacitors at microphone or telecoil output or at amplifier circuit).
- Test the effectiveness of the above solutions, using human subjects and in the laboratory and in the user environment (passer by).
- Suggest, where possible, cooperative, practical, and cost effective approaches to both parties.

**Deliverables**

- Identification of appropriate measures to eliminate interference.
- Effectiveness of these measures in reducing EMI.

**Time Table**

- Preliminary results by April 1996
- Final Report by October 1996.
- Progress reports bi-monthly.

**Q5: Effects of various phone technologies on EMI**
**Objectives**

- Test the EMI characteristics of NADC phone technologies, particularly those not tested by European and Australian studies, such as, PCS 1900 and CDMA.
- Work with phone companies to develop solutions including cooperative work by the HA industry.
- Test the effectiveness of such solutions.

**Deliverables**

- Potential EMI problem to HA users due to the introduction of new phone technologies.
- Appropriate measures to eliminate interference.
- Probability of or risk of actual interference events.

**Time Table**

- Preliminary results by May 1996.
- Final Report by October 1996.
- Progress reports bi-monthly.

**Q6: Effects of various HA technologies**
**Objectives**

- Work with HA manufacturers and research labs to identify new EMI-reduced HA technologies (e.g. cochlear implant).
- Determine their impacts on EMI.

**Deliverables**

- Identification of new HA technologies that would significantly suppress interference problems.

## Time Table

- Preliminary results by May 1996.
- Final Report by October 1996.
- Bi-monthly progress reports.

## VI. Reporting of Results

- Bi-monthly progress, or significant breakthrough reports to the EMC Center Industry Advisory Board and to the HA Test Design Group.

- Review of Preliminary reports by the above groups, the HA manufacturers who have provided HA for tests and the phone companies who have provided the phones for tests.

- Preliminary reports are then released to the public with safeguards to protect the confidentiality of specific company names.

- Same procedures will be followed for the final report.

DRAFT

# PROTOCOL FOR THE STUDY OF HEARING AID INTERACTION WITH WIRELESS PHONES

Version 3.0

**CENTER FOR THE STUDY OF WIRELESS ELECTROMAGNETIC COMPATIBILITY**

SCHOOL OF INDUSTRIAL ENGINEERING
UNIVERSITY OF OKLAHOMA

September 11, 1995

## INTRODUCTION

This protocol has been developed in support of a study on the interaction between various types of wireless telephones and hearing aids to be conducted at the University of Oklahoma. The overall purpose of the study is to objectively and subjectively evaluate the interference between wireless phone technology and hearing aids. The Phase I objectives of the study are to:

1. define the test protocol for physical measurement of the interference generated in hearing aids by wireless phone signals of varying types. The resulting protocol shall produce repeatable results and include parameters such as field strength, threshold distance of interference, and intensity and frequency of the resulting audio interference output;

2. define a standard methodology for measuring the immunity of hearing aids, including standards for acceptable "noise floors"; and

3. define the test protocol for subjective measurement of the extent of the interference generated in hearing aids by wireless phone signals of varying types. The protocol shall include the use of both hearing-impaired and unimpaired individuals.

## BACKGROUND

This protocol is based on input from the references listed at the end of this document and from members of the Hearing Aid-Wireless Phone Interaction Study Design Group. Much of the protocol is based on a study conducted by the National Acoustic Laboratories, a division of the Australian Hearing Services (Le Strange, Byrne, Joyner, and Symons, 1995).

European and Australian clinical and laboratory studies have demonstrated that audible interference can be produced in hearing aids by hand-held wireless phones operated in close proximity (a few centimeters to several meters). This effect has been demonstrated in the US but little has been published in terms of research results.

This protocol encompasses both physical measurement of hearing aid interference (objective testing) and how this interference is perceived by hearing aid users (subjective testing). The model outlined by Bowen (1995) identifies one possible breakpoint that connects the objective and subjective testing. Physical testing involves the RF source, RF path, and the hearing aid (objective). Output from the hearing aid is acoustically coupled to the user who develops a perception of the interference signal (subjective). Objective and subjective tests can be independent.

