

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

Accredited by the American National Standards Institute

Sponsored by the
Accredited Standards Committee on Electromagnetic Compatibility, C63



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

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 part of ANSI C63.19-2001, 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, D.C. 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. This document is the result of that committee's efforts.

Membership of C63.19 Task Group

At the time that this standard was published, the Accredited Standards Committee on Electromagnetic Compatibility, C63, had the following membership:

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Edwin L. Bronaugh, *Vice Chair*
Robert Pritchard, *IEEE Secretariat*

Membership of C63.19 Task Group

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H. Stephen Berger, *Co-Chair*
Tom Victorian, *Co-Chair*
Edwin L. Bronaugh, *Secretary*

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Contents

1.	Overview	1
1.1	Scope	1
1.2	Purpose	1
1.3	Organization and use of the document	2
2.	References	5
3.	Definitions, acronyms and abbreviations	8
3.1	Definitions	8
3.2	Acronyms and abbreviations	11
4.	Wireless device, RF emissions test	12
4.1	Test equipment and facilities	12
4.2	Test setup and validation	13
4.3	Near-field test procedure	14
5.	Hearing aid RF near-field immunity test	22
5.1	Test facilities and equipment	23
5.2	Test setup and validation	24
5.3	RF immunity test procedure	26
6.	Wireless device audio band, magnetic signal test	31
6.1	Test facilities and equipment	31
6.2	Test configurations and setup	32
6.3	Test procedure for audio band magnetic field	33
7.	Performance	38
7.1	Articulation weighting factor (AWF)	38
7.2	Audio coupling mode	38
7.3	Audio band magnetic coupling mode	40
7.4	Accessories and options	42
8.	Calibration and measurement uncertainty	43
8.1	General	43
8.2	Ambient conditions	43
8.3	Specific calibration requirements	43
8.4	Measurement uncertainty	43
9.	Test report	44
9.1	Test plan	44
9.2	Applicable standards	44
9.3	Equipment unit tested	44
9.4	Test configuration	44

9.5	List of test equipment.....	45
9.6	Units of measurement	45
9.7	Location of test site.....	45
9.8	Measurement procedures	45
9.9	Reporting measurement data.....	45
9.10	General and special conditions	45
9.11	Summary of results	46
9.12	Required signatures.....	46
9.13	Test report annexes	46
9.14	Test report disposition.....	46
10.	Bibliography	46
	Annex A (normative) Definition of reference axes	49
	Annex B (normative) Acoustic test frequencies	52
	Annex C (normative) Equipment and setup calibration	53
	Annex D (normative) Test equipment specifications	62
	Annex E (informative) Sample measurement uncertainty estimates	75
	Annex F (informative) Use of Helmholtz coils for calibration.....	79
	Annex G (informative) RF envelope comparison for US WD systems.....	88
	Annex H (informative) Explanation of rationale used in this standard	91
	Annex I (informative) Alternate test method for Rf immunity.....	92

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

1. Overview

1.1 Scope

This standard applies to both wireless communications devices (WD) 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 wireless communications devices, including cordless, cellular, and Personal Communications Service (PCS) phones, 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 800–950 MHz and 1.6–2.0 GHz frequency bands. Future versions may add tests for the 2.4 GHz or 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 T-coil input mode.

The field levels called for in various places shall be maintained within the limits for RF safety, set forth in IEEE Std C95.1, 1999 Edition.¹

1.2 Purpose

The purpose of this standard is to establish categories for hearing aids and for WDs that can indicate to health care 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

¹Information on references can be found in Clause 2.

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:

- a) Radio frequency (RF) measurements of the near-field electric and magnetic fields emitted by a WD to categorize these emissions for correlation with the RF immunity of a hearing aid.
- b) Magnetic 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.
- c) 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 radio frequency (RF) and audio band emissions are measured. Hence, the following are measurements made for the WDs:

- a) RF E-Field emissions
- b) RF H-Field emissions
- c) T-coil mode, magnetic signal strength in the audio band
- d) T-coil mode, magnetic signal and noise articulation index
- e) T-coil mode, magnetic signal frequency response through the audio band

Corresponding to the WD measurements, the hearing aid is measured for:

- 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 term *shall* is used in this document, it indicates something mandatory. The term *should* indicates something that is advisory.

1.3 Organization and use of the document

These technical requirements define the measurement methods and categorical levels to ensure hearing aid operational compatibility with wireless devices (WD).

To ensure hearing aid and WD compatibility, it is essential that uniform measurement methods be defined for hearing aid immunity to electric and magnetic fields and WD emission of electric and magnetic 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 magnetic field signal, generated by the WD, becomes the signal source. During T-coil operation the magnetic field generated by the WD is intended to be the primary coupling mechanism to the hearing aid. The WD also can produce unintended magnetic fields (the result of circulating currents). Such magnetic 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 electric and magnetic 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 the summary of each clause:

Clause 1—Overview: describes the scope and purpose of the document.

Clause 2—References: references used in this standard.

Clause 3—Definitions, acronyms, and abbreviations: definitions, acronyms, and abbreviations used in this standard.

Clause 4—Wireless device, RF emissions test: prescribes the measurements of the near electric (E) and magnetic (H) fields generated by pulsed RF wireless communications devices (WD) in the region controlled for use by a hearing aid.

Clause 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.

Clause 6—Wireless device audio band, magnetic emission test: describes the WD audio band magnetic emission measurement. Two quantities are measured—the desired and undesired magnetic field levels.

Clause 7—Performance: 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, which is contained in 7.3.1 and 7.3.2, are a recommended, but not mandatory, portion of this standard. Hence, the mandatory portion of this standard is the set of parameters governing the acoustic or microphone mode of operation.

Clause 8—Calibration and measurement uncertainty: provides guidance for estimating the uncertainty and reproducibility of measurements made in accordance with this standard.

Clause 9—Test report: outlines the general requirements of the test report and follows the similar arrangement described in Clause 10 of ANSI C63.4-1992.

Figure 1 depicts the organization and use of this standard. Both the WD and hearing aid have mandatory tests (Clause 4 and Clause 5) and optional tests (for the T-coil mode, Clause 6). 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.

