



American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids

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American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids

Accredited Standards Committee on Electromagnetic Compatibility, C63™

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American National Standards Institute

Secretariat

Institute of Electrical and Electronic Engineers, Inc.

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The Accredited Standards Committee on Electromagnetic Compatibility, C63™, thanks the IEEE and Edwin L. Bronaugh (author) for granting permission to use *Helmholtz Coils for Calibration of Probes and Sensors: Limits of Magnetic Field Accuracy and Uniformity*, from the 1995 IEEE Symposium on EMC, Atlanta, GA, in Annex F of this standard.

Abstract: Uniform methods of measurement for compatibility between hearing aids and wireless communications devices are set forth.

Keywords: American National Standard, electromagnetic compatibility, hearing aid, hearing aid compatibility (HAC), measurement methods, operational compatibility, personal communications service (PCS), wireless communications device

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Introduction

This introduction is not a part of ANSI C63.19-2007, American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

In the fall of 1995 the Federal Communications Commission (FCC) initiated a Steering Committee to initiate a summit on Hearing Aid Compatibility and Accessibility to Digital Wireless Telecommunications. The goal of the summit was to formalize and continue discussions among the three key affected interests in this issue: organizations representing people with hearing loss, hearing aid manufacturers, and the digital wireless telephone industry. The ultimate purpose of the summit was to find a resolution of the interference problem that was acceptable to the industries involved.

A summit meeting was held on January 3–4, 1996, in Washington, DC. At this summit meeting three working groups were formed to pursue issue resolution. Subsequently, the Long-Term Solutions User and Bystander Interference Group reached a consensus that a standards project was needed to document the consensus definition of and method of measurement for hearing aid compatibility and accessibility to wireless telecommunications. Subsequently ANSI C63™ was petitioned to undertake the joint standards projects documenting the methods of measurement and defining the limits for hearing aid compatibility and accessibility to wireless telecommunications.

At its April 1996 meeting, ANSI C63™ established a task group under its subcommittee on medical devices (SC 8). The charge to this task group (TC C63.19) was to develop such standards in cooperation with representatives of organizations representing people with hearing loss, hearing aid manufacturers, the digital wireless telephone industry, and other interested parties. ANSI C63.19-2001 was the result of that committee's efforts.

The FCC adopted this standard to provide the technical requirements for its Report and Order establishing mandatory requirements for wireless hearing aid compatibility on July 10, 2003.^a Following the adoption by the FCC and for several reasons, including technical changes in wireless communications devices and hearing aids and new understanding coming from experience gained in working with the 2001 version of this standard, a new revision effort was started. The result of this revision effort culminated in the production of ANSI C63.19-2006.

During the final approval process for the ANSI C63.19-2006 version, several issues were raised. The working group and ANSI ASC C63™ decided to open an amendment project to deal with these issues. The successful completion of that effort resulted in the publication of this version of the standard, ANSI C63.19-2007.

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^a FCC Docket 03-168

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<i>Organization Represented</i>	<i>Name of Representative</i>
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American Council of Independent Laboratories (ACIL)	Michael F. Violette
.....	William Stumpf (<i>Alt.</i>)
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Cisco Systems	Werner Schaefer
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Dell Inc.	Richard Worley
ETS-Lindgren	Michael Foegelle
.....	Zhong Chen (<i>Alt.</i>)
Federal Communications Commission (FCC)	William Hurst
Food and Drug Administration (FDA).....	Jon P. Casamento
.....	Jeffrey L. Silberberg (<i>Alt.</i>)
Hewlett-Packard.....	Kenneth Hall
.....	Colin Brench (<i>Alt.</i>)
Information Technology Industry Council (ITIC)	John Hirvela
.....	Joshua Rosenberg (<i>Alt.</i>)
Institute of Electrical and Electronics Engineers, Inc. (IEEE)	Donald N. Heirman
IEEE-EMCS	H. Stephen Berger
.....	Donald Sweeney (<i>Alt.</i>)
Lucent Technologies.....	Dheena Moongilan
Motorola	Joseph Morrissey
.....	Jag Nadakuduti (<i>Alt.</i>)
National Institute of Standards and Technology (NIST).....	Dennis Camell

Polycom	Jeff Rodman
.....	Tony Griffiths (<i>Alt.</i>)
Research in Motion (RIM)	Paul Cardinal
.....	Masud Attayi (<i>Alt.</i>)
Samsung Telecommunications	Tony Riveria
.....	Kendra Green (<i>Alt.</i>)
Society of Automotive Engineers (SAE)	Poul Andersen
.....	Gary Fenical (<i>Alt.</i>)
Sony Ericsson Mobile Communications	Gerard Hayes
.....	Steve Coston (<i>Alt.</i>)
Telecommunication Certification Body (TCB) Council	Arthur Wall
.....	Tim Dwyer (<i>Alt.</i>)
Telecommunications Industry Association (TIA)	Stephen Whitesell
TUV-America, Inc.	David Zimmerman
Underwriters Laboratories	Michael Windler
.....	Robert Delisi (<i>Alt.</i>)
U.S. Department of Defense—Joint Spectrum Center	Marcus Shellman
.....	Joseph Snyder (<i>Alt.</i>)
U.S. Department of the Navy—SPAWAR	David Southworth
Individual Members	Robert Hofmann
.....	Daniel Hoolihan
.....	John Lichtig
.....	Ralph M. Showers
Members Emeritus	Warren Kesselman
.....	Herbert Mertel
.....	Norman Violette

At the time this standard was completed, C63™ Subcommittee 8 had the following membership:

Daniel Hoolihan, *Chair*

Matthew Bakke	Robert Hofmann	Jeffrey L. Silberberg
H. Stephen Berger	William Hurst	William Stumpf
Paul Cardinal	Bob Jenkins	James Turner
Jon P. Casamento	Victor Kuczynski	Michael F. Violette
Chrys Chrysanthou	Harry Levitt	Robert Wegner
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Donald N. Heirman	Werner Schaefer	Don Witters
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At the time this standard was completed, the C63™ Working Group had the following officers:

H. Stephen Berger, *Chair*

Tom Victorian, *Vice Chair*

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American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids

1. Overview

1.1 Scope

This standard applies to both wireless communications devices (WDs) and hearing aids. It sets forth uniform methods of measurement and parametric requirements for the electromagnetic and operational compatibility and accessibility of hearing aids used with WDs, including cordless, cellular, personal communications service (PCS) phones, and voice over internet protocol (VoIP) devices, operating in the range of 800 MHz to 3 GHz. However, this version is focused on existing services, which are in common use. Accordingly, in this version tests are provided for services in the 800 MHz to 950 MHz and 1.6 GHz to 2.5 GHz frequency bands. Future versions may add tests for other frequency bands, as they come into more common use.

This standard is intended to apply to all types of hearing aids with acoustic output, including, as examples, behind-the-ear (BTE), in-the-ear (ITE), in-the-canal (ITC), and completely-in-the-canal (CIC) types. Test methods are provided for hearing aids operating in acoustic (microphone input) mode or in tele-coil (T-Coil) input mode.

The field levels called for in various places shall be maintained within the limits for radio frequency (RF) safety, set forth in IEEE Std C95.1.¹

¹ For information on references, see Clause 2.

1.2 Purpose

The purpose of this standard is to establish categories for hearing aids and for WDs that can indicate to healthcare practitioners and hearing aid users which hearing aids are compatible with which WDs and to provide tests that can be used to assess the electromagnetic characteristics of hearing aids and WDs and assign them to these categories. The various parameters required, in order to demonstrate compatibility and accessibility are measured. The design of the standard is such that when a hearing aid and WD achieve one of the categories specified, as measured by the methodology of this standard, the indicated performance is realized.

In order to provide for the usability of a hearing aid with a WD, several factors must be coordinated as follows:

- RF measurements of the near-field electric (E) and magnetic (H) fields emitted by a WD to categorize these emissions for correlation with the RF immunity of a hearing aid
- H-field measurements of a WD emitted via the audio transducer associated with the T-Coil mode of the hearing aid, for assessment of hearing aid performance
- Measurements with the hearing aid and a simulation of the categorized WD T-Coil emissions to assess the hearing aid RF immunity in the T-Coil mode

The WD's RF and audio band emissions are measured. Hence, the following are measurements made for the WDs:

- 1) RF E-field emissions
- 2) RF H-field emissions
- 3) T-Coil mode, magnetic signal strength in the audio band
- 4) T-Coil mode, magnetic signal and noise articulation index
- 5) T-Coil mode, magnetic signal frequency response through the audio band

Corresponding to these quantities, the hearing aid is measured for the following:

- a) RF immunity in microphone mode
- b) RF immunity in T-Coil mode

The hearing aid T-Coil reception characteristics are also important when assuring the usability of the T-Coil mode. When these characteristics are coordinated, the goals of compatibility and accessibility are accomplished.

Two principal conditions expose hearing aid equipped users to undesired RF electromagnetic disturbances. The far-field condition corresponds to the type of field a hearing aid equipped bystander would experience when adjacent to a WD user. The near-field condition corresponds to the more intense fields that a hearing aid equipped user of a WD would experience. This standard assesses the near-field or user condition.

This standard describes preferred test methods and test facilities and, in some cases, alternative test methods and facilities. If alternative test methods or facilities are employed, every effort shall be made to establish correlation with the preferred ones. Any deviation from the preferred test methods, as set forth in this standard, shall be fully described in the test report.

Wherever the word *shall* is used in this standard, it indicates something mandatory. The word *should* indicates something that is advisory. The word *may* indicates an option, which is at the discretion of the test engineer.

1.3 Organization and use of the standard

These technical requirements define the measurement methods and categorical levels to ensure hearing aid operational compatibility with WDs.

To ensure hearing aid and WD compatibility, it is essential that uniform measurement methods be defined for hearing aid immunity to E- and H-fields and WD emission of E- and H-fields. In addition, in order to provide for T-Coil mode, the WD T-Coil signal must be evaluated for signal strength, intended/unintended signal ratio and the frequency response of the signal in the audio band.

There are several factors impacting hearing aid performance when used in the presence of a WD. The hearing aid can be exposed to near-field illumination (when the hearing aid user uses a WD) or to far-field illumination (when the radiating element is at a distance from the hearing aid user). Different styles of hearing aids (BTE, ITE, ITC, and CIC) are positioned differently with respect to the WD. WDs can operate at different frequencies and utilize different transmission schemes.

Hearing aids can operate in an acoustic coupling mode or a T-Coil coupling mode. In acoustic mode, hearing aids use a microphone to pick up acoustic sound waves generated by the WD. In T-Coil mode, the microphone output is disabled (or attenuated) and a H-field signal, generated by the WD becomes the signal source. During T-Coil operation the H-field generated by the WD is intended to be the primary coupling mechanism to the hearing aid. The WD also can produce unintended H-fields (the result of circulating currents). Such H-fields produce noise, if detected during T-Coil operation, or may introduce interference in hearing aid circuits, even in the acoustic mode.

The WD generates an electromagnetic field as the main communication means with the public telephone network. However, it is possible for this field to interfere with the hearing aid's proper operation. Interference is produced as a result of pickup and demodulation within the hearing aid circuitry. The goal is to control the E-field and H-field distribution such that levels in direct proximity to the hearing aid (with WD in normal position) are manageable and do not interfere with basic hearing aid functionality.