## PROTOCOL FOR THE STUDY OF HEARING AID INTERACTION WITH WIRELESS PHONES

## CURRENT RESEARCH

Currently reported studies in Europe and Australia have examined the interference between hearing aids and analog wireless phones, D-AMPS phones, and GSM phones, all at 900 MHz. GSM, the predominant wireless phone technology outside of the US, uses a Time Division Multiple Access (TDMA) signal structure as do most digital wireless phones in the US (D-

AMPS). The TDMA principle results in the carrier being pulsed in a fashion that allows audio frequency devices (hearing aids, portable stereos, etc.) to demodulate the radio frequency (RF) envelope and produce a constant, distinctive buzzing sound. Various levels of interference to hearing aids from these TDMA signals have been reported. At a range of 3 to 5 meters, hearing aid users may experience a 200 Hz humming noise overpowering all other signals. The degree of interference depends on the output power of the phone and also varies widely by hearing aid type, with in-the-ear (ITE) devices typically having higher immunity than behind-the-ear (BTE) models. The level of interference is also affected by the relative orientation of the hearing aid and the phone. This is a particular problem for hearing aid wearers who wish to use wireless phones.

## Physical Measurements

Quantification of the sensitivity of a particular hearing aid (HA) to wireless phone interference is the first step in the ultimate development of immunity standards. Physical testing of HA immunity requires an RF signal source for generation and propagation of the appropriate cell phone signal, a controlled RF environment, a means for mounting and orienting the HA, and instrumentation for measuring the level of the audio interference output.

### RF Test Signal

Previous researchers have employed various RF test signals to represent the GSM RF signal, including:

1. a 900 MHz pulse modulated carrier with a modulation frequency of 217 Hz, a duty cycle of 1:8 and 100% modulation (EHIMA, 1993; Joyner et al., 1993; National Telecom Agency of Denmark, 1994), and
2. a 900 MHz carrier, 80% modulated by a 1000 Hz sine wave (IEC, 1994; Le Strange et al., 1995).

No reports have been located in which the physical measurement testing was conducted using actual wireless phones. Some subjective testing has been reported with actual phones (Le Strange et al., 1995).

*This study will use actual wireless phones. Some models will be "hot wired" or programmed in a continuous transmission mode. Other models will communicate with an HP 8920A RF Communications Test Set functioning as a base station simulator. This approach provides the greatest realism in terms of actual signal structure including the format for control and voice traffic (e.g., paging, power control, channel changes). This approach requires an accurate means of measuring RF field intensities generated by the phones at various distances.*

### RF Environment

Previous researchers have employed or compared various RF test environments, including:

1. a radio frequency anechoic room (EHIMA, 1993; IEC, 1994; Le Strange et al., 1995),
2. "stripline" consisting of a ground plane, stripline conductor, and 50 ohm resistive matching network (EHIMA, 1993), and
3. a waveguide (Joyner et al., 1993; Le Strange et al., 1995).

RF field intensities have either been fixed at 10 V/m or varied up to 200 V/m.

*None of the three previously used RF test environments have been selected for this study. Options 2 and 3 are precluded by the fact that actual phones along with their self-contained antennae will be used as the signal source. Testing will be conducted at the AT&T Open Area Test Site (OATS) in Oklahoma City. A radio frequency anechoic room (Option 1) is not currently available at this facility. Therefore, testing will be conducted within the shielded room at the OATS facility. The shielded room must also be characterized acoustically in that the room reverberation, if any, must not affect the test results. The possibility of using a GTEM cell and waveguide (Joyner et al., 1993) will also be explored.*

### Mounting and Orienting the Hearing Aid

The hearing aid must be positioned in the RF test field away from objects that could distort the field and in such a way that it can be manipulated for maximum interference. Previous protocols have used the following:

1. place HA in chamber in "normal use" position, rotate (clockwise) in 90° steps in the horizontal plane, measure interference at maximum SPL (EHIMA, 1993; IEC, 1994; National Telecom Agency of Denmark, 1994),
2. use both horizontal and vertical polarization of the RF field (EHIMA, 1993),
3. gimbal style mounting device for positioning HA in the waveguide about three axes, rotate for maximum pickup (Le Strange et al., 1995), and
4. mount within the Kemar head (no reference found at present).