ORGANIZATION AND USE OF THIS STANDARD

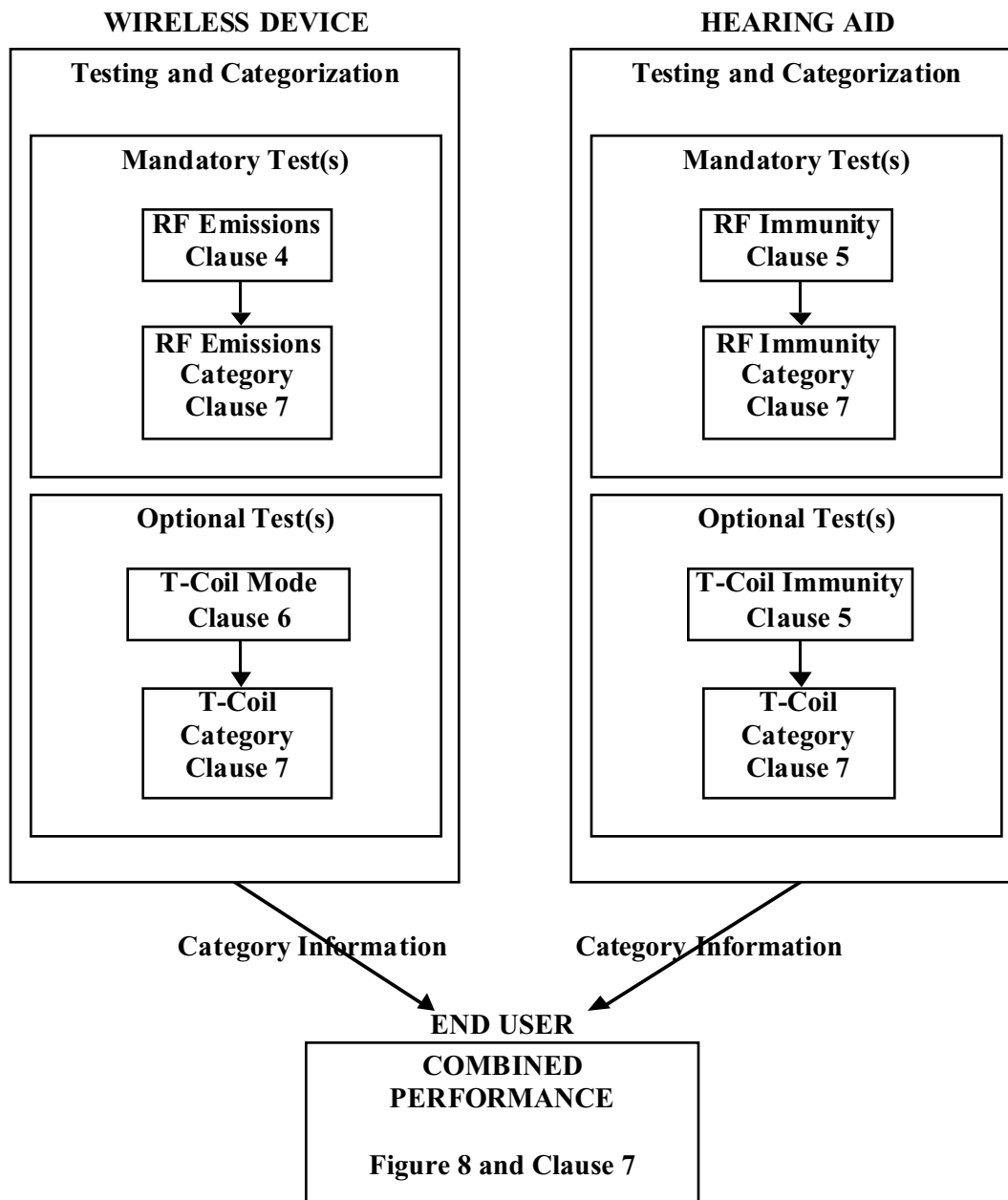


Figure 1—Organization of this standard

The measurements of WD emissions and hearing aid EMC are performed fairly close to the source of these emissions, where small errors in instrumentation, EM 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 informative 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 perception 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. References

The following references shall form a part of this standard to the extent that they are referenced herein. When any of the references are superseded by a revision, the version specified in this document shall apply.

ANSI C63.2-1996, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications.²

ANSI C63.4-1992, 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.

ANSI C63.5-1998, American National Standard for Electromagnetic Compatibility—Radiated Emission Measurements in Electromagnetic Interference (EMI) Control—Calibration of Antennas (9 kHz to 40 GHz).

ANSI C63.14-1998, American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD) (Dictionary of EMC/EMP/ESD Terms and Definitions).

ANSI S3.5-1969, American National Standard Methods for the Calculation of the Articulation Index.

ANSI S3.7-1995 (R1999), American National Standard Method for Coupler Calibration of Earphones.

ANSI S3.22-1996, American National Standard Specification of Hearing Aid Characteristics.

ANSI S3.25-1979, American National Standard Occluded-Ear Simulator.

Draft ANSI S3.79, American National Standard Methods for the Calculation of the Speech Intelligibility Index.³

EIA RS-504-1983, Magnetic Field Intensity Criteria for Telephone Compatibility with Hearing Aids.⁴

²ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³This ANSI standards project was not approved by the ANSI Standards Board at the time this publication went to press. For information about obtaining a draft, contact ANSI.

⁴EIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

FCC 47 CFR 2, Frequency Allocation and Radio Treaty Matters; General Rules and Regulations (1997).⁵

FCC 47 CFR 15, Radio Frequency Devices (1997).

FCC 47 CFR 68, Connection of Terminal Equipment to the Telephone Network (1997).

IEC 118-0:1993, Hearing Aids—Part 0: Measurement of Electroacoustical Characteristics.⁶

IEC 118-4:1981, Methods of Measurement of Electroacoustical Characteristics of Hearing Aids—Part 4: Magnetic Field Strength in Audio-Frequency Induction Loops for Hearing Aid Purposes.

IEC 118-7:1983, Methods of Measurement of Electroacoustical Characteristics of Hearing Aids—Part 7: Measurement of the Performance Characteristics of Hearing Aids for Quality Inspection for Delivery Purposes.