The technical requirements have been organized into nine general clauses. The following is a summary of each clause:

- 1 *Overview*: Describes the scope and purpose of the standard.
- 2 *Normative references*: References used in this standard.
- 3 *Definitions, acronyms, and abbreviations*: Definitions, acronyms, and abbreviations used in this standard.
- 4 *Wireless device, RF emissions test*: Prescribes the measurements of the near E- and H-fields generated by pulsed RF WD in the region controlled for use by a hearing aid.
- 5 *Hearing aid RF near-field immunity test*: Prescribes the measurement method to be used in determining the immunity level of a hearing aid to radiated electromagnetic fields originating from a WD.
- 6 *Wireless device T-Coil signal test*: Describes the WD T-Coil signal measurement. Two quantities are measured: the desired and undesired H-field levels.
- 7 *Performance criterion*: Provides the criterion required for acceptable interoperability of a hearing aid with a WD. When these criteria are met, as defined by the tests described in this standard, a hearing aid operates acceptably with a WD. The performance criterion for the T-Coil mode is contained in 7.3.1 and 7.3.2. This standard provides the set of parameters for the microphone and T-Coil modes of operation.

- 8 *Calibration and measurement uncertainty*: Provides guidance for estimating the uncertainty and reproducibility of measurements made in accordance with this standard.
- 9 *Test report*: Outlines the general requirements of the test report and follows the similar arrangement described in ANSI C63.4-2003, Clause 10.

Figure 1.1 depicts the organization and use of this standard. Both the WD and hearing aid have mandatory tests, in Clause 4 through Clause 6. These provide for both microphone and T-Coil modes of operation. The appropriate test is run for each device and a category is determined, using the parameters found in Clause 7. The category information is then made available to the end user. Using the category information from both a WD and hearing aid the end user is able to determine the performance to be expected from any particular WD and hearing aid combination. Clause 8 and Clause 9 provide guidance on calculating the measurement uncertainty and preparation of the test report. The test report is delivered to the relevant authority, requiring the testing.

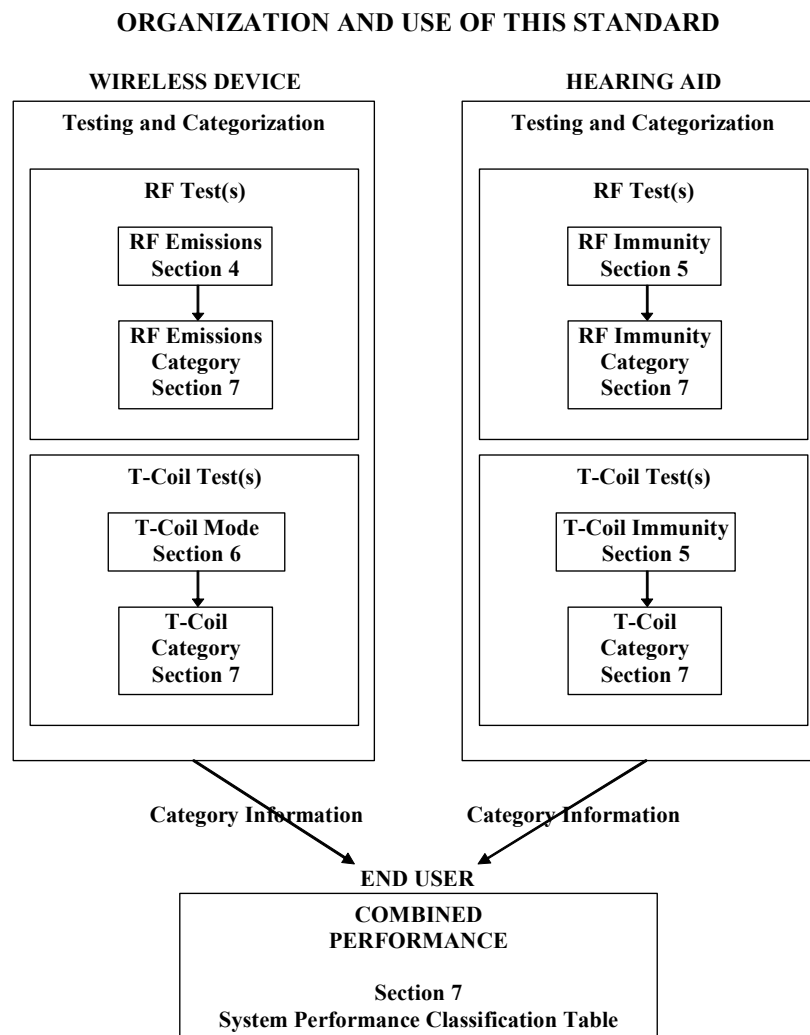


Figure 1.1—Organization of this standard

Using the category system, a user may determine whether a particular WD will be compatible and generally usable with a particular hearing aid. To do this, the immunity rating of the hearing aid is added to the emissions rating of the WD. A sum of 4 would indicate that the combination of WD and hearing aid is usable. A sum of 5 would indicate that the WD and hearing aid would provide normal use, and a sum of 6 or greater would indicate that the WD and hearing aid would provide excellent performance.

The measurements of WD emissions and hearing aid electromagnetic compatibility (EMC) are performed fairly close to the source of these emissions, where small errors in instrumentation, electromagnetic field measurements, and hearing aid position can manifest in large uncertainties in measurement results. Clause 8 describes the uncertainties involved in these measurements and instrument calibration procedures to control these.

This standard also contains several annexes with additional information about the measurements, instrumentation, calibration of instruments, and uncertainty of the measurements.

This standard is intended to provide a measure of the compatibility between hearing aid devices and WD products. The device categories are based on testing with hearing aid devices in the laboratory and in actual use. However, there is a wide range of human perceptions of normal communications with WD or even wired communications. Thus, even when compatibility between a particular hearing aid and WD is indicated by these tests, it cannot be guaranteed that the vocal output of the WD will be intelligible to all users of the two devices.

2. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C63.4, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.²

ANSI C63.14, American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD).

ANSI S3.22, American National Standard for Specification of Hearing Aid Characteristics.

Cellular Telecommunications and Internet Association (CTIA) Performance Evaluation Standard for 800 MHz AMPS and Cellular/PCS CDMA Dual Mode Wireless Subscriber Stations, 2003, Revision 3.21.

CISPR/TR 16-4-1, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 4-1: Uncertainties, Statistics and Limit Modelling—Uncertainties in Standardized EMC Tests.³

CISPR 16-4-2, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 4-2: Uncertainties, Statistics and Limit Modelling—Uncertainty in EMC Measurements.

CISPR/TR 16-4-3, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 4-3: Uncertainties, Statistics and Limit Modelling—Statistical Considerations in the Determination of EMC Compliance of Mass-Produced Products.

² ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ CISPR documents are available from the International Electrotechnical Commission, 3, rue de Varembe, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). They are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

CISPR/TR 16-4-4, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 4-4: Uncertainties, Statistics and Limit Modelling—Statistics of Complaints and a Model for the Calculation of Limits.

Code of Federal Regulations Title 47 Part 2 (47CFR2), Frequency Allocations and Radio Treaty Matters; General Rules and Regulations.⁴

Code of Federal Regulations Title 47 Part 6 (47CFR6), Subpart C, Access to Telecommunications Service, Telecommunications Equipment, and Customer Premises Equipment by Persons with Disabilities.

Code of Federal Regulations Title 47 Part 15 (47CFR15), Radio Frequency Devices.

Code of Federal Regulations Title 47 Part 20 Section 19 (47CFR20.19), Hearing Aid-Compatible Mobile Handsets.

Code of Federal Regulations Title 47 Part 22 (47CFR22), Public Mobile Services.

Code of Federal Regulations Title 47 Part 24 (47CFR24), Personal Communications Services.

Code of Federal Regulations Title 47 Part 68 (47CFR68), Connection of Terminal Equipment to the Telephone Network.

Code of Federal Regulations Title 47 Part 90 (47CFR90), Private Land Mobile Radio Services.

Code of Federal Regulations Title 47 Part 90 (47CFR90), Subpart S, Specialized Mobile Radio Services.

IEC 60118, Hearing Aids—Part 0: Measurement of Electroacoustical Characteristics.⁵

IEC 60118-1, Hearing Aids—Part 1: Hearing Aids with Induction Pick-Up Coil Input.

IEC 60118-7, Hearing Aids—Part 7: Measurement of the Performance Characteristics of Hearing Aids for Production, Supply and Delivery Quality Assurance.

IEC 60126, IEC Reference Coupler for the Measurement of Hearing Aids Using Earphones Coupled to the Ear by Means of Ear Inserts.

IEC 60711, Occluded-Ear Simulator for the Measurement of Earphones Coupled to the Ear by Ear Inserts.

IEC 61000-4-3, Electromagnetic Compatibility (EMC)—Part 4: Testing and Measurement Techniques—Radiated, Radio Frequency, Electromagnetic Field Immunity Test.

IEC 61094-2, Measurement Microphones—Part 2: Primary Method for Pressure Calibration of Laboratory Standard Microphones by the Reciprocity Technique.

IEC 61094-3, Measurement Microphones—Part 3: Primary Method for Free-Field Calibration of Laboratory Standard Microphones by the Reciprocity Technique.

IEC 61094-4, Measurement Microphones—Part 4: Specifications for Working Standard Microphones.

⁴ U.S. Regulatory Guides are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (<http://www.access.gpo.gov/>).

⁵ IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

IEEE Std 269™, IEEE Standard Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets, Handsets, and Headsets.^{6,7}

IEEE Std 1027™, IEEE Standard Method for Measurement of the Magnetic Field in the Vicinity of a Telephone Receiver.

IEEE Std 1309™-2005, IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz.

IEEE Std C95.1™, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

IEEE Std C95.3™, IEEE Recommended Practice for the Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields, 100 kHz–300 GHz.

ISO 3-1973, Preferred Numbers—Series of Preferred Numbers.⁸

ISO 266-1975, Acoustics—Preferred Frequencies.

ITU-T Recommendation P.79, Calculation of Loudness Ratings for Telephone Sets.⁹

ITU-T, Blue Book, Volume V, P.37, Telephone Transmission Quality Series P Recommendations, Recommendation, Magnetic Field Strength around the Earcap of Telephone Handsets which Provide for Coupling to Hearing Aids.

ITU-T, Blue Book, Volume V, P.50-1993, Telephone Transmission Quality Series P Recommendations, Recommendation, Artificial Voices.

NIS 81: Edition 1, May 1994, The Treatment of Uncertainty in EMC Measurements.¹⁰

NIS 3003: Edition 8, May 1995, The Expression of Uncertainty and Confidence in Measurement for Calibrations.

NIST Technical Note 1297, Sept. 1994, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results.

SAE J551/1, Performance Levels and Methods of Measurements of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (50 Hz to 18 GHz).¹¹

TIA/EIA/IS-55-A (Sept. 1993), Recommended Minimum Performance Standards for 800 MHz Dual-Mode Mobile Stations.¹²

⁶ The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

⁷ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁸ ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁹ ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Genève 20, Switzerland/Suisse (<http://www.itu.int/>).

¹⁰ NIS standards are published by NAMAS (UKAS) and may be ordered from UKAS, National Physical Laboratory, Teddington, Middlesex, TW11 0LW, U.K.; Tel. 011-81-943-7140, FAX 011-81-943-7134.

¹¹ SAE publications are available from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096, USA (<http://www.sae.org/>).

¹² TIA/EIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

TIA/EIA/IS-91 (Oct. 1994), Mobile Station—Base Station Compatibility Standard for 800 MHz Analog Cellular.

TIA/EIA/IS-95 (July 1993), Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System.

TIA/EIA-136 Series, 800 MHz TDMA Cellular Standards.

TIA/EIA/IS-2000 Series, CDMA 2000 Series, Release 0.

TIA/EIA TSB31-A Part 68 (Mar. 1992), Rationale and Measurement Guidelines.