*Discussions of the Study Design Group led to the conclusion that the Kemar head (Option 4) was not an effective means of mounting the hearing aids since it did not provide a good RF analog of the human head. Option 3 is unique to the waveguide approach which is not being used in this study. Options 1 and 2 will be combined through the use of a non-RF distorting mounting device for alignment of the HA and a device for positioning of the phone.*

### Measuring Hearing Aid Output

The output of the HA must be measured without introducing instrumentation that could distort the RF field or the performance of the meaurement system. This has typically been accomplished by using small diameter (2 mm) plastic tubing with a length between 50 mm and 500 mm to distance the HA and the acoustic monitor (IEC, 1994). Specific examples include:

1. ear simulator (IEC 711) to audio test station, amplifier, and DAT recorder via 500 mm tubing (EHIMA, 1993; National Telecom Agency of Denmark, 1994), and
2. standard 2 cc acoustic coupler to measuring microphone (B&K 4155) and measuring amplifier (B&K 2636) via 500 mm length of 2 mm Tygon© tubing (Le Strange et al., 1995).

*Option 2 will be used in this study based on available models of audio monitoring equipment.*

## Subjective (Psycho-acoustic) Measurements

Subjective evaluation of wireless phone interference is important since the detectability and annoyance of the interference depend on the individual hearing acuity of each HA user. Detectability and annoyance levels should be determined for hearing-impaired people with hearing losses appropriate to each type of HA. Persons with normal hearing should also be included to represent worst case situations of detectability and annoyance. Detectability can be determined through the application of standard psychophysical techniques such as the method of limits or method of constant stimuli. The degree of annoyance is typically ascertained through the use of subjective scaling techniques.

**Interference Source**

Subjects may be presented with either actual or recorded interference signals. Specific examples include:

1. recorded interference signal together with pink noise, "party sounds", or connected speech (EHIMA, 1993; National Telecom Agency of Denmark, 1994), and
2. actual phone with call placed to pre-recorded message (Le Strange et al., 1995).

A variation of Option 2 can be achieved through the use of the base station simulator and the cell phone loopback (talkback) mode or audio transmission from the base station.

**Detectability**

Interference can be recorded on DAT or generated directly with actual phones for evaluation of detectability. Any of the following schemes can be used:

1. samples of various levels of recorded interference can be replayed in random sequence at random intensity levels while subjects are asked to respond as to the presence or absence of interference,
2. subjects wearing hearing aids are tested by moving an actual phone across a number of test sites from far (4 m) to near and back while the subject indicates the presence or absence of an interference sound (Le Strange et al., 1995), and
3. subjects can listen through tubing to actual hearing aid output with the HA at various locations (e.g., close to phone as in listening to a call, one meter, and up to several meters). The acoustic level of interference is classified as: "not perceptible", "just perceptible", "moderately perceptible", and "annoyingly perceptible" (Le Strange et al., 1995).

**Annoyance/Usability**

The interference signal is presented at random intensity levels and/or varying distances while subjects are asked to respond with the corresponding level of annoyance. Examples of the scales used include:

1. "not annoying", "slightly annoying", "annoying", and "very annoying" (EHIMA, 1993), and
2. "usable", "sometimes usable", and "unusable" (Le Strange et al., 1995).

*Tests for Detectability and Annoyance will be combined using a hybrid mixture of Options 2 and 3 above under detectability. This provides a more authentic test for the extent of the*

*problem as determined by subjects listening to the actual interference. An audiologist will be used to evaluate the results.*

**Experimental Variables**

The experimental variables in the study consist of the independent variables which are manipulated, dependent variables which are measured, and control variables. The control variables are defined by the test environment ("test bed" and shielded room), test apparatus and experimental procedure. The dependent variables include the physical measurements and characteristics of the interference levels and immunity "scores", and the subjective responses for detectability and annoyance. The independent variables represent those factors which are tested to determine their influence on the dependent measures (both objective and subjective). Potential factors in this study are presented in outline form in the following section labeled Experimental Design.