Draft IEC 118-13, Methods of Measurement of Electroacoustical Characteristics of Hearing Aids—Part 13: IEC 77B/153/CD June, 1995.⁷

IEC 126:1973, IEC Reference Coupler for Measurement of Hearing Aids Using Earphones Coupled to the Ear Means of Ear Inserts.

IEC 60118-0:1983, Hearing Aids—Part 0: Measurement of Electroacoustical Characteristics.

IEC 60118-7:1983, Hearing Aids—Part 7: Measurement of Performance Characteristics of Hearing Aids for Quality Inspection for Delivery Purposes.

IEC 60118-13:1997, Hearing Aids – Part 13: Electromagnetic Compatibility (EMC) – Product Standard.

IEC 61000-4-3:1998, Electromagnetic Compatibility for Electrical and Electronic Equipment—Part 4: Testing and Measurement Techniques—Section 3: Radiated, Radio Frequency, Electromagnetic Field Immunity Test.

IEC 61094-1 (1992-06), Measurement Microphones—Part 1: Specifications for Laboratory Standard Microphones.

IEC 61094-2 (1992-03), Measurement Microphones—Part 2: Primary Method for Pressure Calibration of Laboratory Standard Microphones by the Reciprocity Technique.

IEC 61094-3 (1995-11), Measurement microphones—Part 3: Primary Method for Free-Field Calibration of Laboratory Standard Microphones by the Reciprocity Technique.

IEC 61094-4 (1995-11), Measurement Microphones—Part 4: Specifications for Working Standard Microphones.

IEC 711:1981, Occluded-Ear Simulator for the Measurement of Earphones Coupled to the Ear by Ear Inserts.

⁵For information on how to purchase FCC publications, contact the Superintendent of Documents, US Government Printing Office, Washington, DC 20402, USA.

⁶IEC 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.

⁷This IEC standards project was not approved by the IEC Standards Board at the time this publication went to press. For information about obtaining a draft, contact the IEC.

IEC 60318-1 (1998-07), Electroacoustics—Simulators of Human Head and Ear—Part 1: Ear Simulator for the Calibration of Supra-aural Earphones.

IEC 60318-2 (1998-08), Ed. 1.0, Electroacoustics—Simulators of human head and ear—Part 2: An interim acoustic coupler for the calibration of audiometric earphones in the extended high-frequency range.

IEC 60318-3 (1998-08), Ed. 1.0, Electroacoustics—Simulators of human head and ear—Part 3: Acoustic coupler for the calibration of supra-aural earphones used in audiometry.

IEEE Std 149-1979, IEEE Standard Test Procedures for Antennas.⁸

IEEE Std 269-1992, IEEE Standard Method for Measuring Transmission Performance of Telephone Sets.

IEEE Std 291-1991, IEEE Standards Methods for Measuring Electromagnetic Field Strength of Sinusoidal Continuous Wave, 30 Hz to 30 GHz.

IEEE Std 299-1991, IEEE Standard for Measuring the Effectiveness of Electromagnetic Shielding Enclosures.

IEEE Std 661-1979, IEEE Standard Method for Determining Objective Loudness Ratings of Telephone Connections.

IEEE Std 1027-1996, IEEE Standard Method for Measurement of the Magnetic Field in the Vicinity of a Telephone Receiver.

IEEE Std 1028-1996, IEEE Recommended Practice for RF Absorber Performance Evaluation in the Range 30 MHz to 5 GHz.

IEEE Std 1309-1996, IEEE Standard Method for the Calibration of Electromagnetic Field Sensors and Field Probes, Excluding Antennas, from 9 kHz to 40 GHz.

IEEE Std C95.1, 1999 Edition, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

IEEE Std C95.3-1991 (R1997), IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields—RF and Microwave.

ISO 3-1973, Preferred Numbers—Series of Preferred Numbers.⁹

ISO 266-1975, Acoustics—Preferred Frequencies for Measurements.

ITU-T, Blue Book, Volume V, Telephone Transmission Quality Series P Recommendations, Recommendation P.37-1993, Magnetic Field Strength around the Earcap of Telephone Handsets which Provide for Coupling to Hearing Aids.¹⁰

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

⁸IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁹ISO 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, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

¹⁰ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (<http://www.itu.int/>).

NIS 81: Edition 1, *The Treatment of Uncertainty in EMC Measurements*, May 1994.¹¹

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

NIST Technical Note 1297, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, Sept. 1994.¹²

TIA/EIA/IS-55-A, *Recommended Minimum Performance Standards for 800 MHz Dual-Mode Mobile Stations* (Sept. 1993).¹³

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

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

TIA/EIA/IS-136.1, *800 MHz TDMA Cellular-Radio Interface—Mobile Station-Base Station Compatibility—Digital Control Channel* (Dec. 1994).

TIA/EIA/IS-136.2, *800 MHz TDMA Cellular-Radio Interface—Mobile Station-Base Station Compatibility—Traffic Channels and FSK Control Channel* (Dec. 1994).

TIA/EIA/IS-137, *800 MHz TDMA Cellular-Radio Interface—Minimum Performance Standards for Mobile Stations* (Dec. 1994).

TIA/EIA/IS-138, *800 MHz TDMA Cellular-Radio Interface—Minimum Performance Standards for Base Stations* (Dec. 1994).

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

3. Definitions, acronyms, and abbreviations

3.1 Definitions

Definitions in ANSI C63.14-1998 and IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B13], apply throughout this document, unless otherwise noted in the definitions in 3.1 of this standard. Particular product standards or applicable regulation definitions take precedence. Definition sources (if applicable) are enclosed in brackets following the definition.

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

3.1.2 articulation weighting factor: 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

¹¹NIS standards are published by NAMUS (UKAS) and may be ordered from UKAS, National Physical Laboratory, Teddington, Middlesex, TW11 0LW, England; Tel. 011-81-943-7140, FAX 011-81-943-7134.

¹²For information on how to purchase NIST publications, contact the Superintendent of Documents, US Government Printing Office, Washington, DC 20402, USA.

¹³TIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

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.

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

3.1.4 audio frequency: Any frequency corresponding to a normally audible sound wave.

NOTES:

1) Audio frequencies range roughly from 15 hertz to 20,000 hertz.