UKAS M3003 (Dec. 1997), The Expression of Uncertainty and Confidence in Measurement.¹³

3. Definitions, acronyms, and abbreviations

The definitions given in ANSI C63.14-1998 and IEEE 100 [B31]¹⁴ apply throughout this standard, unless otherwise noted in 3.1. Particular product standards or applicable regulation definition take precedence. Definition sources (if applicable) are enclosed in brackets or parentheses following the definition.

3.1 Definitions

3.1.1 accessibility: The capability of a WD used together with a hearing aid device to provide the audibility and intelligibility needed for communication.

3.1.2 anechoic enclosure: An enclosure whose internal walls have low reflection characteristics. [ANSI C63.14-1998]

NOTE—Note that this implies that all six surfaces of the enclosure have low reflection characteristics for incident waves. For audio use, the anechoic enclosure may not necessarily be a metallic enclosure; for RF applications, the anechoic enclosure is a shielded (against RF ingress or egress) metallic enclosure. Both types of enclosures use absorbing material (suited to the frequency range of use) to implement the low reflection characteristics desired.¹⁵

3.1.3 articulation weighting factor (AWF): A weighting factor that is used to normalize readings of interference from differing sources based upon the acoustic spectral content of the interference. As one example, interference created by a 217 Hz TDMA source degrades hearing intelligibility by approximately 5 dB more than that from a 50 Hz TDMA signal. This is because of the relative impact of the 217 Hz interference signal on the regions of the audio spectrum that are most important to speech recognition.

3.1.4 audio coupling mode: Transmission of a signal between two pieces of equipment using sound.

3.1.5 audio frequency: Any frequency corresponding to a normally audible sound wave. (IEEE 100 [B31])

NOTE 1—Audio frequencies range roughly from 15 Hz to 20 000 Hz.

NOTE 2—This term is frequently shortened to audio and used as a modifier to indicate a device or system intended to operate at audio frequencies, for example, audio amplifier.

¹³ UKAS documents are available at http://www.ukas.com/information_centre/publications.asp.

¹⁴ The numbers in brackets correspond to those of the bibliography in Annex K.

¹⁵ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

3.1.6 audio band: The frequency range from 15 Hz to 20 000 Hz. *See:* **audio frequency.**

3.1.7 audio band magnetic signal—desired (ABM1): Measured quantity of the desired magnetic signal.

3.1.8 audio band magnetic signal—undesired (ABM2): Measured quantity of the undesired magnetic signal, such as interference from battery current and similar non-signal elements.

3.1.9 audio band magnetic (ABM) articulation weighting factor: Audio band magnetic AWF from ABM1 and ABM2.

3.1.10 band: Frequency range between two defined limits. (IEEE 100 [B31])

3.1.11 bandwidth: The range of frequencies within which performance, with respect to some characteristic, falls within specific limits. (IEEE 100 [B31])

3.1.12 compatibility: The capability of a WD and a hearing aid, used together, to provide the user with the audibility and intelligibility needed for communication. The more specific term T-Coil compatibility means that the coupling of the WD signal to the hearing aid T-Coil meets the requirement set forth in this standard.

3.1.13 dBm0: Power level in dBm, relative to a reference point called the zero transmission level point, or 0 TLP. A signal level of X dBm at the 0 TLP is designated X dBm0. In a codec, the 0 TLP is specified in relationship to the full-scale digital level or saturation. However, digital saturation is generally not 0 dBm0. For m-law codecs 0 dBm0 is 3.17 dB below digital full scale. For A-law codecs 0 dBm0 is 3.14 dB below digital full scale.

3.1.14 digital wireless telephone: RF-based, wireless telephones utilizing digital transmission formats over an air interface.

NOTE—Generally these are devices regulated under Parts 15, 22, and 24 of the Rules of the Federal Communications Commission. Annex G contains a more detailed discussion of these devices.

3.1.15 directional coupler: A transmission coupling device for separately (ideally) sampling (through a known coupling loss for measuring purposes) either the forward (incident) or the backward (reflected) wave in a transmission line. (IEEE 100 [B31])

3.1.16 far-field region: That region of the field of an antenna where the angular field distribution is essentially independent of the distance from a specified point in the antenna region.

NOTE 1—For a half-wavelength dipole, the reference point is usually taken as the center of the antenna, but may be anywhere on the surface of the antenna.

NOTE 2—For a half-wavelength dipole, the far-field region is considered to exist at distances much greater than $\lambda/2\pi$, where λ is the wavelength. For a half-wavelength dipole, this distance is at the geometric center of the transition region between the near-field and far-field regions.

NOTE 3—The distance 3λ is considered to lie in the far-field region. (IEEE 100 [B31]; (EMC) 377-1980r)

3.1.17 forward power: That power supplied by the output of an amplifier (or generator) traveling towards a load. [SAE J551/1]

3.1.18 gigahertz transverse electromagnetic chamber (GTEM): *See:* **wideband TEM (WB TEM) cell.**

3.1.19 hearing aid: A professionally dispensed, wearable, air-conduction, sound amplifying device that is intended to compensate impaired hearing.

3.1.20 input referenced ambient noise (IRAN): The equivalent acoustic input sound pressure level that would produce the acoustic noise output observed from a hearing aid. IRAN may be obtained by subtracting the acoustic gain in decibels from the acoustic noise output.

3.1.21 input referenced interference level (IRIL): The equivalent acoustic input sound pressure level (typically at 1 kHz) that would produce the same acoustic output in a hearing aid as that produced by an RF interference source. IRIL may be obtained by subtracting the acoustic gain in decibels from the acoustic interference output.

3.1.22 intentional radiator: A device that intentionally generates and emits RF energy by radiation or induction. [FCC 15.3(o)]

3.1.23 measurement reference point: Generally, the center of the earpiece receiver speaker openings. Physical location may be offset from earpiece center, if a secondary induction source is used.

NOTE—Wireline phones referenced this as ERP (ear reference point), this conflicts with the use of ERP as effective radiated power.

3.1.24 near-field region: That part of space between the antenna and the far-field region. (IEEE 100 [B31]: (AP) 145-1993)

NOTE 1—The near field includes the quasi-static and induction fields varying as r^{-3} and r^{-2} , respectively, but does not include the radiation field varying as r^{-1} (IEEE 100 [B31]: (PE/T&D) 1260-1996).

NOTE 2—For a half-wavelength dipole, the near-field region is considered to exist at distances much less than $\lambda/2\pi$, where λ is the wavelength.

NOTE 3—For a very short dipole, or equivalent radiator, the outer boundary is commonly taken to exist at a distance of $\lambda/2\pi$ from the antenna surface. (IEEE 100 [B31]: (AP) 145-1993)

NOTE 4—For the purposes of this standard, the near field is considered to be a distance of no more than 1/5 of a wavelength from the WD at the operating frequency. Therefore, the near field is calculated to be 75 mm for 800 MHz, decreasing to 20 mm for 3 GHz.

3.1.25 net power: Forward power minus reflected power at the same location on a transmission line. [SAE J551/1]

3.1.26 personal communications service device: Intentional radiators operating in the frequency band specified by the applicable regulating agency that provide a wide array of mobile and ancillary fixed communication services to individuals and businesses. [Modification of FCC 15.303(g)]

3.1.27 quality factor: The ratio of the resonance frequency to the bandwidth between the frequencies on opposite sides of the resonance frequency (known as half-power points) where the response of the resonant structure differs by 3 dB from that at resonance. (IEEE 100 [B31])

3.1.28 reflected power: That power traveling towards the amplifier (or generator) reflected by a load caused by impedance mismatch between the transmission line and load. [SAE J551/1]

3.1.29 shielded enclosure: A mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and the external environment. [ANSI C63.14-1998]

3.1.30 sound pressure level (SPL): The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. (IEEE 100 [B31])

NOTE—For this standard, the reference level shall be 20 μ Pa.

3.1.31 tele-coil (T-Coil): An inductive coil used in some hearing aids to allow reception of an audio band magnetic field signal, instead of an acoustic signal. The magnetic or inductive mode of reception is commonly used in conjunction with telephones, auditorium loop systems, and other systems that provide the required magnetic field output.

3.1.32 transverse electromagnetic (TEM) cell: A measuring device that is designed to utilize the TEM mode over the frequency range of interest. Common examples are the two port TEM cell (also known as the Crawford Cell) and the wideband TEM cell. [ANSI C63.4-2003]

3.1.33 wavelength (λ): Of a monochromatic wave, the distance between two points of corresponding phase of two consecutive cycles in the direction of the wave normal. (IEEE 100 [B31])

3.1.34 wideband TEM (WB TEM) cell: A TEM cell that has been altered to extend the usable frequency range. Often this is achieved by replacing one port of a two port TEM cell with a wideband load. One example is commonly called a GTEM (gigahertz transverse electromagnetic). [ANSI C63.4-2003]

3.1.35 wireless communications device (WD): A communications device using RF energy. These devices are used in a wireless communications networks such as cellular or personal communication service.

3.2 Acronyms and abbreviations

ABM	audio band magnetic
ABM1	audio band magnetic signal—desired
ABM2	audio band magnetic signal—undesired
AGC	automatic gain control
AI	articulation index
AM	amplitude modulation
AMPS	advanced mobile phone system
ANSI	American National Standards Institute
AWF	articulation weighting factor
BTE	behind the ear (hearing aid)
CCDF	complementary cumulative distribution function
CDF	cumulative distribution function
CDMA	code division multiple access
CFR	Code of Federal Regulations
CIC	completely in the canal (hearing aid)
CW	carrier wave
DAI	digital audio interface
dB	decibel
dBc	decibels below carrier
dB SPL	decibels referenced to a sound pressure level of 20 μ Pa
dBm0	power level in dBm relative to zero transmission level point
DTX	discontinuous transmission
EHIMA	European Hearing Instrument Manufacturers Association
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ETSI	European Telecommunications Standards Institute
f	frequency
FDTD	finite difference time domain
FFT	fast Fourier transform
GSM	Global System for Mobile communication
GTEM	gigahertz transverse electromagnetic
HFA	high frequency average

i.d.	inside diameter
iDEN ^{®16, 17}	integrated digital enhanced network
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IRAN	input referenced ambient noise
IRIL	input referenced interference level
ISO	International Organization for Standardization
ITC	in the canal (hearing aid)
ITE	in the ear (hearing aid)
ITU	International Telecommunications Union
kHz	kilohertz
MHz	megahertz
NADC	North American Digital Cellular
o.d.	outside diameter
OSPL	output sound pressure level
P	transmit power or forward power (watts)
PAR	peak to average power ratio
PC	personal computer
PCM	pulse code modulation
PCS	personal communications services
PEP	peak envelope power
RL	return loss
Q	quality factor
QAM	quadrature amplitude modulation
RBW	resolution bandwidth
RF	radio frequency
RLR	receive loudness rating
RTP	reference test position
rms	root mean square
Rx	receiver
SPL	sound pressure level
T-Coil	tele-coil
TDMA	time division multiple access
TEM	transverse electromagnetic
TMFS	telephone magnetic field simulator
Tx	transmitter
UARFCN	UTRA absolute radio frequency channel
UKAS	United Kingdom Accreditation Service
UMTS	Universal Mobile Telecommunications System
UTRA	universal terrestrial radio access
VoIP	voice over internet protocol
VSWR	voltage standing wave ratio
WB TEM	wideband transverse electromagnetic
WCDMA	wideband code division multiple access
WD	wireless communications device

¹⁶ The following information is given for the convenience of users of this standard and does not constitute an endorsement by the IEEE of these products.