## EXPERIMENTAL DESIGN

### FACTORS AND LEVELS

**Hearing Aids**

- **Hearing aid types**
  - Behind the ear (BTE)
  - In the ear (ITE)
  - In the canal (ITC)
  - Completely in canal (CIC)
    - (ITE, ITC and CIC comprise 80% of market)
- **New devices vs. current patients**
- **Specific manufacturers, models, units/model**
- **Modes of operation, frequency response tolerances, telecoil operation**

**Phones**

- **Phone technology (in priority order)**
  1. Analog @ 800 MHz
  2. TDMA (D-AMPS) @ 800 MHz (IS-54) and 1900 MHz (IS-136)
  3. MIRS (IDEN)
  4. CDMA @ 800 MHz (IS-95) and 1900 MHz (J008)
  5. PCS @ 1900 MHz (J007) - same as GSM @ 1900 MHz
  6. GSM @ 900 MHz (for benchmarking against prior European studies)
- **Participating Manufacturers**

**Test Procedure Variables**

**Distance between phone/simulator and HA**

**Side of head**

Ipsilateral (same side) vs. contralateral (opposite side) use

(important because of Class I vs. Class II standards)

Phone use by others vs. phone use by HA wearer

**Relative orientation**

Antenna position/field polarization

Angle of coupling (HA orientation)

## REFERENCES

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# HEARING-AID CELLULAR PHONE INTERACTION STUDY

# HEARING-AID CELLULAR PHONE INTERACTION STUDY

- OBJECTIVES
  - Survey Existing Literature
  - Develop Protocol for Test
  - Execute Test Plan
  - Recommend Solutions

# HEARING AID - CELLULAR PHONE INTERACTION STUDY

## Phase I Objectives

1. Define the test protocol for physical measurement of the interference generated in hearing aids by cellular phone signals of varying types. The resulting protocol shall produce repeatable results and include parameters such as field strength, threshold distance of interference, and intensity and frequency of the resulting audio interference output;

# HEARING AID - CELLULAR PHONE INTERACTION STUDY

**Phase I Objectives (cont'd)**

2. Define a standard methodology for measuring the immunity of hearing aids, including standards for acceptable "noise floors"; and

3. Define the test protocol for subjective measurement of the extent of the interference generated in hearing aids by cellular phone signals of varying types. The protocol shall include the use of both hearing-impaired and unimpaired individuals.

# HEARING AID - CELLULAR PHONE INTERACTION STUDY

<u>Phase II Objectives</u>

(1) Determination of overall immunity levels for hearing aids and user guides for buying hearing aids with high immunity.

(2) Identification of appropriate measures to eliminate interference.

- For phone technology (e.g. use of small cells, using dynamic power control, use of discontinuous transmission).

- For hearing aids (e.g. reducing size, shielding the equipment, filtering, etc.).

# HEARING AID - CELLULAR PHONE INTERACTION STUDY

**Phones to be Tested**

1. **Analog @ 800 MHZ**

2. **TDMA(D-AMPS) @ 800 MHZ (IS-54) and 1900 MHZ (IS-136)**

3. **MIRS**

4. **CDMA @ 800 MHZ (IS-95) and 1900 MHZ (J008)**

5. **PCS @ 1900 MHZ (J007)**

6. **GSM @ 900 MHZ (not used in US, but included for benchmarking against European studies)**

# HEARING AID - CELLULAR PHONE INTERACTION STUDY

**Hearing Aids to be included**

**Hearing Aid Types**

- **Behind the Ear (BTE)**
- **In the Ear (ITE)**
- **In the Canal (ITC)**
- **Completely in the Canal (CIC)**

**(ITE, ITC, and CIC comprise 80% of the market)**