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.

3.1.5 audio band: The frequency range from 15 hertz to 20,000 hertz (*see also*: **audio frequency**).

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

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

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

3.1.9 band: Frequency range between two defined limits.

3.1.10 compatibility: The capability of a wireless communications device (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.

3.1.11 digital wireless telephone: Radio-frequency-based wireless telephones utilizing digital transmission formats over an air interface.

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

3.1.12 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.

3.1.13 emission bandwidth (B): The signal width, in Hertz, between two points, one below the carrier center frequency and one above the carrier center frequency, that are 26 dB down relative to the maximum level of the modulated carrier. It is based on the use of measurement instrumentation employing a peak detector function with an instrument resolution bandwidth approximately equal to 1.0 percent of the emission bandwidth of the device under measurement. [Extraction from FCC 15.303(c)]

3.1.14 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.

NOTES:

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.

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.

3) The distance 3λ is considered to lie in the far-field region.

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

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

3.1.17 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 a RF interference source. IRIL may be obtained by subtracting the acoustic gain in dB from the acoustic interference output.

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

3.1.19 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.

3.1.20 near-field region: That part of space between the antenna and the far-field region.

NOTES:

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} .

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.

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.

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 7.5 cm for 800 MHz, decreasing to 2 cm for 3 GHz.

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

3.1.22 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)]

3.1.23 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]

3.1.24 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.

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

3.1.25 tele-coil (T-coil): An inductive coil used in some hearing aids to allow reception of a 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.

3.1.26 transverse electromagnetic (TEM) cell: A measuring device that is designed to utilize the transverse electromagnetic (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.

3.1.27 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.

3.1.28 wireless communications device (WD): A communications device using radio frequency 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
AM	amplitude modulation
ANSI	American National Standards Institute
AWF	articulation weighting factor
BTE	behind the ear (hearing aid)
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
dB SPL	decibels referenced to a sound pressure level of 20 μ Pascals
EHIMA	European Hearing Instrument Manufacturers Association
ETSI	European Telecommunications Standards Institute
f	frequency
GSM	global system for mobile
i.d.	inside diameter
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IRAN	input referred ambient noise
IRIL	input referred interference level
ISO	International Organization for Standardization
ITC	in the canal (hearing aid)
ITE	in the ear (hearing aid)
NADC	North American Digital Cellular
o.d.	outside diameter
OSPL	output sound pressure level
P	transmit power or forward power (Watts)
PC	personal computer
PCS	personal communications services
Q	quality factor

RF	radio frequency
RMS	root mean square
Rx	receiver
SPL	sound pressure level
T-coil	tele-coil
TDMA	time division multiple access
TEM	transverse electromagnetic
Tx	transmitter
VSWR	voltage standing wave ratio
WB TEM	Wideband transverse electromagnetic
WD	wireless communications device

4. Wireless device, RF emissions test

This clause provides guidance on the measurements of the near electric (E) and magnetic (H) fields generated by wireless communications devices (WD) 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 non-continuous 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.

4.1 Test equipment and facilities

Portions of this standard place requirements on the test facilities, in addition to the general requirements of ANSI C63.4-1992, and are discussed below, as well as in C.1. Unless stated otherwise, the requirements of ANSI C63.4-1992 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 of this standard. Efforts made to reduce the measurement uncertainty improve the stability and reproducibility of the measurement.

4.1.1 Test equipment

Subclause 4.1.1 provides a list of the test equipment required to perform this test. The test equipment used shall meet the applicable specifications of Annex D.

- a) E-field, near-field probe
- b) H-field, near-field probe
- c) Probe positioning system
- d) WD support
- e) RF enclosure

4.1.2 Near-field measurement system

The near-field measurement system shall consist of a small (with respect to a wavelength) electric field probe and a magnetic field probe, suitable for measuring the field strength of the RF fields without significantly perturbing the fields generated by the WD. 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 C95.3-1991 advises that to avoid certain measurement errors, a probe should not be used closer than a distance equal to 3 times the length of the active elements of the probe. Because of the required 1 cm measurement distance, the active elements of these probes shall be less than the smaller of either 0.33 cm or 0.1 of a wavelength in their largest dimension at the frequency of measurement.

The probes shall be calibrated to a measurement uncertainty of no worse than ± 2 dB. Probe calibration in accordance with IEEE Std 1309-1996 is discussed in C.3 of this standard.

A method for holding and moving the probes close to the WD is also required. This mechanism shall be capable of a sufficient accuracy and repeatability in position so as to guarantee a measurement uncertainty within ± 2 dB; also, this mechanism shall minimally perturb the RF fields to be measured. Therefore, it is recommended that all parts of the probe holding and movement mechanism be made using RF-transparent materials, or be kept at a distance so as to not degrade the measurement accuracy.

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.

4.2 Test setup and validation

4.2.1 Test setup

The WD shall be supported in such a way that there are no RF reflecting objects within a distance of at least 2 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 2 wavelength distance to the nearest RF reflection 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 2 wavelength spacing rule may be used. The WD and measurement probe shall be contained within a shielded enclosure conforming to C.1.1. Support structures such as expanded foam and 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.

4.2.2 WD setup and use

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 best hear the WD desired acoustic output. This would typically be with the speaker of the WD in close proximity to the microphone of the hearing aid. This is likely to be true for all types of hearing aids. For the purposes of this standard, it is assumed that the proximity of the WD and the hearing aid meet this assumption. For this reason a 5 cm by 5 cm region—1 cm from surface of the WD—is controlled, so as to be usable by a hearing aid. This region begins at the top of the WD housing and covers the WD receiver area. It is centered about the center line of the WD. See Figure A.2 for further details.

The WD shall be operated at its maximum RF output power, 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 exter-

nal connections unless specifically required 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 normal operation 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.

4.3 Near-field test procedure

The electric field probe, and, separately, the magnetic field probe, are to be used to measure the highest field strength in the 5 cm by 5 cm scan surface. The average field strength,¹⁴ measured over many pulse cycles, may be measured, with the peak then being calculated from the measured average value and the known duty cycle of the WD.