¹⁷ iDEN is a registered trademark of Motorola, Incorporated.

4. Wireless device, RF emissions test

This clause provides guidance on the measurements of the near E- and H-fields generated by WDs in the region controlled for use by a hearing aid. Clause 5 sets forth the companion measurement, the immunity of the hearing aid. For the purposes of this standard, the term pulsed refers to the use of a noncontinuous RF envelope or carrier. Examples of wireless telephone systems of this type are described in Annex G. These systems may be deployed at a variety of RF frequency ranges, but this standard is restricted to the range of 800 MHz to 3 GHz. Additionally, it is generally considered sufficient to measure a particular pulsed RF WD at the frequencies at which the WD is capable of transmission as part of its normal operation, as specified by the manufacturer. However, the evaluation need not be limited to those frequencies.

As is stated in the scope (see 1.1) and organization and use (see 1.3) subclauses of this standard, the issue of interest is “interference to hearing aids.” To that end, the purpose of the measurements in this clause is to measure the quantity of the RF signal most closely correlated with the intensity of interference to hearing aids.

The following discussion is given to clearly and succinctly describe the physical quantity to be measured.¹⁸ This quantity, which shall be called “RF interference level,” is defined by the following characteristics. Conceptually, this definition is intended to correlate to the user perception of interference received through an idealized hearing aid and is characterized by the following attributes (depicted in Figure 4.1):

- The full signal bandwidth shall be presented to a wideband detector, meaning that the sensing elements and the detector shall have a bandwidth greater than or equal to the emission bandwidth.
- The RF signal shall be detected by a square law detector.¹⁹
- The post-detection, recovered audio signal shall be limited to greater than or equal to the audio band.²⁰
- The typical response of human hearing is applied to the detected signal before determining the final category.²¹

The test procedure specified in this revision does not yet address all elements of the preceding conceptual model.

¹⁸ In some cases the instrumentation use to measure this quantity can perform a direct measurement. In other cases, a compensation, known as a probe modulation factor, must be utilized, to accurately measure the required RF value.

¹⁹ After the square law detector, the signal is the recovered audio interference that would be received by a hearing aid.

²⁰ The signal that is available after the square law detector is the post-detection signal. It contains the demodulated AM envelope and therefore the recovered audio signal. However, it also contains components that are outside the audio band and therefore, this step calls for the signal to be band limited to the audio band.

There is general agreement that for hearing aid users the upper boundary of the audio band is no higher than the 20 kHz specified in the definition of the audio band. A final determination on the lower boundary band and the frequency weighting within the audio frequency band has not been made. A-weighting has been shown to be a good predictor of human perception for steady-state interference but is not necessarily valid for interference that has substantial variation over time.

²¹ The committee is continuing to study a generalized method for characterizing the human perception of interference signals. Human hearing is characterized by several characteristics of the signal, including its spectral and temporal features. A typical characterization might be an rms reading of the audio signal over a period of 120 ms $\pm$ 30 ms and taking the highest value during any 2 s period to arrive at a final reading in determining the category. The value of 120 ms is selected because it is consistent with the natural integration time of the human ear. The 2 s interval is selected to be consistent with the “click” relaxation in ANSI C63.4-2003, CISPR 14, and CISPR 16. Generally, variations in volume that occur less frequently than 2 s do not disrupt word recognition. However, a final determination of these values has not been made in this revision.

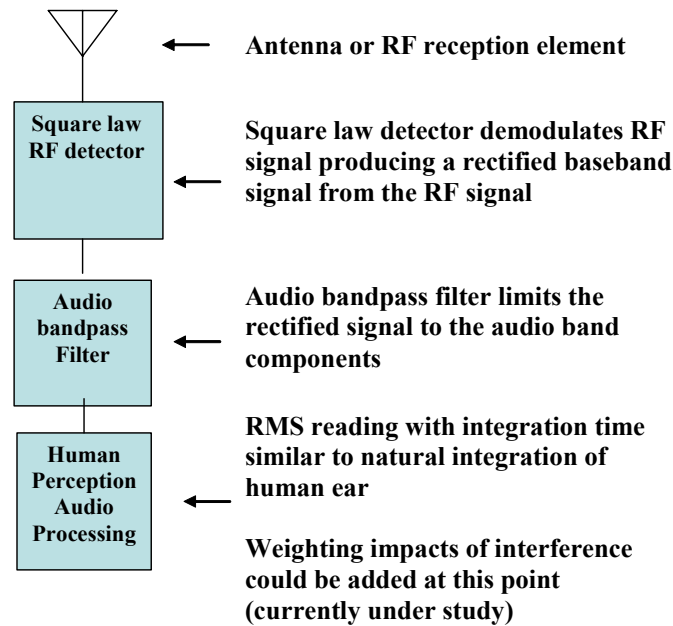


Figure 4.1—Conceptual model of RF interference level

4.1 Measured RF interference level

Measurement of the “RF interference level” requires adaptations for the test equipment being used. The purpose of Clause 4 is to give guidance on the proper measurement of the “RF interference level.” Guidance on the proper measurement of the “RF interference level” is provided in the remainder of this subclause and related annexes, particularly Annex C and Annex D.

The instrumentation specification and test instructions that follow in this subclause and its related annexes are intended to provide guidance on properly measuring this quantity.

- 1) The RF signal shall be delivered to a square law detector with a bandwidth greater than or equal to the emission bandwidth.
- 2) The post-detection signal, after the square law detector, contains the recovered audio interference that would be received by a hearing aid and might be heard by a hearing aid user.

The detected signal shall be measured so as to provide a result equivalent to a probe connected to a spectrum analyzer, using the instrument settings in Table 4.1.

- 3) (See Table 4.1.)
- 4) Convert the reading to field strength by applying the probe calibration factor including probe modulation factor per C.3 to obtain the final RF interference level field strength. If the probe and its associated instrumentation has a response bandwidth of ≥ 20 kHz and is calibrated accordingly, the desired quantity may be measured directly. Otherwise, a probe modulation factor shall be used to determine the final value of the reading.
- 5) Apply the scan procedures of 4.4 to identify the position of maximum field strength.
- 6) Use the resulting reading at the location of maximum field strength to determine the category per 7.2.

Table 4.1—Spectrum analyzer settings for measurement of RF interference level

RBW	$\geq$ Emission bandwidth ^a
Video bandwidth	≥ 20 kHz ^b
Span	Zero
Center frequency	Nominal center frequency of channel
Amplitude scale	Linear (Logarithmic scale may be used if it provides the same result as in linear mode. Care shall be taken if a logarithmic scale is used to assure that it produces the same result as the linear scale.)
Detection	Peak detection ^c
Trigger	Video or IF trigger, adjusted to give a stable display of the transmission
Sweep rate	Sufficiently rapid to permit the complete transmit pulse to be resolved accurately. In addition, the sweep time shall be set to display a full transmission cycle, including the on and off time.

^a To measure the emission bandwidth follow the procedure provided in ANSI C63.17, Clause 6.

^b Spikes shorter than 50 μ S do not need to be measured as they fall outside of the audio band. This can be accomplished by setting the video bandwidth to 20 kHz.

^c The peak transmit power is the maximum of the rms power during a transmit burst. Typical spectrum analyzers are frequency-selective, peak-responding voltmeters calibrated to display the rms value of a sine wave. Therefore, using the peak detection function on most spectrum analyzers will produce the intended measurement when the bandwidth and trigger functions are properly set.

4.2 Test equipment and facilities

Portions of this standard place requirements on the test facilities, in addition to the general requirements of ANSI C63.4, and are discussed in this clause, as well as in C.1. Unless stated otherwise, the requirements of ANSI C63.4 apply to the test facilities, including the site design, dimensions, and validation. Additional site validation requirements above 1 GHz are currently under development.

The stability of the measurement equipment, facilities and setup can significantly affect the accuracy of the measurement. Therefore it is important that a careful review be made of the factors affecting measurement uncertainty, as described in Clause 8 and Annex E. Efforts made to reduce the measurement uncertainty improve the stability and reproducibility of the measurement.

4.2.1 Test equipment

This subclause provides a list of the test equipment required to perform this test. The test equipment used shall meet the applicable specifications of Annex D.

- 1) E-field, near-field probe
- 2) H-field, near-field probe
- 3) Probe positioning system
- 4) WD support
- 5) Reference dipole antenna as described in 4.3.2 and D.5
- 6) RF enclosure, if applicable

4.2.2 Near-field measurement system

The near-field measurement system shall consist of a small, with respect to a wavelength, E-field probe and an H-field probe, suitable for measuring the field strength of the RF fields. Typically such probes are constructed of low dielectric plastics and utilize high resistance conductors to deliver the measurement information from the active element to the measurement equipment.

IEEE Std C95.3 advises that to avoid certain measurement errors, a probe should not be used closer than a distance equal to three times the length of the active elements of the probe. The probes shall meet the requirements given in D.10 for the E-field and D.11 for the H-field probes.

The use of an automated movement system, such as robotic arms or three-axis positioners, is preferred, as it can provide superior probe placement accuracy and placement repeatability. However, each system used shall be verified as having the required placement accuracy and repeatability. Alternatively, manual placement systems may be used. It is recommended that a placement fixture be used with manual systems to assist in accurate probe placement. Such a fixture should be constructed of expanded foam or other RF-transparent materials.

A non-isotropic probe may be used, such as a probe with a single loop for H-field or a probe with a coaxial cable to allow both frequency and amplitude measurements. For single-axis probes, the initial scan shall be done in all three axes. In these cases the orientation of the probe and routing of the cabling shall be recorded in the test report.

The probe shall be held in such a way as to not significantly influence the readings. For manual measurements, the use of an extension handle, made of low dielectric material, allows the body of the operator to remain sufficiently distant from the test area. In addition, such a probe handle can also serve to assist in maintaining the required 10 mm separation distance from the nearest point on the probe element(s) to the reference plane for the WD under test.

4.2.2.1 Probe modulation factor

In consideration of the measurement probes' responses to the RF power envelope employed by the WD, for probes and instruments with a response bandwidth of < 20 kHz a probe modulation conversion factor must be applied to the E-field and H-field probe readings, in order to accurately determine the "RF interference level."²² The procedure to determine RF modulation response is provided in C.3.1.

4.3 Test setup and validation

This subclause provides procedures to prepare for testing, including: supporting the device, reducing reflections, validating the measurement system, and configuring the WD.

4.3.1 Device support and check for reflections

The WD shall be supported in such a way that there are no significant RF reflecting objects within a distance of at least two wavelengths at the frequency of measurement, or at a distance such that the total reflections from these objects is kept at least 20 dB below the desired direct signal. The purpose of a two-wavelength distance to the nearest significant RF reflective object is to maintain at least a 20 dB reflection loss due to these objects. If it is not practical to measure the reflection loss, then the

²² Probes that have a response of ≥ 20 kHz to variations in the RF envelope do not require the probe modulation factor.

two-wavelength spacing rule may be used. Support structures such as expanded foam and very low dielectric constant plastics may be used for supporting the WD. The region of the WD that is to be in close proximity to a hearing aid during normal operating conditions shall be available for access by the measurement system.

To check for reflections or other influence from nearby objects move the WD $\frac{1}{4}$ wavelength relative to the structure, repositioning the measurement probe, so as to keep the same relative spacing between the WD and measurement probe. Rescan the WD and compare the results. The WD may also be reoriented by 45° or 90° and rescanned.

The RF ambient and noise floor shall be > 20 dB below the intended measurement limit. If the RF ambient is within 20 dB of the intended measurement limit, the WD and measurement probe shall be contained within an RF test enclosure conforming to C.1.1.