The 5 cm by 5 cm area is divided into nine subgrids (see the diagram in Figure A.2). Three contiguous subgrids on the perimeter may be excluded from the measurement. This allows for RF “hot spots” that can easily be avoided in actual use.¹⁵ The highest reading found in the area defined by the middle subgrid and the five remaining subgrids determines the category rating. The field probe is carefully moved through the measurement area and the maximum reading is located. In order to accurately scan the entire 5 cm by 5 cm 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 5 cm by 5 cm area, increased by half (1/2) the probe diameter on all sides. The method of displaying the data is not important as long as good measurement techniques are followed and the resultant highest field strength is obtained.

The distance from the WD reference plane to the nearest point on the probe element shall be 1.0 cm. The WD reference plane is a plane parallel with the front “face” of the WD and containing the highest point on its contour. 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 1.0 cm distance as this would place the sensing elements at an indeterminate distance from the reference plane. Although it is theoretically possible to measure at almost any distance and calculate the equivalent field strengths at 1.0 cm, it is not recommended as these calculations are very difficult and prone to errors.

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 the electromagnetic sensing element of the probe. This may be determined from physical measurements, or

¹⁴Many field probes have relatively slow response times and cannot measure the peak field strength in a time varying RF signal. Therefore, the reading is an average of the peak field, averaged over the response time of the probe.

¹⁵The 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 cm. 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, WD, 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.

4.3.1 Detailed near-field test procedure example

4.3.1.1 Pre-test procedure

The steps listed here shall be performed before the WD near-field emissions test is performed. 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- and H-field probes for peak 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.

Pre-Test Instructions

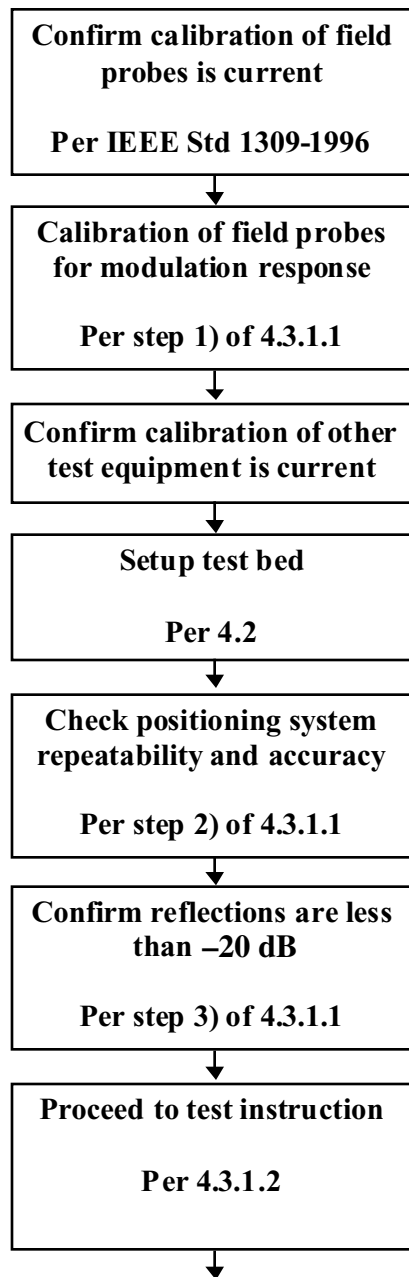


Figure 2—WD near-field emissions pre-test flowchart

4.3.1.2 Test procedure

The following are sample step-by-step test procedures. Other comparable procedures may be used.

4.3.1.2.1 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. In this fixture, permissible exclusion blocks are used to isolate the six subgrids used for the evaluation. The permissible exclusion block is shaped in such a way as to close off three of the subgrid areas. Thus, the six areas to be used to determine the WD's peak emissions are identified and outlined for the final manual scan.

- 1) Confirm the proper operation of the field probe, the probe measurement system, and other instrumentation.
- 2) Position the WD in its intended test position.
- 3) Configure the WD operation for maximum rated RF output power, at the desired channel and other operating parameters, as intended for the test.
- 4) Perform an initial scan of the 5 x 5 cm area.

The physical opening in the test fixture shall be wider than the 5 x 5 cm area by half the diameter of the probe. Thus the opening is such that the center of the probe scans the full 5 x 5 cm area.

The probe shall be held in such a way as to not significantly influence the readings. 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 1 cm separation distance from the WD under test.

- 5) Identify the five contiguous subgrids around the center subgrid with the lowest field readings. Place the exclusion block into the fixture in the three contiguous subgrids containing the highest field readings. The reason for allowing three contiguous subgrids 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 is allowed so as not to make the requirements needlessly harsh.
- 6) Rescan the remaining six subgrid areas. Identify the highest field reading within the six subgrid area, made up of the center subgrid and the five subgrids identified in step 5). Care shall be taken to identify the highest emission within the six subgrid area. Once the highest emission is identified, the probe should be rotated to align it for the maximum reading. The rotation is recommended in order to eliminate errors due to anisotropy in the probe.
- 7) Convert the highest field reading taken in step 6) to peak V/m or A/m, as appropriate. This conversion shall be done using the appropriate factors derived from the calibration specified in Annex C.3.
- 8) Compare this reading to the categories in Clause 7 and record the resulting category.
- 9) Repeat steps 1) through 8) for both the E- and H-field. The lowest category, per Figure 12, obtained in step 8) for either E- or H-field, determines the overall WD category. Record the WD category rating.

Test Instructions

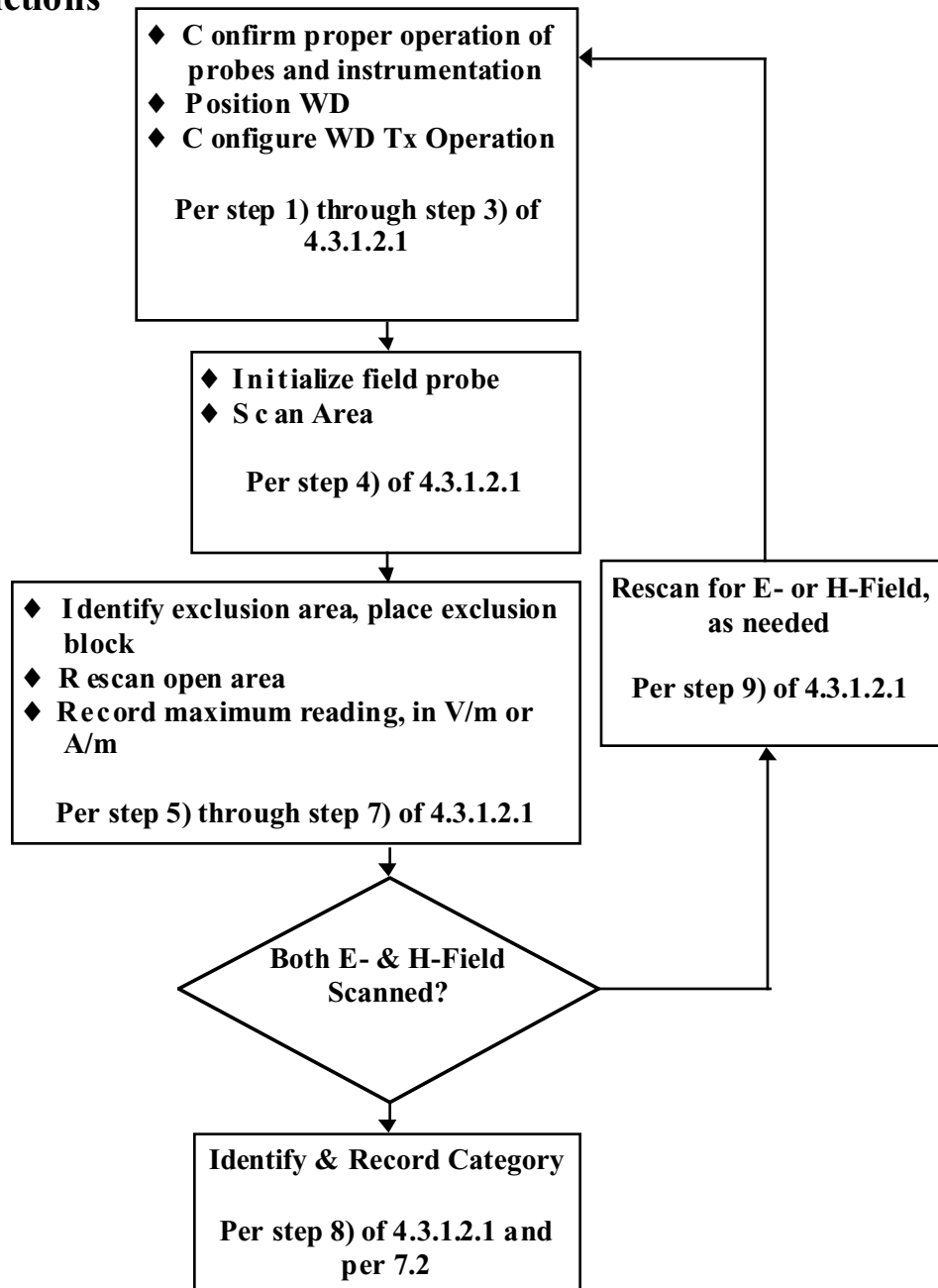


Figure 3—WD near-field emission manual test flowchart

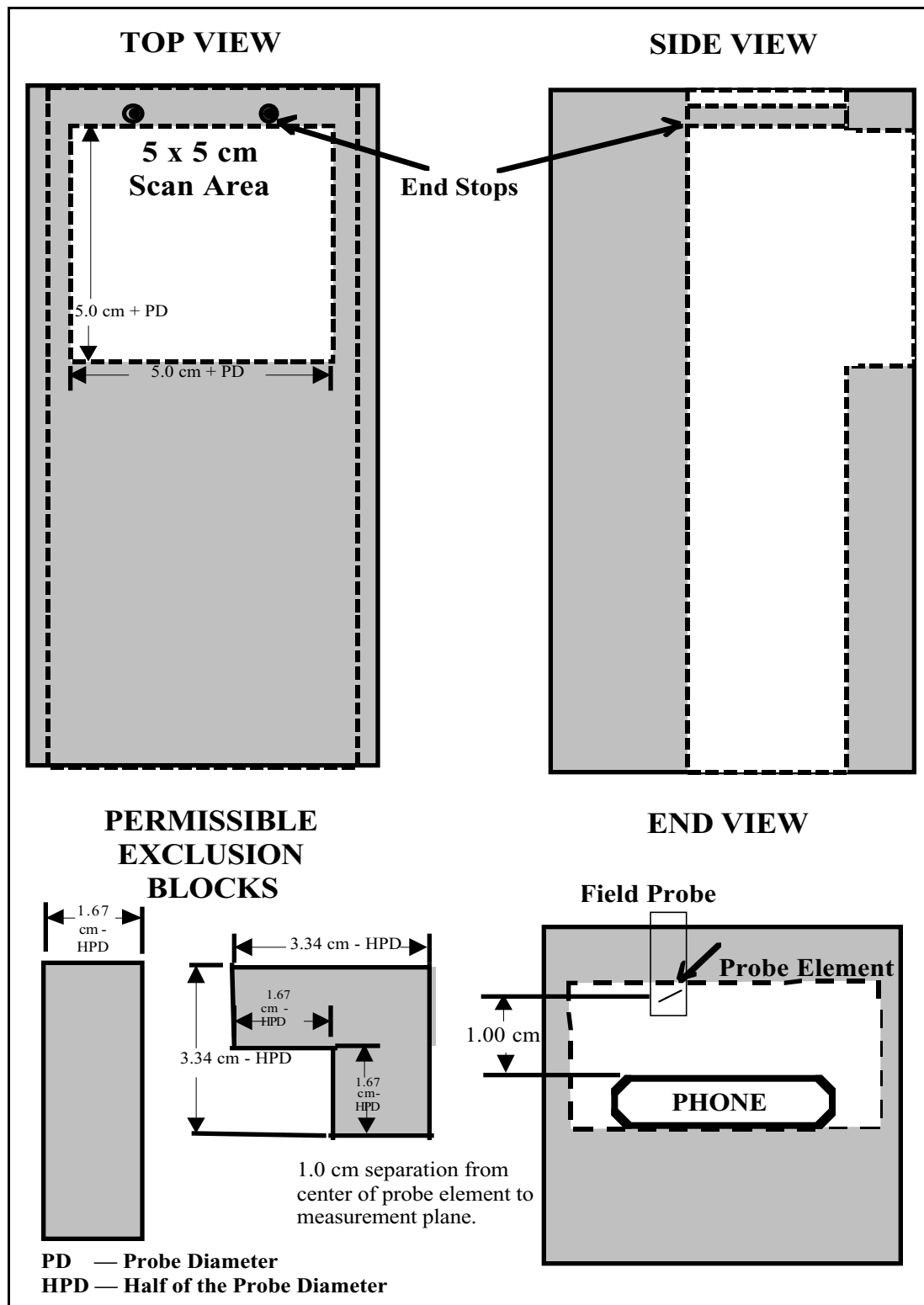


Figure 4—Near-field emissions test fixture, manual scan method

TOP VIEW

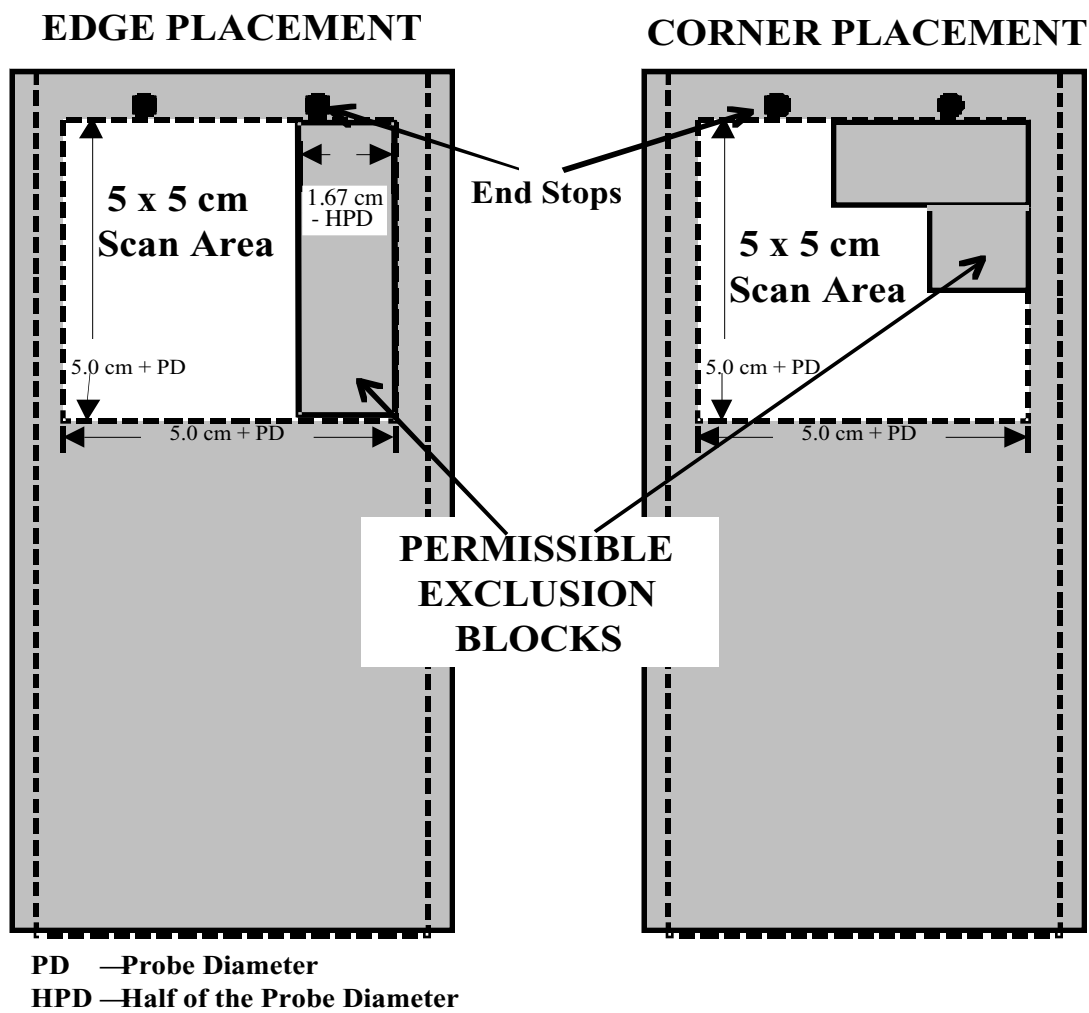


Figure 5—Exclusion block placement

4.3.1.2.2 Automated scanning method

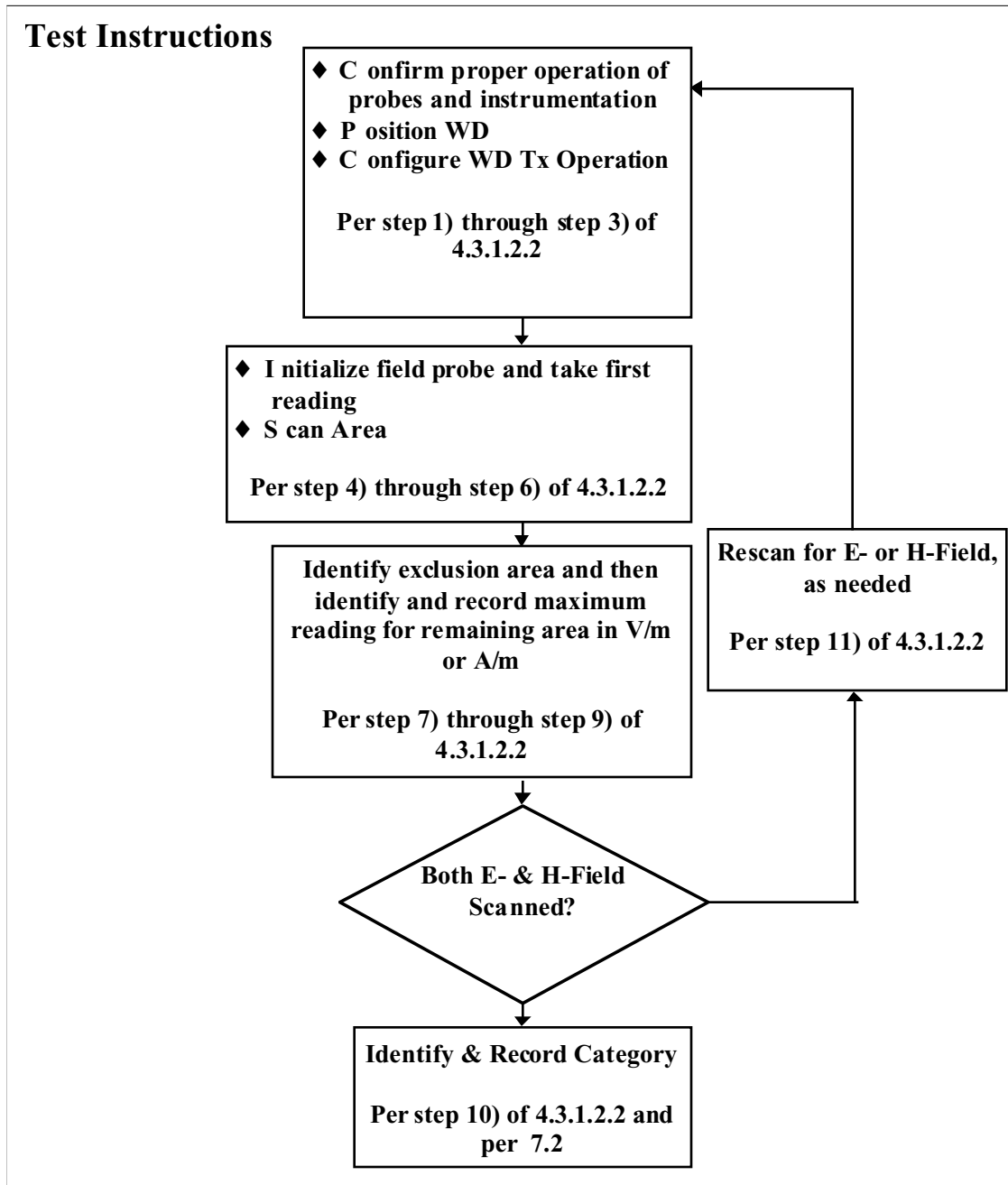


Figure 6—WD near-field emission automatic test flowchart

- 1) Confirm the proper operation of the field probe, the probe measurement system, and other instrumentation.
- 2) Position the WD in its intended test position.
- 3) Configure the WD operation for maximum rated RF output power, at the desired channel and other operating parameters, as intended for the test.
- 4) Locate the field probe at the initial test position. If the field alignment method is used, align the probe for maximum field reception.
- 5) Record the reading.
- 6) Scan the 5 x 5 cm areas, repeating steps 4) and 5) for each measurement point. The distance between measurement points shall be sufficient to assure the identification of the peak reading.
- 7) Identify the five contiguous subgrids around the center subgrid with the lowest field readings.
- 8) Identify the highest field reading within the six subgrids, made up of the center subgrid and the five subgrids identified in step 7).
- 9) Convert the highest field reading taken in step 8) to peak V/m or A/m, as appropriate. This conversion shall be done using the appropriate factors derived from the calibration specified in C.3 of this standard.
- 10) Compare this reading to the categories in Clause 7 and record the resulting category.
- 11) Repeat step 1) through step 10) for both the E- and H-field. The lowest category, per Figure 12, obtained in step 10) for either E- or H-field determines the overall WD category. Record the WD category rating.