4.3.2 Setup validation

The test setup should be validated when first configured and verified periodically thereafter to ensure proper function. The procedure provided in this subclause is a validation procedure using dipole antennas for which the field levels were computed by numeric modeling. Alternate procedures may be used if fully justified.

4.3.2.1 Validation procedures using dipoles

This subclause provides guidance on a validation procedure using dipole antennas. Separate but equivalent procedures are provided for both regular dipoles and planar dipoles.

A simulation of dipole free-space E- and H-fields should be made, if possible, to obtain theoretical calculated values for the validation measurements. Compare the measured readings to the simulated values for the reference dipole. Target values derived from numeric modeling for dipoles constructed to the specifications in D.5.1.3 and following are provided in Table 4.2. Note that these dipoles have different specifications from those used in Clause 5.

Probe measurements are generally recorded as rms and, when required, the results are converted to desired quantity per C.3.1.

The validation described in subsequent clauses should be performed according to the following:

- Average input power $P = 100$ mW rms (20 dBm rms) after adjustment for return loss.
- A dipole as described in D.5 should be used.
- The test fixture should meet the two-wavelength separation criterion, per 4.3.1.
- The probe-to-dipole separation, which is measured from closest surface of the dipole to the center point of the probe sensor element, should be 10 mm, as shown in Figure C.2 and Figure C.3.

See E.1 for measurement uncertainty values for E- and H-fields.

RF power shall be recorded using both an average reading meter and a peak reading meter per the setup illustrated in Figure C.1 and Figure C.3. Readings of the probe shall be provided by the calibrated near-field probe measurement system.

Table 4.2—Illustrative dipole calculated and measured values ^a

Dipole (see Annex D)	Baseband frequencies (MHz)	Frequency (MHz)	E-field calculated values (V/m)	E-field measured values (V/m)	E-field delta (calculated to measured) (V/m) & %	H-field calculated values (A/m)	H-field measured values (A/m)	H-field delta (calculated to measured A/m & %)
D.5.1 thick	790–850	835	187			0.476		
D.5.1 thick	806–821	813.5	190			0.481		
D.5.1 thick	896–901	898.5	185			0.477		
D.5.1 thick	1880–2000	1880	149			0.456		
D.5.1 planar		813.5	224.6–236.4			0.5139–0.5226		
D.5.1 planar		835	214.9–232.2			0.4954–0.5164		
D.5.1 planar		898.5	213.2–220.9			0.5032–0.5005		
D.5.1 planar		1880	153.6–149.3			0.4478–0.4035		

NOTE 1—Numeric modeling results will vary based on several factors, including the size of the computational area, boundary conditions selected, grid resolution, accuracy of models for material properties, and other factors. Further, the results obtained by numeric modeling will vary from measured results based on many additional factors, including the degree to which the probe perturbs the field, the degree to which the probe averages the field strength over its dimensions, the linearity of the probe, the differences between the physical dipole and its modeled representation, and many other factors. Numeric computations provided to the committee showed significant variability between different results. Accordingly the values provided should be used judiciously and not interpreted to be absolutely correct. The calculated values provided for dipoles were developed using theoretical numerical computation.

NOTE 2—Delta % = $100 \times (\text{measured peak minus calculated}) / \text{calculated}$. Values within $\pm 25\%$ are acceptable, of which 12% is deviation and 13% is measurement uncertainty. Values independently validated for the dipole actually used in the measurements should be used, when available.

^a The peak field mentioned in this table is sinusoidal peak. The values cannot be directly compared to the “desired quantity.”

To assure proper operation of the near-field measurement probe, the input power to the dipole shall be commensurate with the full rated output power of the wireless device (e.g., for a cellular phone wireless device, the average peak antenna input power will be on the order of 100 mW (i.e., -20 dBm) rms after adjustment for any mismatch, but peak output power may be as high as 32 dBm.

4.3.2.1.1 Validation procedure

Place a dipole antenna meeting the requirements given in D.5 in the position normally occupied by the WD. The dipole antenna serves as a known source for an electrical and magnetic output. Position the E- and H-field probes so that:

- The probes and their cables are parallel to the coaxial feed of the dipole antenna
- The probe cables and the coaxial feed of the dipole antenna approach the measurement area from opposite directions; and
- The center point of the probe element(s) are 10 mm from the closest surface of the dipole elements.

Scan the length of the dipole with both E- and H-field probes and record the maximum values for each. Compare the readings to expected values.

4.3.2.1.2 Test cases

Three test cases are recommended. The real or emulated WD transmission signal, an unmodulated (CW), and an 80% amplitude modulation (AM) RF signal shall be used for each relevant frequency band. Each of the cases below shall be measured with both an E-field and H-field probes.

4.3.2.1.2.1 Measurement of real or emulated signal

Set a WD or emulated signal source to apply full rated power into the reference dipole. For TDMA protocols set the probe measurement system averaging interval duration to be an integer multiple of the TDMA frame duration.

Measure both the peak and average input power applied to the antenna and record these values.

Using the near-field measurement system, scan the antenna over the appropriately sized area and record the greatest average power reading observed. Field strength measurements shall be made only when the probe is stationary.

NOTE—The uncertainty for the WD signal step in 4.3.2.1.2.1 is greater than when using AM or CW, as in 4.3.2.1.2.2.

4.3.2.1.2.2 Measurement of CW and AM modulated signals

Set the RF signal generator set for CW or 80% AM. Set its output power so the peak power applied to the antenna is equal to that recorded for the real or emulated signal using the WD modulation format.

Measure both the peak and average input power applied to the antenna and record these values. Calculate the peak to average power ratio (PAR). The PAR for the CW signal should be 0.0 dB from each other and the target values for the dipole being used. The PAR for the AM signal with 80% modulation depth should be 5.1 dB from each other and the peak should be that amount above the target values.

The input signal peak power and peak to carrier ratios applied to the antenna should be confirmed. The values should be measured and recorded, and the ratio calculated.²³

Using the near-field measurement system, scan the antenna over the appropriately sized area and record the greatest average power reading observed. Field strength measurements shall be made only when the probe is stationary.

4.3.2.1.3 Procedure using regular dipoles

The probe is positioned over the illuminated dipole at 10 mm distance from the center point of the probe sensor element to the top surface (edge) of the dipole element as shown in C.4.3.

4.3.2.1.4 Procedure using planar dipoles

Position the reference dipole in a suitable holder that enables meeting the RF ambient conditions prescribed in 4.3.1. The near field measurement probe is positioned and scanned over the illuminated dipole at a distance of 10 mm from the nearest point on the probe sensor element(s) to the top surface (edge) of the etched dipole (not the edge of the PC board). A gauge block, as depicted in A.2.1, simplifies the alignment of the probe to the dipole. Note that a separate E-field and H-field gauge block will be needed if the edges of the probe sensors are at different distances from the tip of the probe. The scan area for 813 MHz to 899 MHz is 20 mm by 180 mm, and at 1880 MHz it is 20 mm by 90 mm. Figure C.3 illustrates the instrumentation setup.

4.3.3 WD setup and use

The WD shall be operated at its maximum RF output power setting, and at the normal operating temperature and voltage, as specified by the manufacturer. To assure WD operation at maximum RF output power automatic power control shall be disabled. Since the presence of wires or conductors in the close vicinity of the WD will disturb the RF fields, the WD should also be operated solely under its own power source, with no external connections unless specifically required so by the manufacturer for normal operation. It is assumed that the user of a WD will operate the device in a manner that is consistent with the recommendations of the manufacturer with regards to maximum efficiency of the WD. Some WDs have more than one antenna position, for example stowed and deployed. In such cases, it is only necessary to test the WD in the condition of maximum antenna efficiency, as defined by the manufacturer. This is considered to be the recommended or specified operation by the manufacturer for the WD. If the fields were found to be higher at another antenna position, the results would be of little concern as the user of the WD would simply have to move the antenna to the more efficient position to reduce the field strength at the hearing aid. However, in cases where the advertised category can only be achieved in certain user controllable configurations it is very important that the consumer be properly informed. Therefore, when the category advertised can only be achieved in certain antenna position(s) or other user configuration instructions are required, these conditions shall be reported with the assigned category in the user documentation, label or other locations where the category information is communicated to the user.

4.4 Near-field test procedure

In actual use, the wearer of a hearing aid would place the WD in a position that gives the best acoustic coupling from the WD to the hearing aid. In other words, the WD would be located so that the user could

²³ The ratio of the peak with 80% AM applied to unmodulated CW is different from the peak to carrier power with 80% AM applied. The ratio of the peak with 80% AM applied to unmodulated CW is 5.1 dB. However, the ratio of the peak to carrier for an 80% AM signal is 3.9 dB. Information on ratio characteristics is given in Annex I.

hear the WD desired acoustic or T-Coil output the best. This would be with the output transducer (receiver or T-Coil signal source) of the WD in close proximity to the microphone or T-Coil receiver of the hearing aid. For the purposes of this standard the measurements are made in these areas of the WD. In order to best estimate this usage condition as well as provide a repeatable test procedure a measurement grid in the vicinity of the audio output (receiver or T-Coil signal source) as been defined.

A measurement grid is defined over which the electric and magnetic RF field strength will be measured. The grid is a 50 mm by 50 mm area that is divided into nine evenly-sized blocks or sub-grids. The grid is centered on the audio frequency output transducer of the WD (speaker or T-Coil). The grid is located by reference to a reference plane. This reference plane is the planar area that contains the highest point in the area of the WD that normally rests against the user's ear. A measurement plane is located parallel to the reference plane and 15 mm from it, out from the phone. The grid is located in the measurement plane.

The E-field probe, and separately the H-field probe, are to be used to measure the highest field strength in the 50 mm by 50 mm reference plane.

If the assessment T-Coil location is in a different location from the acoustic output, then two different 50 mm by 50 mm areas may need to be scanned, the first for the microphone mode assessment and the second for the T-Coil assessment. The location of the microphone mode 50 mm by 50 mm area is centered on the acoustic output of the WD and is defined in A.2 and depicted in Figure A.2. If needed, the location of the second grid for the T-Coil assessment is identical in shape, but is centered on the T-Coil axial measurement location, as defined in A.3 and depicted in Figure A.3.

The 50 mm by 50 mm area is divided into nine sub-grids (see the diagram in Figure A.2). Three contiguous sub-grids may be excluded from the measurement. The reason for allowing three contiguous sub-grids to be excluded is that extreme "hot spots" are often encountered at the base of the antenna. These high field areas are very localized and easily avoided by the user. Therefore, an exclusion area is allowed so as to not make the requirements needlessly harsh. This allows for RF "hot spots"²⁴ that can easily be avoided in actual use. However, it is required that four sub-grids be common to the E- and H-field scans for a given grid. The highest reading defined by the sub-grid in the center, containing the acoustic output, and the five remaining sub-grids, with four of these six sub-grids being common between the E- and H-field scans, determines the category rating. The field probe is carefully moved through the measurement area and the highest reading is located. In order to accurately scan the entire 50 mm by 50 mm area, the center of the probe shall be moved through this area. Accordingly the total area covered by the outside edge of the probe shall be the 50 mm by 50 mm area, increased by half ($\frac{1}{2}$) the probe diameter on all sides.

The distance from the WD reference plane to the center point of the probe element shall be 15 mm. The WD reference plane is a plane parallel with the front "face" of the WD and containing the highest point on its contour in the area of the phone that normally rests against the user's ear. The probe element is that portion of the probe that is designed to receive and sense the field being measured. The physical body of the probe housing shall not be used when setting this 15 mm distance as this would place the sensing elements at an indeterminate distance from the reference plane. See Figure A.2.

In the case of a field probe that may have less than three orthogonal elements, it is necessary to rotate the probe to obtain the measurement. Two methods may be used. In the preferred method, the probe shall be rotated in three dimensions for maximum alignment and the reading at maximum field alignment used. An alternative method is to rotate the probe about its geometric center so as to obtain measurements in all three mutually orthogonal orientations. The geometric center is the point that is physically located at the center of electromagnetic sensing element(s) of the probe. This may be determined from physical measurements or

²⁴ The presence of RF "hot spots," typically at the base of the WD antenna, presented a particular problem for the committee. At these locations extreme field amplitudes are found but these extremes fall off very quickly, often being a fraction of the peak value in less than a centimeter. In addition, it is unclear that these areas transfer proportionate power in reality, due to their responsiveness to loading effects. In practical use a user can shift the WD slightly and find a location of good acoustic output while avoiding such RF "hot spots." Representatives of consumers, WDs, and hearing aid manufacturers discussed this issue at length in the committee and concluded that allowing for a RF "hot spot" exclusion was important in finding a solution which met the requirements of users and was realistically achievable by all parties.

from field pattern measurements during calibration. The maximum field shall be the vector sum of all three individual mutually orthogonal measurements. Note that even when using three element probes the probe may be rotated so as to align one element for maximum field coupling. When this is done the reading of the single, maximally aligned element is used as the field reading at that location. Readings taken in this manner are preferred over those taken with the non-aligned method because of the greater accuracy. However, when the alignment method is used, the probe shall be realigned at every measurement point.

In summary, the scan shall adhere to the following requirements:

- The center of the probe shall scan to the edges of the grid. Accordingly the total area covered by the outside edge of the probe shall be the 50 mm by 50 mm area, increased by half ($\frac{1}{2}$) the probe diameter on all sides.
- The center point of the probe measurement element(s) shall be held 15 mm from the WD reference plane. The probe element is that portion of the probe that is designed to receive and sense the field being measured. The physical body of the probe housing shall not be used when setting this 15 mm distance as this would place the sensing element(s) at an indeterminate distance from the reference plane.
- The step size of the scan shall be determined by the target measurement uncertainty. Scanning increments of 5 mm or less (see E.2.3) in most cases should meet the uncertainty recommendations. (See E.2.3 and Figure E.1 for specific guidance on step size selection.)
- Up to three blocks can be excluded for each field measurement.
- The center block containing the WD output may not be excluded.
- A maximum of five blocks can be excluded for both E-field and H-field measurements for the WD output being measured. Stated differently, the center sub-grid or block and three other blocks must be common to both the E-field and H-field measurements for a given grid.

4.4.1 Detailed near-field test procedure

4.4.1.1 Pre-test procedure

The following steps shall be performed before the WD near-field emissions test is performed (see Figure 4.2). However, these steps need not be performed before every test. They shall be performed periodically, consistent with good laboratory practice and as required, for example, before testing types of WDs not assessed previously at a laboratory.

- 1) Calibrate E-field and H-field probes for proper reading of the modulation used by the intended WD (see Annex C).
- 2) Check for probe positioning system repeatability and accuracy.
- 3) Confirm interference of reflective objects is less than -20 dB of the intended signal. This may be done by performing the same measurements on the same WD using multiple WD positions and orientations. The readings shall not differ, due to reflections, by more than ± 0.8 dB.²⁵

²⁵ A common practice is to move the EUT $\frac{1}{4}$ wavelength relative to the structure, repositioning the measurement probe, so as to keep the same relative spacing between the EUT and measurement probe. Changing the relative orientation of the probe and EUT to the structure can also be a helpful test. If the readings change significantly then reflections from nearby structures may be indicated.

Pre-Test Instructions

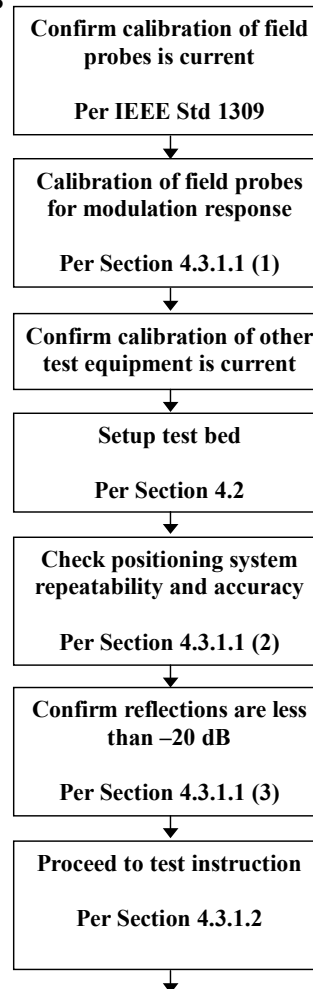


Figure 4.2—WD near-field emissions pre-test flowchart

4.4.1.2 Test procedure

The following methods are sample step-by-step test procedures. Other comparable procedures may be used. Both manual and automatic test procedures are provided. The automated test procedure is preferred.

4.4.1.2.1 Manual scanning method

When performing the test manually, a test fixture shall be used, to improve positioning accuracy. Such a fixture shall be constructed from low dielectric materials, such as foam plastic, which do not significantly affect the readings being taken. An example of such a test fixture is shown in Figure 4.4. In this fixture, permissible exclusion blocks are used to isolate the six sub-grids used for the evaluation. The permissible exclusion block is shaped in such a way as to close off three of the sub-grid areas. Thus the six areas to be used to determine the WD's maximum emissions are identified and outlined for the final manual scan. Four of the six areas shall be used in both the E- and H-field measurements. See Figure 4.3 for a diagram of the manual scanning method.

- 1) Confirm proper operation of the field probe, probe measurement system, and other instrumentation.
- 2) Position the WD in its intended test position. The gauge block, depicted in A.2.1, can simplify this positioning. Note that a separate E-field and H-field gauge block will be needed if the center of the probe sensor elements are at different distances from the tip of the probe.
- 3) Configure the WD operation for maximum rated RF output power, at the desired channel and other operating parameters, as intended for the test.

Test Instructions

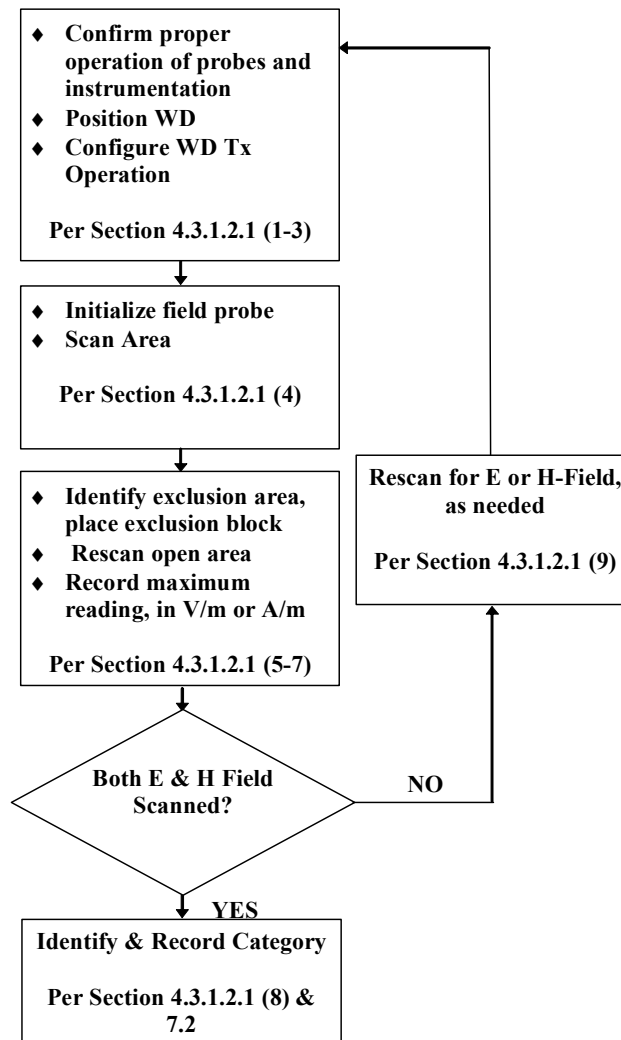


Figure 4.3—WD near-field emission manual test flowchart

- 4) Perform an initial scan of the 50 mm by 50 mm area.
The physical opening in the test fixture shall be wider than the 50 mm by 50 mm area by half the diameter of the probe. Thus the opening is such that the center of the probe scans the full 50 mm by 50 mm area.
- 5) Identify the five contiguous sub-grids around the center sub-grid with the lowest field readings.
The center sub-grid shall be centered on the center of the T-Coil mode axial measurement point

or the acoustic output, as appropriate. Place the exclusion block into the fixture in the three contiguous sub-grids containing the highest field readings (see Figure 4.5). Thus the six areas to be used to determine the WD's maximum emissions are identified and outlined for the final manual scan. Please note that a maximum of five blocks can be excluded for both E-field and H-field measurements for the WD output being measured. Stated another way, the center sub-grid and three others must be common to both the E-field and H-field measurements.