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. Far-field illumination testing is commonly required in other standards as well. Some may prefer to test immunity using a WB TEM either to avoid duplicative testing or for other reasons. Annex I 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 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

Subclauses 5.1 through 5.1.2 describe the test facility and equipment to be used for these measurements.

5.1.1 General test conditions

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 radio-frequency fields is electromagnetically shielded to the extent necessary to meet federal government RF safety regulations and electromagnetic emission regulations. A soundproof booth is not a mandatory requirement. However, ambient noise levels in the test area should be as low as possible and consistent for the duration of the test.

5.1.2 Test equipment

Subclause 5.1.2 lists the test equipment needed to perform the near-field immunity tests, using the generic test equipment hookup diagram shown in Figure 7. The test equipment used shall meet the applicable specifications of Annex D.

- a) Two resonant dipoles designed to radiate between 800–950 MHz and 1.6–2.48 GHz
- b) RF signal generator
- c) RF power amplifier
- d) RF directional coupler
- e) RF power meters (2)
- f) Microphones
 - 1) Pressure field microphone
 - 2) Free field microphone
- g) Microphone preamplifier
- h) Frequency analyzer
- i) Ear coupler
- j) Microphone calibrator
- k) Audio signal generator
- l) Acoustic transmission line
- m) Hearing aid immunity test fixture
- n) RF cables

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 pretest 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 pretested per ANSI S3.22-1996.