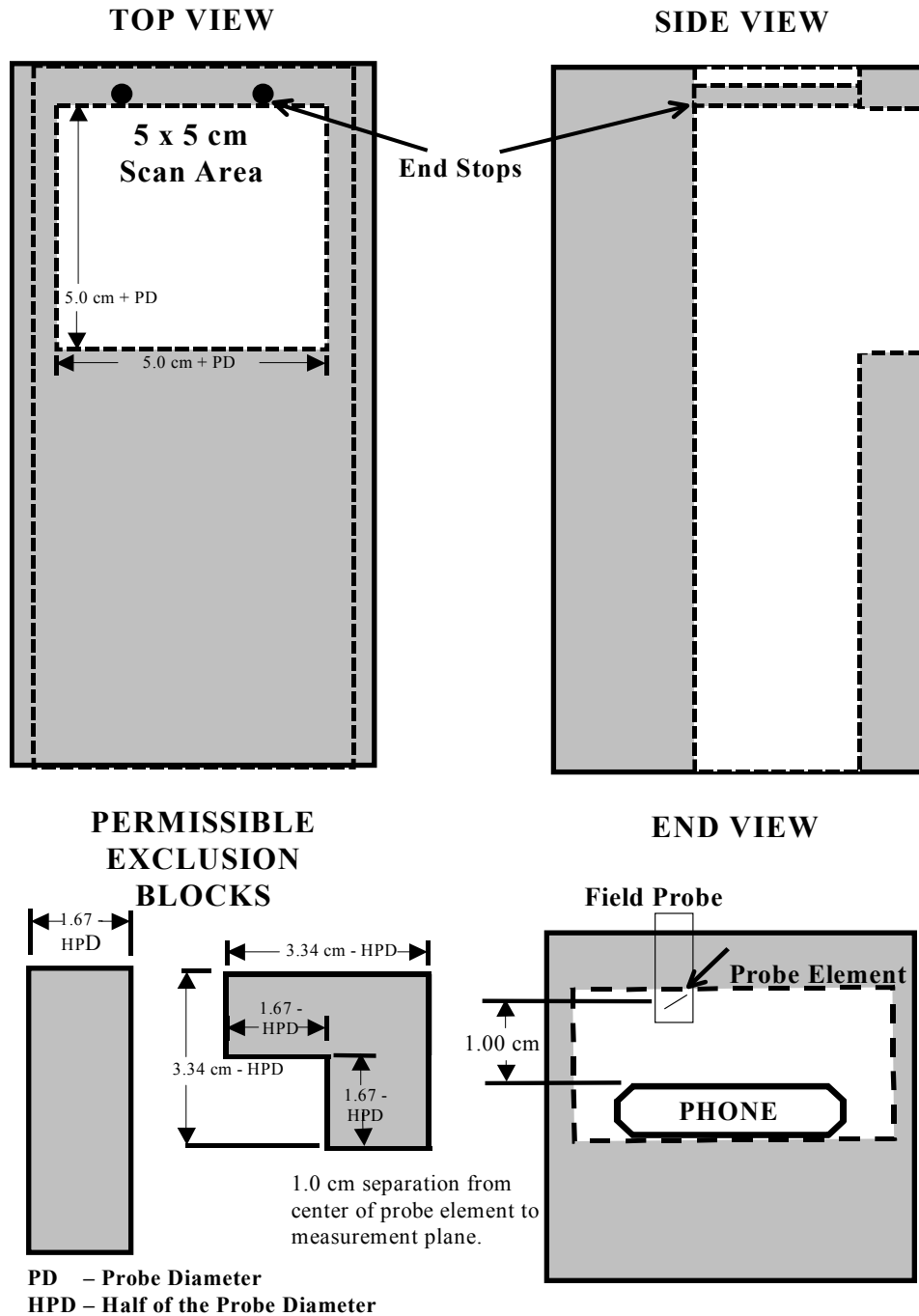


Figure 4.4—Near-field emissions test fixture, manual scan method

- 6) Identify the five contiguous sub-grids around the center sub-grid with the lowest field readings. The center sub-grid shall be centered on the center of the T-Coil mode axial measurement point or the acoustic output, as appropriate. Place the exclusion block into the fixture in the three contiguous sub-grids containing the highest field readings (see Figure 4.5). Thus the six areas to be used to determine the WD's maximum emissions are identified and outlined for the final manual scan. Please note that a maximum of five blocks can be excluded for both E-field and H-field measurements for the WD output being measured. Stated another way, the center sub-grid and three others must be common to both the E-field and H-field measurements.

TOP VIEW

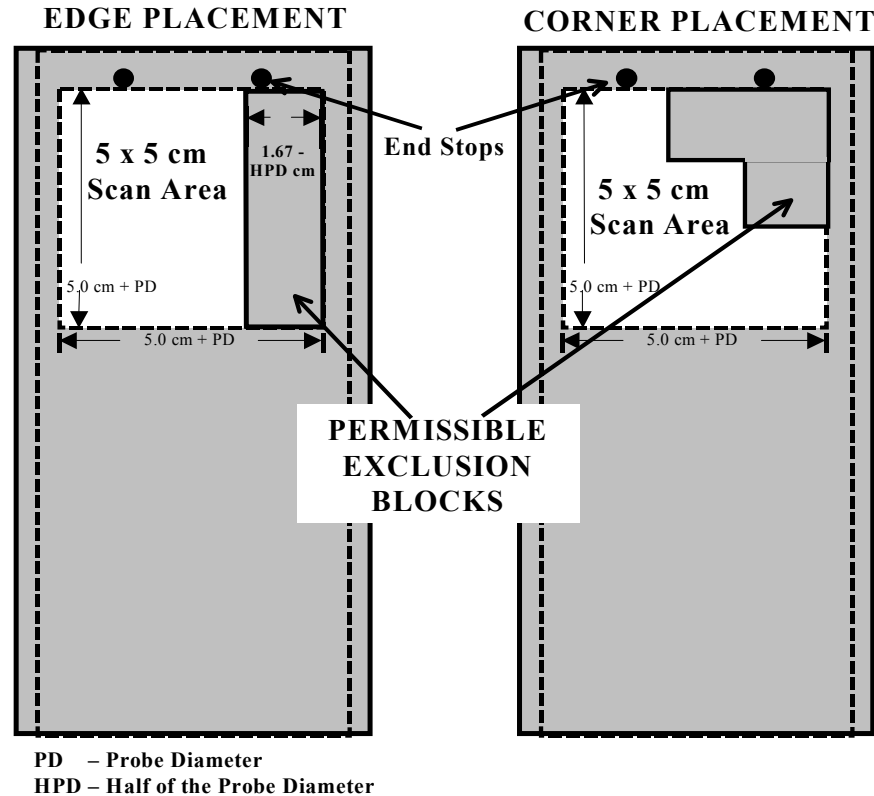


Figure 4.5—Exclusion block placement, manual scan method

- 7) Rescan the remaining six sub-grid areas. Identify the maximum field reading within the six sub-grid area identified in Step 5). Care shall be taken to identify the highest emission within the six sub-grid areas.²⁶
- 8) Convert the highest field reading taken in Step 6) to V/m or A/m, as appropriate. For probes that require the use of a probe modulation factor, this conversion shall be done using the appropriate probe modulation factor described in 4.2.2.1 and the calibration specified in C.3.1.
- 9) Compare this reading to the categories in Clause 7 and record the resulting category.

²⁶ Probe anisotropy may add significantly to the measurement uncertainty. This factor may be minimized by first moving the probe to the location of maximum measurement and then rotating the probe to align it for the maximum reading at that position. This rotation is recommended in order to minimize uncertainty due to anisotropy in the probe.

- 10) Repeat Step 1) through Step 8) for both the E- and H-fields. The lowest category, per the tables in 7.2, obtained in Step 8) for either the E- or H-field determines the M category. Record the WD category rating.
- 11) For the T-Coil mode M-rating assessment, determine if the chosen axial measurement point is contained in an included sub-grid of the first scan, for both E- and H-fields. If so, then a second scan is not necessary. The first scan and resultant category rating may be used for the T-Coil mode M rating.

Otherwise, repeat Step 1) through Step 9), with the grid shifted so that it is centered on the axial measurement point. The lowest category, per the tables in 7.2, obtained in the first or the repeated Step 8) for either E- or H-field determines the M category assessment. Record the WD category rating.

4.4.1.2.2 Automated scanning method

The following steps, depicted in Figure 4.6, shall be followed when using the automatic scanning method:

Test Instructions

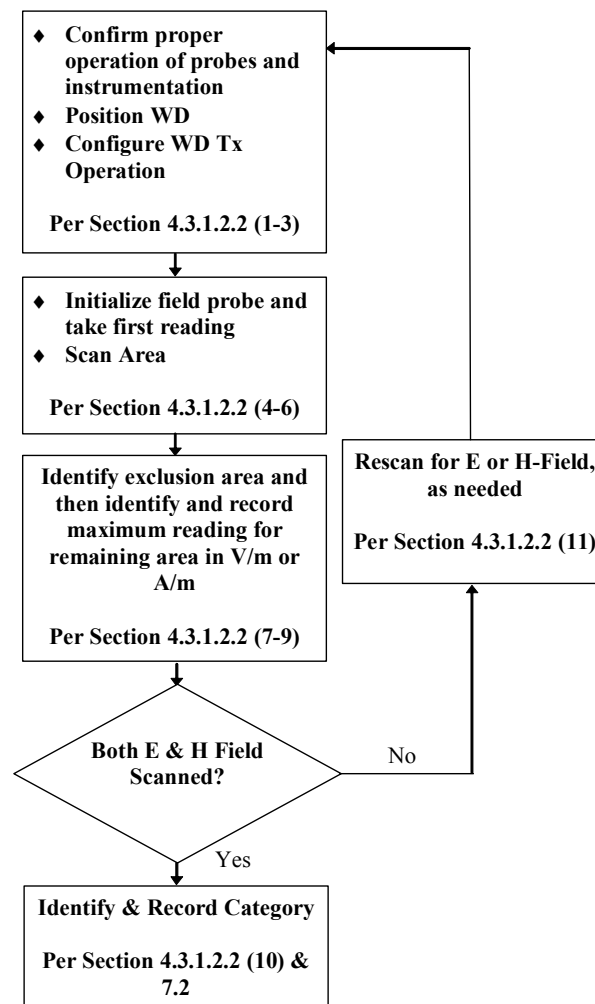


Figure 4.6—WD near-field emission automated test flowchart

- 1) Confirm proper operation of the field probe, probe measurement system and other instrumentation and the positioning system.
- 2) Position the WD in its intended test position. The gauge block, depicted in A.2.1, can simplify this positioning. Note that a separate E-field and H-field gauge block will be needed if the center of the probe sensor elements are at different distances from the tip of the probe.
- 3) Configure the WD normal operation for maximum rated RF output power, at the desired channel and other operating parameters (e.g., test mode), as intended for the test.^{27, 28}
- 4) The center sub-grid shall be centered on the center of the T-Coil mode axial measurement point or the acoustic output, as appropriate. Locate the field probe at the initial test position in the 50 mm by 50 mm grid, which is contained in the measurement plane, described in 4.3.3 and illustrated in Figure A.2. If the field alignment method is used, align the probe for maximum field reception.
- 5) Record the reading.
- 6) Scan the entire 50 mm by 50 mm region in equally spaced increments and record the reading at each measurement point. The distance between measurement points shall be sufficient to assure the identification of the maximum reading. See E.2.3 for guidance in determining the distance between measurement points.
- 7) Identify the five contiguous sub-grids around the center sub-grid with the lowest maximum field strength readings. Thus the six areas to be used to determine the WD's highest emissions are identified and outlined for the final manual scan. Please note that a maximum of five blocks can be excluded for both E-field and H-field measurements for the WD output being measured. Stated another way, the center sub-grid and three others must be common to both the E-field and H-field measurements.
- 8) Identify the maximum field reading within the non-excluded sub-grids identified in Step 7).²⁹
- 9) Convert the maximum field strength reading identified in Step 8) to V/m or A/m, as appropriate. For probes which require a probe modulation factor, this conversion shall be done using the appropriate probe modulation factor described in 4.2.2.1 and the calibration specified in C.3.1.
- 10) Repeat Step 1) through Step 10) for both the E-field and H-field measurements.
- 11) Compare this reading to the categories in Clause 7 and record the resulting category. The lowest category number listed in 7.2, Table 7.4, or Table 7.5 obtained in Step 10) for either E- or H-field determines the M category for the audio coupling mode assessment. Record the WD category rating.
- 12) For the T-Coil mode M-rating assessment, determine if the chosen axial measurement point is contained in an included sub-grid of the first scan, for both E- and H-fields. If so, then a second scan is not necessary. The first scan and resultant category rating may be used for the T-Coil mode M rating.

Otherwise, repeat Step 1) through Step 9), with the grid shifted so that it is centered on the axial measurement point. The lowest category, per the tables in 7.2, obtained in the first or the repeated Step 8) for either E- or H-field determines the M category assessment. Record the WD category rating.

²⁷ Normally the amount of time a display remains on is a customer defined option. When this is true the display should not be illuminated during the test.

²⁸ Some devices allow for no transmission during silent intervals of a call. This feature must be disabled during the test, e.g., no DTX.

²⁹ Probe anisotropy may add significantly to the measurement uncertainty. This factor may be minimized by first moving the probe to the location of maximum measurement and then rotating the probe to align it for the maximum reading at that position. This rotation around the axis or shaft of the probe is recommended in order to minimize uncertainty due to anisotropy in the probe.

5. Hearing aid RF near-field immunity test

This clause prescribes the measurement method to be used in determining the immunity level of a hearing aid to radiated electromagnetic fields originating from a WD. The method is intended to simulate the RF fields experienced by a hearing aid equipped user of a WD and so evaluates the hearing aid's immunity.

This test procedure uses near-field illumination in assessing the hearing aid immunity rather than far-field illumination. This is a more realistic simulation of the near-field condition experienced by the hearing aid, the result is a better correlation between the measured immunity level and the immunity level experienced by an actual hearing aid equipped user of a WD.

Far-field illumination testing, such as in a WB TEM, offers advantages of being more repeatable and less sensitive to issues of placement and positioning. Also far-field illumination testing is commonly required in other standards. Some may prefer to test immunity using a WB TEM to avoid duplicative testing or for other reasons. Subclause 5.4 provides guidance on WB TEM testing as an alternate method. However, in case of dispute the results obtained with the near-field illumination test, as described in this clause shall take precedent.

All acoustic measurements are to be made unweighted (i.e., with the acoustic instrumentation set for "linear" or flat frequency response), unless otherwise noted.

The evaluation of the interference effect of the WD's RF emissions on a hearing aid in acoustic coupling mode is procedurally very similar to that used for the T-Coil mode. For this reason the procedures for evaluating a hearing aid's immunity to the RF emission, set forth in this clause, is called for in evaluating the T-Coil coupling mode. For simplicity, some helpful notes are contained within the procedures in this clause for evaluation of the T-Coil coupling mode. However, for the T-Coil mode an evaluation must be made of the effects of baseband interference sources to fully evaluate the signal quality that a user experiences.

5.1 Test facilities and equipment

This subclause describes the test facility and equipment to be used for these measurements.

5.1.1 General test conditions

This subclause lists the test equipment and provides the general test conditions that should be used when performing the test described in this clause. Any deviation from the recommendations contained in this clause shall be identified in the test report.

5.1.1.1 Ambient conditions

See 8.2 for ambient conditions.

5.1.1.2 Power supply voltage

A fresh battery of the type specified by the hearing aid manufacturer shall be mounted inside of the hearing aid during the immunity test. The battery should be within $\pm 5\%$ of its rated voltage, under no-load conditions.

5.1.1.3 Test sites

Any indoor site meeting the conditions as specified in 8.2 and C.1.1 is acceptable, provided the equipment used for application of RF fields is electromagnetically shielded to the extent necessary to meet federal government RF safety regulations and electromagnetic emission regulations.³⁰ A sound-proof booth is not a mandatory requirement. However, ambient noise levels in the test area should be as low as possible and constant for the duration of the test.

5.1.2 Test equipment

This subclause lists the test equipment needed to perform the near-field immunity tests, using the generic test equipment hookup diagram shown in Figure 5.1. The test equipment used shall meet the applicable specifications of Annex D.

- 1) Two resonant dipoles designed to radiate between 800 MHz and 950 MHz and 1.6 GHz and 2.5 GHz
- 2) RF signal generator
- 3) RF power amplifier
- 4) RF directional coupler
- 5) RF power meters (2)
- 6) Microphones
 - a) Pressure field microphone
 - b) Free field microphone
- 7) Microphone pre-amplifier
- 8) Frequency analyzer
- 9) Ear coupler
- 10) Microphone calibrator
- 11) Audio signal generator
- 12) Acoustic transmission line
- 13) Hearing aid immunity test fixture
- 14) RF cables

³⁰ See IEEE Std C95.1 and relevant sections of FCC regulations, CFR 47, for more details.

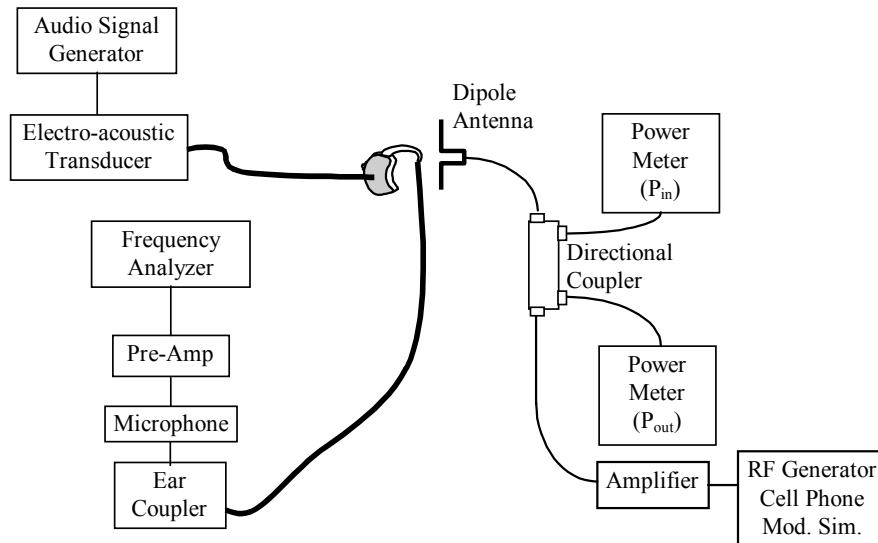


Figure 5.1—Near-field immunity test setup

5.2 Test setup and validation

Subclause 5.2.1 describes how to configure the experimental setup required for hearing aid RF immunity tests. Before hearing aid testing commences, the experimental setup shall be validated. Subclauses 5.2.1 through 5.2.5 include a set of pre-test procedures designed to validate the experimental setup in order to ensure the accuracy of the results. In order to verify that the hearing aid performs per the manufacturer's specifications, 5.2.5 advises that the hearing aid be pre-tested per ANSI S3.22.

5.2.1 Hearing aid near-field immunity test setup

Figure 5.1 is a schematic of how the equipment listed in 5.1.2 is set up for RF immunity testing. As shown, the hearing aid acoustic output is connected to the microphone via an acoustic transmission line and ear coupler. The microphone is then coupled to the audio frequency analyzer via a pre-amplifier. This constitutes the audio frequency measurement system. From the RF source, an RF signal is fed to an RF power amplifier, to supply power to the dipole. A two-way directional coupler with RF power meter is placed in-line just before the dipole in order to monitor forward and reflected RF power into the dipole. The RF power level to the dipole is set using a CW RF signal. After the proper test level is established 1 kHz 80% AM is added for the actual test.³¹

The relative spacing between the hearing aid under test and the dipole is critical to the accuracy and repeatability of the test. See E.2.3 for a more detailed discussion of the effect of variation in the relative spacing on the measurement uncertainty.

³¹ A 1 kHz 80% AM is used because of its availability in most signal generators and its common usage in other RF immunity test standards. The 1 kHz 80% AM modulation has a fixed and well understood relationship to the modulations used in WDs. This relationship and the physics which determines the relationship is described in Appendix 4 of [B37] by Joyner, K. H., *et al.*, and in Annex A of IEC 61000-4-3-2002.

5.2.2 Check for RF interference to test equipment

Set up the equipment as illustrated and described in 5.2.1. With the hearing aid battery removed and RF off, record the ambient spectrum and sound pressure level (SPL). Then energize the dipole with the maximum RF power that will be used in the test plus 3 dB, at 900 MHz. Apply 1 kHz 80% AM. Record the audio band spectrum and overall SPL from the frequency analyzer. Alternative measurements can be made at the 1/3 octave bands from 300 Hz to 3.4 kHz, to determine if any change in SPL, due to the RF from the dipole, has occurred.

Repeat the procedure with a 1 W, 1.8 GHz RF signal modulated with a 1 kHz 80% AM. Record the spectrum and overall SPL.

There should be no change in spectrum and overall SPL from ambient during this system check (with the hearing aid battery removed), indicating that the system is immune to interference.³² If there is an increase in recorded SPL or peaks in the spectrum that appear due to exposure to the energized dipole, it shall be necessary to provide a separation distance between the victim device (which shall be determined) and the radiating dipole. Repeat the above test with increasing separation distance between the victim device and dipole and record the distance at which the interference disappears. Configure the test setup described in 5.2.1 such that this minimum separation distance is achieved between the test equipment and the dipole. If the determined separation distance is impractical, shielding may be employed to eliminate the interference to the test equipment.

5.2.3 Characterization of tubing acoustic attenuation and resonances

The required level of interference is to be assessed at the output of the hearing aid. Therefore, it is important to characterize the tubing between the hearing aid under test and the microphone used to monitor it during the test.³³

5.2.4 Audio input source setup

The experimental setup for this subclause is illustrated in Figure 5.1. See C.2 for a description of the audio input source.

5.2.5 RF field strength validation

The RF field strength presented to the EUT shall be validated either by measuring the field strength using RF field probes or by having the dipoles calibrated per C.4.

³² The requirement of “no change” is defined as the undesired signal or reading being at least 20 dB less than the measured value. The 20 dB requirement is consistent with the similar requirement for RF test enclosures, found in C.1.1.

³³ Longer lengths of tubing have the effect of attenuating the higher audio frequencies as well as introducing tubing resonances. Therefore, it is important to characterize the acoustic transmission line used in testing. See C.6.

Depending on the measurement, characterization of tubing over the entire frequency range may not be necessary. Because acoustic output SPL measurements are at 1 kHz and 1.3 kHz, tubing attenuation needs only to be determined at these two frequencies for near-field immunity testing. This can be accomplished easily by connecting the desired length of tubing to the acoustic output of the hearing aid being tested, and with its volume set at the reference test position (RTP), as defined in ANSI S3.22, its acoustic output SPL relative to changing input SPL at a fixed frequency can be measured. From these input/output curves, the input SPL relative to a changing acoustic output level at this fixed frequency can be easily determined. However, if an accurate view of the overall spectrum is desired, then the tubing should be characterized.

5.2.6 Pre-tests required for the hearing aid under test

A hearing aid shall be verified to be operating properly and set at an appropriate gain for the test.³⁴

5.3 RF immunity test procedure—primary

This subclause describes the procedures, illustrated in Figure 5.2, for testing a hearing aid for immunity to near-field electromagnetic interference (EMI). The measurements are performed first using the dipole for the 800 MHz to 950 MHz band and then repeated with the dipole for the 1.6 GHz to 2.5 GHz band.

1) Equipment setup

Configure the equipment as illustrated in Figure 5.1 and described in 5.2.

2) Hearing aid setup

- a) Set the hearing aid to acoustic mode.
- b) Couple the hearing aid through an acoustic transmission line, as defined in 5.2.3. The acoustic transmission line, in turn is connected to an ear coupler in a hearing aid test box or other suitable test arrangement.
- c) Adjust the hearing aid to the reference test gain with 60 dB SPL input using HFA (high frequency average) measurements as defined in ANSI S3.22.
- d) Secure the volume control against movement with non-conductive tape, glue, or other means.
- e) Connect the audio input source.

3) Measure hearing aid input versus output gain curve at 1000 Hz and 1300 Hz

Perform an input/output measurement curve of the hearing aid with an acoustic input to the hearing aid covering the range of measurement noise floor to 90 dB SPL in 5 dB steps, at 1000 Hz and 1300 Hz.³⁵

4) Measure the IRAN (input referred ambient noise) at 1000 Hz

- a) Record the acoustic output SPL from the hearing aid, in the 1 kHz 1/3 octave filter band, with the RF source and acoustic source turned off.
- b) Using the input/output characteristics at 1000 Hz, determine the gain for the measured acoustic output level.
- c) Subtract the 1000 Hz gain from the acoustic output SPL. The result is the ambient acoustical noise referenced to the input, which shall be called the IRAN. The IRAN should be sufficiently below the target input referenced interference level (IRIL) to permit accurate measurement. (The IRAN should be at least 10 dB below the IRIL.)

³⁴ The verification that a hearing aid is operating properly and setting it to a reference test gain may be accomplished by selecting and performing the appropriate pre-tests from ANSI S3.22-1996.

³⁵ In the following steps, this input–output characteristic information shall be used to determine IRIL levels at 1 kHz and to determine the 65 dB SPL input related biasing level at 1300 Hz.