5.2.1 Hearing aid near-field immunity test setup

Figure 7 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 preamplifier. 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 modulation is added for the actual test.¹⁶

The relative spacing between the hearing aid under test and the dipole is critical to the accuracy and repeatability of the test. Figures D.2 through D.8 describe the construction of a recommended fixture. Other fixture implementations are allowed, provided that they can be demonstrated to give equivalent performance.

5.2.2 Check for RF interference to test equipment

Set up the equipment as illustrated in Figure 7 and as described in 5.2.1. With the hearing aid battery removed and RF off, record the ambient spectrum and sound pressure level. 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 modulation. Record the audio band spectrum and overall sound pressure level 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 modulation. Record the spectrum and overall sound pressure level.

There should be no change in spectrum and overall sound pressure level from ambient during this system check (with the hearing aid battery removed), indicating that the system is immune to interference. If there is an increase in recorded sound pressure level 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.

¹⁶The 1 kHz 80% AM modulation 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 determine the relationship is described in Appendix 4, "Square Law Detection of RF Signals," of Joyner, K.H. et al, Interference to Hearing Aids by the Digital Mobile Telephone System, Global System for Mobile Communications (GSM), NAL Report #131 [B16] and in Annex A, "Rationale for the choice of modulation for tests related to the protection against RF emissions from digital radio telephones," in IEC 61000-4-3-1998.